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HUMAN DIMENSION AND WELFARE IMPLICATIONS OF THE URBAN WILD BOAR PHENOMENON AND ITS MANAGEMENT

PhD Thesis 2022

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Wild boar management in urban areas

Human dimension

Welfare implications

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El catedrático **Santiago Lavín González** y el doctor **Jordi Ramón López Olvera**, profesores del Departamento de Medicina y Cirugía Animal de la Facultad de Veterinaria de la Universidad Autónoma de Barcelona y el doctor **Gregorio Mentaberre García,** profesor del Departamento de Sanidad Animal de la Universidad de Lleida,

Informan:

Que la memoria titulada: **"Human dimension and welfare implications of the urban wild boar phenomenon and its management"**, presentada por Carles Conejero Fuentes para la obtención del grado de Doctor en Veterinaria por la Universidad Autónoma de Barcelona, se ha realizado bajo nuestra dirección y, una vez considerada satisfactoriamente finalizada, autorizamos su presentación por tal que sea evaluada por la comisión correspondiente.

Y para que así conste respecto a los efectos que se consideren oportunos, firmamos el presente informe en Bellaterra, 15 de Setiembre de 2022.

Gregorio Mentaberre García
director

Santiago Lavín González
director y tutor

Jordi Ramón López Olvera
director

Carles Conejero Fuentes
doctorando

Since human-wildlife conflicts are becoming a major concern for both (people and wildlife), this thesis was conceived to achieve the coherent human-wildlife coexistence into current socio-ecosystems. A trend to produce beneficial outcomes for all living organisms sharing the same landscape can only emerge through daily understanding of natural cycles, with knowledge and love, never through fear.

"Love is not desire. It is a great thing to find out this for oneself. And if love is not desire then what is love? Love is not mere attachment to your baby, love is not attachment in any form; love is not jealousy, ambition, fulfillment or becoming; love is not desire or pleasure. The fulfillment of desire, which is pleasure, is not love. So, I have found out what love is. It is none of these things."

-Jiddu Krishnamhurti in Saanen 1979-

A mi abuela Luisa, a mi yaya,

por criarme con inestimable paciencia.

Greetings - Agradecimientos

De este viaje he aprendido sobre materias que ni siquiera sabía que existían. A destacar, aprendí que nadie logró nada relevante sin la contribución de su propio entorno, por lo que se hace necesario cuidar del mismo sin esperar nada a cambio, teniendo por seguro que todo suceso vital dependerá enteramente de la relación ecológico-social que propiciemos. Krishnamhurti me ayudó a comprender que "verse solo" es necesario para llegar a comprender términos tan abstractos como son la confianza y el respeto. Sólo de esa manera el primate cooperante puede llegar a amar, y así lograr aquellas metas aparentemente inalcanzables. Nunca olvidaré que la ignorancia no exime la responsabilidad y que la incompetencia en conjunción con la iniciativa engendra resultados desafortunados de laborioso arreglo. Que nadie nació enseñado ni experto, que la curiosidad es necesaria para aprender y que el saber, limitado por la soberbia, se nutre de humildad.

En estos momentos me veo incapaz de nombrar a todo ente que, consciente o inconscientemente, ha colaborado con su granito de tierra, puñado de piedras, montículos o cordilleras en el proceso de elaboración de esta tesis. Lo que sí puedo afirmar es que no podría sentirme más afortunado por disponer de un tesoro tan inmaterial como preciado. Por lo que me uno a Quevedo afirmando que "no es dichoso aquel a quien la fortuna no puede dar más, sino aquel a quien no se le puede quitar nada".

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El cuarto artículo de esta tesis se lo debemos enteramente al equipo de Estrateko: Santi, Enric, Cesc, Martí y Manel. Gracias por enseñarme lo bonito que puede resultar un buen trabajo.

Para llegar hasta aquí, agradezco la contribución todo el equipo pasado y presente del SEFaS-WE&H y del WildCoM. Me refiero a todos aquellos estudiantes de máster, prácticas, TFG's, TFM's, doctorandos, internos, residentes y técnicos del equipo. Gracias por trabajar tan duro sin perder la ilusión. Hoy en día no me puedo sentir más

Judith Nova

In memoriam of Ramón Borda Crespo.

From left to right: Carles Conejero, Ramón Borda and Luis Chavarría "The Lehendakari". Ramón was poet, bricklayer and activist. Being an active member of La Floresta's Neighborhood Council (Consell de Barri de La Floresta), he encouraged our project from the very beginning. The photo was taken by my friend Judit Nova, the 9th of June of 2017, at Plaça Miquel Ros in La Floresta (Sant Cugat) during a performance action. Sadly, Ramón left us the 15th of November of the same year. The activity was carried out as part of a citizen awareness campaign to prevent incidences with the urban wild boar under the title: "Campanya informativa per millorar el coneixement del senglar i reduir les incidències". The proposal was voted by locals in 2017, executed along 2018 and funded through the Sant Cugat Council Participative Budget.

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The urban wild boar phenomenon is a more recent consequence of the generalized increase of wild boar (*Sus scrofa*) populations occurring worldwide in the last decades. The habituation of wild boar to anthropogenic contexts and resources has driven to a common presence of wild boar in suburban areas of the Metropolitan Area of Barcelona (MAB). In this new scenario, it is not only wild boar that change its attitudes towards people by losing fear to human presence; determinant processes of either habituation or sensitization towards wild boar presence in urban settings occur on the human side. Regarding "reciprocal habituation", which we describe for the first time, citizens become familiar with the presence of wild boar because of repeated encounters, resulting in a lower perception of conflicts and the acceptance of wild boar presence in urban settings. In contrast, conflicts may cause negative perceptions and reduce tolerance of other citizens towards these animals -sensitization-. Consequently, Human-Wild Boar Conflict (HWBC) management in the urban scene faces to specific challenges derived from sociological determinants. Most notably, a sounding part of the urbanite population considers that public safety is not important or menaced enough to accept lethal control and defends cohabitation with wild boar in the urban environment. Because citizen attitudes (habituation or sensitization) either complicate or facilitate control measures, we analyze human drivers of these attitudes to better adjust the management of wild boar population to specific cultural and socio-ecological contexts. We conducted face-to-face questionnaires to passers-by from Barcelona along the natural-to-urban gradient and grouped the response variables to score citizen and urban characteristics, as well as citizen past experiences, emotions, and lay-knowledge related to wild boar. We used a recursive partitioning approach (through regression trees) and Principal Component Analyses (PCA) to explore the relationship between HWBC perception, acceptance of management measures, citizen characteristics, experiences and expressed attitudes towards wild boar presence in urban areas.

Moreover, we hypothesized that the urban environment is detrimental for the health and welfare of wild boar, which, if confirmed, would be a better argument to achieve a consensus with those currently defending cohabitation on the need to move wild boar away from the urban ecosystem. To assess the effect of synurbization on wild boar health and welfare, we went through the necropsy findings observed in 845 wild boars either hunt-harvested or captured and euthanized for management purposes in the MAB and classified lesions non-attributable to the capture method using a Severity Score ranging 1 (less severe) to 3.

Finally, whereas the need for implementation of management measures is clear, the range of possibilities is reduced and with (lethal) population control as the only cost-effective option in most cases. Hunting is the main strategy for wild boar population management, but it is unfeasible in urban scenarios where live trapping takes action. Since the design and handling of live traps must assure animal welfare according to internationally accepted humane trapping standards, we also aimed at assessing welfare performance of a remote-controlled drop-net system (Estrateko®) to capture wild boars in the MAB. Namely, we randomly selected for pathological and histological examination 20 out of 32 wild boars drop-net captured and euthanized for management purposes. This is the minimum number required for this aim, according to the guidelines provided in the Agreement on International Human Trapping

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Standards (AIHTS) and by the International Organization for Standardization (ISO-10990-5). Namely, we aimed at assessing the presence of significant lesions related to the capture method as well as other related operational parameters according to proposed humane trapping standards.

We show that citizen perception of HWBC depends mainly on the previous experience of human-wild boar coexistence, as well as a combination of emotions and lay-knowledge about the wild boar. In urban areas, when intense human-wild boar coexistence conditions are occurring, HWBC -sensitization- is boosted by previous incidents suffered by the respondent, independently of citizen profile, current experiences, level of contact and acceptance of management measures. Moreover, socio-demographic variables such as gender, education and public health concern are less important than past experiences in driving citizen perception and explaining resident attitudes. Regarding reciprocal habituation, wild-boar habituated citizens (with a positive perception of wild boar presence in urban areas) contribute to reinforce the phenomenon by feeding, and thus habituating wild boars to urban environments. On the other hand, the urban wild boar is more likely to suffer severe traumatic lesions than their rural counterparts. These injuries are attributable to vehicle collision, dog attacks and even poaching, amongst others. In addition, although wild boar lethal control may not desirable, it is for now necessary in urban environments. The Estrateko's drop-net system assessment determined that the proportion of wild boars displaying moderate to severe injuries attributable to the capture method was 15% (3 out of 20), below the 20% threshold set by the AIHTS. Even more, the significance of the capture myopathy lesions observed in two out of the three affected wild boars is not clear and could be classified also as mild, depending on the interpretation. However, both the AIHTS and the ISO standards have been repeatedly criticized with a growing list of concerns including ineffectiveness in ensuring animal welfare due to insufficient and outdated standards and test procedures, incomplete list of mammal species included and/or lacking or insufficient thresholds of acceptance. Based on the thresholds of acceptance of a new standards proposal, the humaneness of drop-nets in our study ranged 66% to 78%, under the 85% required. The capture success and selectivity were 100%, as ensured by operator-driven triggering, and no disturbances against the capture system or operations by people contrary to wild boar removal occurred.

The diversity of citizen attitudes towards wild boar should be considered to assure the most suitable design, application and acceptance of management measures, namely in awareness campaigns that seek to reduce behaviors promoting wild boar presence (e.g., feeding). Educational campaigns on causes, prevention of conflict and effective management options for urban wildlife could help to improve social understanding of the circumstances through knowledge rather than fear. Likewise, our study of the tensions between conflict and reciprocal habituation can help to understand why some management measures (e.g., the capture of specific individuals or sounders) are rejected by the public, even if these animals can endanger suburban residents. However, we also bring to light that, even dismissing the mortality due to lethal control management actions, the urban landscape is not a suitable habitat for wild boar, resulting in a higher probability of losing fitness, health and welfare. But conforming to the harsh reality, lethal control measures are up to date necessary. This is the first assessment of a drop-net capture method according to internationally accepted mammal trapping standards, with unconclusive results. However, it should be noted that the existing standards were designed to assess the capture of other

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wildlife species with different trap/capture systems; hence, there is a need for adapted procedures and thresholds of acceptance aimed specifically at drop-nets. Compared to other live-capture methods, drop-nets minimize the duration of the stressful situation -at the expense of a strong adrenergic acute response-, maximize the probabilities of capturing entire sounders of prosocial species, which may be also considered as more humane, and can coordinate higher values of capture success, absolute selectivity and adaptability to difficult environments.

This thesis provides insights into the main drivers of social perception of the urban wild boar, determining the major influence of negative experiences, socioeconomic context, previous knowledge and human emotions on wild boar perception and associated HWBC. In addition, this thesis also makes clear that initiatives aimed at promoting cohabitation with wild boar in urban settings are neither acceptable nor desirable, neither from a human nor from a wild boar perspective.

RESUMEN

El fenómeno del jabalí urbano es una de las consecuencias más recientes del aumento generalizado de las poblaciones de jabalí (*Sus scrofa*) que se ha producido en todo el mundo durante las últimas décadas. La habituación del jabalí al contexto urbano y a los recursos antropogénicos ha conducido a su presencia habitual en la zona periurbana al Área Metropolitana de Barcelona (AMB). En esta situación, no sólo los jabalíes cambian su actitud hacia las personas al perder el miedo a la presencia humana; muchas personas llegan experimentar procesos de habituación o sensibilización hacia la presencia del jabalí en el entorno urbano. En cuanto a la "habituación recíproca", que describimos por primera vez, los ciudadanos se familiarizan con la presencia del jabalí debido al incremento de encuentros sin incidencias, lo que provoca una menor percepción del conflicto y una mayor aceptación de su presencia en el entorno urbano. Por el contrario, los conflictos pueden causar percepciones negativas y reducir la tolerancia de otros ciudadanos hacia estos animales -sensibilización-. En consecuencia, la gestión del conflicto entre humanos y jabalíes (HWBC, por sus siglas en inglés -"Human-Wild Boar Conflict"-) en el escenario urbano se enfrenta a retos específicos derivados de procesos sociológicos. En particular, una parte importante de la población urbana considera que la seguridad pública no es lo suficientemente importante o no está suficientemente amenazada como para aceptar un control letal, defendiendo la convivencia con el jabalí en el entorno urbano. Dado que el posicionamiento de la ciudadanía (habituada o sensibilizada) complica o facilita las medidas de gestión, analizamos aquellos factores humanos que impulsan estas actitudes para ajustar mejor la gestión de la población de jabalí al actual contexto cultural y socioecológico. Realizamos cuestionarios cara a cara a los transeúntes de Barcelona a lo largo del gradiente natural-urbano, agrupando las variables respuesta con el fin de puntuar las características ciudadanas y urbanas, así como las experiencias pasadas de los ciudadanos, las emociones y los conocimientos de cultura popular relacionados con el jabalí. Se utilizó un enfoque de partición recursiva (a través de árboles de regresión) y Análisis de Componentes Principales (PCA) para explorar la relación entre la percepción del HWBC, la aceptación de las medidas de gestión, la caracterización ciudadana, así como también su experiencia y posicionamiento hacia la presencia de jabalíes en el área urbana.

Además, planteamos la hipótesis de que el entorno urbano es perjudicial para la salud y el bienestar de los jabalíes: lo que, de confirmarse, sería un mejor argumento para lograr un consenso con la parte de la ciudadanía que defiende la convivencia con el jabalí sobre la necesidad de alejarlo del ecosistema urbano. Para evaluar el efecto del proceso de sinurbización sobre la salud y el bienestar de los jabalíes, revisamos los hallazgos de necropsia de 845 jabalíes cazados o capturados y sacrificados (urbanos) con fines de gestión en el AMB, clasificando las lesiones no atribuibles al método de captura en función de su gravedad en una escala entre 1 (menos grave) a 3.

Por último, aunque la necesidad de aplicar medidas de gestión es evidente, el abanico de posibilidades es reducido y el control (letal) de la población es la única opción rentable en la mayoría de los casos. La caza es la principal estrategia para la gestión de las poblaciones de jabalí, pero es inviable en el escenario urbano, donde se recurre a la captura en vivo y eutanasia. Dado que el diseño y la utilización de los sistemas de captura deben garantizar el bienestar de los animales de acuerdo con estándares internacionales de captura no cruel, también nos propusimos evaluar el

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rendimiento en términos de bienestar de un método de captura mediante red de caída (Estrateko®) utilizado para la captura de jabalíes en el AMB. Con esta finalidad, seleccionamos aleatoriamente 20 de 32 jabalíes capturados con este método y sacrificados por motivos de gestión, para su examen postmortem. Éste es el número mínimo requerido para esta finalidad de acuerdo con las directrices establecidas en el Acuerdo Internacional sobre Estándares de Captura No Cruel (AIHTS, del inglés "Agreement on International Humane Trapping Standards") y por la Organización Internacional de Normalización (ISO-10990-5). En concreto, nuestro objetivo fue evaluar la presencia de lesiones significativas relacionadas con el método de captura en base a las propuestas existentes de estándares de captura no cruel, así como otros parámetros operacionales.

En esta tesis hemos encontrado que la percepción ciudadana del HWBC depende principalmente de la experiencia previa derivada de la coexistencia entre el humano y el jabalí, pero también de una combinación de emociones y conocimiento popular sobre el jabalí. En el área urbana, cuando la convivencia entre personas y jabalíes es frecuente, las incidencias previas sufridas por el encuestado provocan su sensibilización, independientemente del perfil del ciudadano, de las experiencias actuales, de la frecuencia de los encuentros y de su aceptación de las medidas de gestión. Las variables sociodemográficas como el género, la educación y la preocupación por la salud pública resultan menos importantes que la experiencia previa a la hora de condicionar la percepción ciudadana y explicar el posicionamiento de la población residente. En cuanto a la habituación recíproca, los ciudadanos habituados al jabalí (con una percepción positiva de su presencia en el área urbana) contribuyen a reforzar la habituación del jabalí al entorno urbano al alimentarlo. Por otro lado, el jabalí urbano es más propenso a sufrir lesiones traumáticas graves en comparación con su homólogo rural o forestal. Estas lesiones son atribuibles a la colisión con vehículos, a los ataques de perros e incluso a la caza furtiva, entre otros. Además, aunque el control letal del jabalí no sea deseable *per se*, de momento, es necesario en los entornos urbanos. La evaluación del sistema de captura mediante red de caída determinó que la proporción de jabalíes con lesiones moderadas o graves atribuibles al método de captura fue del 15% (3 de 20), por debajo del 20% establecido en el AIHTS. Además, la importancia de las lesiones por miopatía de captura observadas en dos de los tres jabalíes afectados no está clara y podrían clasificarse también como lesiones de carácter leve, dependiendo de la interpretación. No obstante, tanto el AIHTS como la norma ISO han ido recibiendo una lista creciente de críticas que incluyen su ineficacia para garantizar el bienestar animal debido a estándares y procedimientos para su evaluación desactualizados e insuficientes, un listado inclompleto de especies de mamíferos contempladas y la falta o insuficiencia de los umbrales de aceptación utilizados. Según los procedimientos y umbrales de aceptación de una propuesta de nuevos estándares reciente, los resultados de nuestra evaluación del método de captura mediante red de caída arrojarían un rango de probabilidad de capturas satisfactorias (sin lesiones de consideración debidas al método de captura) entre el 66% y el 78%, por debajo del 85% propuesto. Por otro lado, el éxito de las capturas y la selectividad fueron del 100%, esta última garantizada por el accionamiento -remoto- por parte del operador, y no se produjeron incidencias contra las operaciones de captura ni daños vandálicos a los dispositivos utilizados por parte de personas contrarias a la eliminación de jabalíes.

La diversidad de posicionamiento ciudadano hacia la presencia del jabalí debería tenerse en cuenta para asegurar el diseño, la aplicación y la mayor aceptación de las

medidas de gestión, concretamente en las campañas de concienciación que buscan reducir aquellos comportamientos ciudadanos que afianzan la presencia del jabalí en el medio urbano (por ejemplo, la alimentación voluntaria). Las campañas educativas sobre las causas, la prevención de conflictos y las opciones de gestión eficaces para la fauna urbana podrían ayudar a mejorar la comprensión social de la problemática actual a través del conocimiento y no del miedo. Asimismo, nuestro estudio sobre las tensiones entre el conflicto y la habituación recíproca puede ayudar a entender por qué algunas medidas de gestión (p.e., la captura de individuos concretos o piaras enteras) son rechazadas por el público, aunque estos animales puedan poner en peligro a los residentes del área periurbana. También ponemos de manifiesto que, aún descartando la mortalidad debida a las acciones de gestión mediante control letal, el paisaje urbano no es un hábitat adecuado en absoluto para el jabalí, lo que se traduce en una mayor probabilidad de pérdida de aptitud, salud y bienestar. Si además tenemos en cuenta que, de momento, las medidas de control letal son y van a seguir siendo necesarias, la esperanza de vida del jabalí urbano también se ve reducida.

La que aquí hemos presentado es la primera evaluación de un método de captura mediante red de caída en base a estándares internacionales de captura no cruel, con resultados no concluyentes. Sin embargo, hay que tener en cuenta que las normas existentes se diseñaron para evaluar la captura especies de fauna silvestre y métodos diferentes. Por lo tanto, es necesario adaptar y/o establecer procedimientos y umbrales de aceptación específicos para la captura mediante redes de caída. En comparación con otros métodos de captura en vivo, las redes de caída minimizan la duración de la situación estresante -a expensas de una respuesta adrenérgica intensa y aguda- y maximizan las probabilidades de capturar grupos enteros de especies prosociales, lo que también se puede considerar más humanitario, y facilitan el hecho de compatibilizar valores máximos de éxito de captura, selectividad absoluta y adaptabilidad a entornos difíciles.

Esta tesis proporciona información sobre los factores determinantes de la percepción social del jabalí urbano, poniendo de manifiesto la mayor influencia de las experiencias previas negativas con esta especie. Además, esta tesis también deja claro que las iniciativas destinadas a promover la convivencia con los jabalíes en entornos urbanos no son aceptables ni deseables, tampoco desde el punto de vista del jabalí.

RESUM

El fenomen del senglar urbà és una de les conseqüències més recents de l'augment generalitzat de les poblacions de senglar (*Sus scrofa*) que s'ha produït a tot el món durant les darreres dècades. L'habituació del senglar al context urbà i el seu aprofitament dels recursos antropogènics ha conduït a la seva presència habitual en zones periurbanes de l'Àrea Metropolitana de Barcelona (AMB). En aquesta nova situació, no tan sols els senglars canvien la seva actitud cap a les persones en perdre la por a la presència humana; els processos d'habituació o sensibilització envers la presència del senglar dins l'entorn urbà també es produeixen en el costat humà. En quant a la "habituació recíproca", que descrivim per primera vegada, els ciutadans es familiaritzen amb la presència del senglar degut a un increment d'experiències positives amb el suid, la qual cosa genera una menor percepció del conflicte i una major acceptació de la seva presència en l'entorn urbà. Per contra, els conflictes poden causar percepcions negatives reduint la tolerància expressada per altres ciutadans envers la presència d'aquests animals -sensibilització-. En conseqüència, la gestió del conflicte entre humans i senglars (HWBC, per les seves sigles en anglès –"Human-Wild Boar Conflict") dins l'escenari urbà s'enfronta a reptes específics derivats de processos sociològics. En particular, una part important de la població urbana considera que la seguretat pública no és prou important o no es troba prou amenaçada per tal d'acceptar un control letal, defensant doncs la convivència amb el senglar en l'entorn urbà. Atès que el posicionament de la ciutadania (habituada o sensibilitzada) pot complicar o facilitar les mesures de gestió, analitzem aquells factors humans que impulsen aquestes actituds per tal d'ajustar millor la gestió de la població del senglar al context cultural i socioecològic actual. Vam realitzar qüestionaris cara a cara als transeünts de Barcelona al llarg del gradient natural-urbà, agrupant les variables de resposta per tal de valorar les característiques ciutadanes i urbanes, així com les experiències viscudes pels ciutadans, les emocions i els coneixements de cultura popular relacionats amb el senglar. Vam utilitzar un enfocament de partició recursiva (a través d'arbres de regressió) i Anàlisi de Components Principals (PCA) per tal d'explorar la relació entre la percepció del HWBC, l'acceptació de les mesures de gestió, les característiques dels ciutadans, les experiències viscudes i els posicionaments expressats envers la presència de senglars dins l'àrea urbana.

A més, plantegem la hipòtesi que l'entorn urbà és perjudicial per a la salut i el benestar dels senglars: la qual cosa, de confirmar-se, seria un millor argument per tal d'aconseguir un consens amb aquella proporció ciutadana que actualment defensa la coexistència per sobre de la necessitat d'allunyar al senglar de l'ecosistema urbà. Per avaluar l'efecte del procés de sinurbització sobre la salut i el benestar dels senglars, revisem els resultats observats en necròpsia de 845 senglars caçats (no urbans) o capturats i sacrificats (urbans) amb finalitats de gestió a l'AMB, classificant les lesions no atribuïbles al mètode de captura mitjançant una puntuació de gravetat entre 1 (menys greu) fins a 3.

Finalment, encara que la necessitat d'aplicar mesures de gestió és evident, el ventall de possibilitats és reduït i el control (letal) de la població resulta ser l'única opció rendible en la majoria dels casos. La caça és la principal estratègia per a la gestió de la població de senglar, però és inviable en l'escenari urbà, on la captura en viu seguida d'eutanàsia pren una major importància. Atès que el disseny i la manipulació dels paranys per captura en vida han de garantir el benestar dels animals d'acord amb les

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normes de captura humanitària acceptades a nivell internacional, també ens vam proposar avaluar el rendiment en termes de benestar d'un sistema de xarxa de caiguda accionada per control remot (Estrateko®) per a la captura del porc senglar dins l'AMB. Amb aquesta finalitat, vam seleccionar aleatòriament 20 dels 32 senglars capturats amb xarxa de caiguda i sacrificats amb finalitats de gestió, per al seu examen postmortem. Sent aquest (n=20) el número mínim requerit per a aquest objectiu, d'acord amb les directrius establertes en l'Acord sobre Normes Internacionals de Captura Humanitària (AIHTS) i per la Organització Internacional d'Estandardització (ISO-10990-5). Concretament, el nostre objectiu va ser el d'avaluar la presència de lesions significatives relacionades amb el mètode de captura, en base a les propostes existents d'estàndards de captura no cruenta, així com altres paràmetres de caràcter operacional.

Dins d'aquesta tesis hem trobat que la percepció ciutadana del HWBC depèn de l'experiència iderivada de la coexistència entre l'humà i el porc senglar, però també de la combinació de les emocions i el coneixement popular sobre el porc senglar. En l'àrea urbana, quan es donen intenses condicions de coexistència entre persones i senglars, la sensibilització envers el HWBC es veu potenciada a través de les incidències prèvies sofertes per l'enquestat, independentment del perfil del ciutadà, de les experiències viscudes, del nivell de contacte (coexistència) i de la seva acceptació de les mesures de gestió. Les variables sociodemogràfiques com el gènere, l'educació i la preocupació per la salut pública resulten menys importants que l'experiència prèvia a l'hora de condicionar la percepció ciutadana i explicar el posicionament de la població resident. En quant a l'habituació recíproca, els ciutadans habituats al senglar (amb una percepció positiva envers la presència del porc senglar dins l'àrea urbana) contribueixen a reforçar el fenomen alimentant i, per tant, habituant al senglar a l'entorn urbà. D'altra banda, el senglar urbà és més propens a sofrir lesions traumàtiques de caràcter greu en comparació amb el seu homòleg rural. Aquestes lesions són atribuïbles a la col·lisió amb vehicles, als atacs de gossos i fins i tot a la caça furtiva, entre d'altres. A més, encara que el control letal del senglar *per se* no resulti desitjable, a dia d'avui, és necessari dins l'entorn urbà. L'avaluació del sistema de captura per xarxa de caiguda va determinar que la proporció de senglars que presentaven lesions de moderades a greus atribuïbles al mètode de captura era del 15% (3 de 20), per sota del 20% establert per la AIHTS. A més, la importància de les lesions per miopatia de captura observades en dos dels tres senglars afectats no va ser clara i podrien classificar-se també com a lesió de caràcter lleu, depenent de la interpretació. No obstant això, tant els criteris del AIHTS com la normativa ISO han estat criticats en repetides ocasions mitjançant una llista creixent d'arguments, incloent-hi la ineficàcia a l'hora de garantir el benestar suficient dels animals degut a estàndards i procediments per la seva avaluació desactualitzats o insuficients, un llistat incomplert d'espècies de mamífers contemplades i/o la mancança i la insuficiència dels llindars d'acceptació. Segons els llindars d'acceptació d'una nova normativa proposada recentment, els resultats de la nostra avaluació del mètode de captura mitjançant xarxa de caiguda oferiria un rang de probabilitat de captura satisfactòria (sense lesions importants degudes al mètode de captura) entre el 66% i el 78%, per sota del 85% proposat. D'altra banda, l'èxit de las captures i la selectivitat van ser del 100%, aquesta darrera es troba garantida per l'accionament -remot- per part de l'operador, i no es van produir pertorbacions contra les operacions ni contra el sistema de captura per part de persones contràries a l'eliminació de senglars.

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La diversitat del posicionament ciutadà envers la presència del porc senglar hauria de tenir-se en compte per tal d'assegurar el disseny, l'aplicació i la major acceptació de les mesures de gestió, concretament dins les campanyes de conscienciació que busquen la reducció d'aquells comportaments ciutadans que promouen la presència del porc senglar dins l'àrea urbana (per exemple, l'alimentació voluntària). Les campanyes educatives sobre les causes, la prevenció de conflictes i les opcions de gestió eficaç per a la fauna urbana podrien ajudar a millorar la comprensió social de la situació actual a través del coneixement i no de la por. Tanmateix, el nostre estudi sobre les tensions entre el conflicte i l'habituació recíproca pot ajudar a entendre per què algunes mesures de gestió (per exemple, la captura d'individus concrets o porcades senceres) són rebutjades pel públic, encara que aquests animals puguin posar en perill als residents de l'àrea periurbana. No obstant això, també traiem a la llum que, fins i tot descartant la mortalitat deguda a la gestió poblacional amb mesures letals, el paisatge urbà definitivament no és un hàbitat adequat per als senglars, la qual cosa es tradueix en una major probabilitat de pèrdua d'aptitud, salut i benestar. Si a més tenim en compte que, per ara, les mesures de control letal son i seguiran sent necessàries, l'esperança de vida del porc senglar urbà també es veu reduïda.

Aquesta és la primera avaluació d'un mètode de captura amb xarxa de caiguda d'acord als estàndards internacionals de captura no cruenta, amb resultats no concloents. No obstant això, cal tenir en compte que les normes existents es van dissenyar per tal d'avaluar la captura d'altres espècies de fauna i sistemes de parany/captura diferents. Per tant, és necessari adaptar i/o establir els procediments i els llindars d'acceptació específics per la captura amb xarxes de caiguda. En comparació amb altres mètodes de captura en viu, les xarxes de caiguda minimitzen la durada de la situació d'estrès -a costa d'una resposta adrenèrgica forta i aguda- i maximitzen les probabilitats de capturar grups sencers d'espècies pro-socials, la qual cosa també es pot considerar com un mètode més humanitari, i que té la capacitat d'aconseguir valors més alts d'èxit de captura, amb absoluta selectivitat i major capacitat d'adaptació als terrenys difícils.

Aquesta tesi proporciona informació sobre els factors determinants de la percepció social del porc senglar urbà, posant de manifest la major influència de les experiències prèvies negatives viscudes amb aquesta espècie. A més, aquesta tesi també deixa clar que les iniciatives destinades a promoure la convivència amb el porc senglar en entorns urbans no son acceptables ni desitjables, tampoc des de la perspectiva del porc senglar.

1. INTRODUCTION

1.1. The urban ecosystem

Urban ecosystems are the product of human manipulation, which tends to simplify and destabilize natural ecosystems (Mackenstedt et al. 2015, Adams 2016). The post-World War II demographic shifts led to a phenomenon known as the urban sprawl. This fact led to (1) larger concentrations of people and industrial activity occupying relatively smaller areas, (2) consuming more available energy and material than can be produced, and (3) generating more wastes than can be assimilated within the land they occupy (Rees 1997, Czamanski 2008, Adams 2016). Nowadays, the human population on earth is more urban than rural (Mackenstedt et al. 2015, Nyhus 2016). Urban humans produce approximately twice as much waste as their rural counterparts (Townsend et al. 2019). The 8-10% of global greenhouse emissions are associated with non-consumed food. This is accounting for the 17% of worldwide food production (931 million tons) being wasted in urban areas, the 61% of which is originated in domestic households (Forbes et al. 2021). Urbanization fragments, isolates and degrades natural habitats, simplifies and homogenizes species composition, disrupts hydrological systems and modifies energy flow and nutrient cycling (Mackenstedt et al. 2015, Adams 2016, Nyhus 2016). More specifically, urbanization affects the structure and function of Earth's ecosystems through transformation of natural landscapes, alteration of biophysical processes and habitat, and modifications of major biogeochemical processes, therefore being considered as a major anthropogenic force (Alberti 2010, Nyhus 2016). Urban systems go against natural systems in terms of structure and function, which is perpetuated by roads, being the primary mechanism used to access the non-human-influenced lands (Schwarz et al. 2014, Adams 2016). On this context, because humans are the cause of many environmental changes, they are the solution to such challenges (Frank and Glickman 2019). According to that, urban ecosystems need to be studied in the context of an integrated human and ecological conceptual framework (Adams 2016). However, most of past studies on urban systems and natural resource values have been parceled among four different disciplines: sociology, economics, ecology, and politics; and hence examined separately rather than being synthesized into one coherent theoretical framework by all vested interest groups (Adams 2016, Morzillo et al. 2014). As a result, multidisciplinary research involving ecologists and scientists from other areas, as well as managers and engineers, is increasing to understand and manage growing urban ecosystems (Grimm et al. 2008).

1.2. Human dimension in the anthropocene

Today, we consider the *homo sapiens* as an organism that affects the distribution and abundance of many other species, impacting on ecosystems, strongly modifying patterns of relative abundance among competing species and affecting community structure at multiple trophic levels (Morzillo et al. 2014, Nilon 2014, Adams 2016). As human populations grow and transform landscapes, contact with wildlife concurrently increases, with consequences such as crop and livestock depredation, property loss, and so does consequent conflict (Ruiz-Fons et al. 2008, Meng et al. 2009, Strohbach et al. 2014, Wellington et al. 2013). The human-wildlife relationship is a non-static

condition based on the evolving definition of what nature means to society, where humans and wildlife belong, and dynamic interactions occur. Both are learning to survive in many ways, leading to conflict-to-coexistence reactions (Frank and Glickman 2019). Nowadays, urbanized large mammals pose risks such as human injury and vehicle collisions (Kose et al. 2011, Zubergoitia et al. 2014, Nyhus 2016). While traditional wildlife management was based on applied biology, nowadays the field includes studies on wildlife population, ecology and its relationship with people, the later being known as the human dimension of wildlife management (Bath 1998).

The challenge of coexistence in urban landscapes seems to be not so much about whether species are able to cope with human disturbance, but whether humans are willing to share their landscape and host wildlife in their backyards (Cretois et al. 2020). As previously mentioned, humans' influence is the origin of many environmental conflicts; therefore, the pathway to finding solutions is also embedded in human factors, namely the human dimension of conflict (Nyhus 2016, Frank and Glickman 2019). Emotional-based influences on attitudes towards the urban wildlife are clearly motivating citizen behavior facing the conflict, as has already been described for other large mammal species (Benvenuti 2016, Slagle and Bruskotter 2019, Jacobs and Vaske 2019, Nettles et al. 2021, Batavia et al. 2021). Therefore, attitude information is gathered to correlate with the human behavior to better understand the human dimension and to increase reliability and validity of data (Bath 1998, Nyhus 2016). By simply examining current attitudes, emotions, beliefs and knowledge, wildlife managers can obtain a static assessment of this human dimension (Rees 1997, Bath 1998, Lindsey 2016).

1.3. The dual process theory, anthropomorphism, utilitarian considerations and human values

Aiming to better understand human dimension drivers, Grooves and Thomson (1970) hypothesized that 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, developing the dual-process theory. Changes in human behavior are the net result of both competing processes occurring simultaneously inside the subject. Habituation process reduces the potential action magnitude on neurons at pre-synaptic level, hence reducing the number of secreted synaptic vesicles. In return, sensitization process enhances a higher response to a stimulus, with higher neurotransmitter release from the pre-synaptic axon terminal (Arreguín-González 2013, Çevik 2014). Due to that, the magnitude of human-wildlife interaction can modify human perception on a cost-benefit trade-off, depending on positive or negative past experiences (Zhang et al. 2014, Belaire et al. 2016, Bencin et al. 2016). Correspondingly, the overall influence of habituation and sensitization processes, hence their effect, are depending on the stimulus intensity. Greater sensitization results from highly intense stimulus and faster habituation results from low intensity stimulus (Çevik 2014). Accordingly, if a human being encounters a recently discovered experience more frequently, it can habituate (low intensity stimulus) or sensitize (high intensity stimulus) its individual response.

The cognitive stage by defect in humans is anthropomorphism, which nowadays induces empathy, social meaning or other human attributions to animals (Heider and Simmel 1944, Sheelea et al. 2015, Benvenuti 2016). Anthropomorphism is leading to

challenging traditional approaches to wildlife management, where values towards wildlife are not aligned with the ethical paths of traditional wildlife management. It emphasizes the consideration of individual animals and the avoidance of lethal control techniques (Whittaker et al. 2006, Benvenuti 2016). Furthermore, it is enhanced in situations where humans have an increased need for social affiliation, as is the case in urbanized societies or where there is a loss of community (Lute and Gore 2019, Dietch et al. 2019).

Neuroscience is now studying how the human brain represents and processes any problem involving values. Moral values (rights and wrongs) and utilitarian considerations (cost and benefit) are processed in different brain areas (Emre Can and Macdonald 2018). Moral values are positive or negative evaluative variables of some object that can vary considerably by the specificity of this object (Whittaker et al. 2006). On situations where strong (protected or sacred) moral values are disproved, amygdale activity increase (which is also related to fear and emotional processes) and the brain do not use networks associated with utility (Emre Can and Macdonald 2018). Descriptive studies can identify divisions related to public acceptance, but information on the degree to which they are values-based may indicate whether controversies are likely to be resolved (Whittaker et al. 2006, Nyhus 2016, Lute and Gore 2019). Sensitization and conservation policies based solely on utilitarian considerations are likely to fail as the neurological process of rights and wrongs clashes with the process of cost and benefits (Emre Can and Macdonald 2018). Better understanding human values, perceptions and actions has become increasingly important for management agencies (Bath 1998, Lindsey 2016, Lute and Gore 2019).

1.4. Wildlife synantropization and synurbization

In many parts of the human-dominated world, large mammals are threatened by human impacts, but evidence demonstrates that coexistence between humans and wild large mammals is possible (Smith et al. 2014, Cretois et al. 2020). Nowadays it is known that urban areas can provide suitable habitats for wildlife capable of using highly fragmented habitats, favored by urban sprawl and the consequent alteration of the surrounding environments (Carey et al. 2012). In recent decades, there has been an increasing tendency for mammal and other vertebrates to colonize cities. This phenomenon is called synanthropization and refers to the adaptation of animal populations to human-created environments (Luniak 2004). Those wildlife species adapted to human-dominated landscapes are considered synanthropic and therefore can expand their range of distribution and/or become more abundant as a result of anthropogenic activities (Luniak 2004, Francis and Chadwick 2012). When this process takes place in urban environments is called synurbization. Worldwide, a rising number of mammal species are settling and increasing their abundance in urban environments (Figure 1, Escudero-Gómez et al. 2009), including carnivores (Bhatia et al. 2013, Poessel et al. 2017, Loss et al. 2013, Bombieri et al. 2018), ungulates (Cahill et al. 2012, Mcdonald et al. 2012, Toger 2018, Ciach and Frühlich 2019) and smaller species (Bekoff and Ickles 1999, Morzillo et al. 2014).

Most contemporary fauna species shaped their ecological and behavioral status during the last one to 500 million years, while urbanization has occurred only during the last 100-200 years. This explosion of new environments has contributed to destroy natural habitats, but also has created new, free ecological niches attracting animal populations; particularly for species with wide demographic, behavioral and

nutritional spectrum (Nyhus 2016, Cox and Gaston 2018). Generally, specialist species tend to decline in urban areas, while generalist species thrive. This is because specialist species need to accomplish with strict requirements regarding diet, habitat, and/or nesting sites in order to survive (Francis and Chadwick 2012). As the specialists leave, the decrease in interspecies competition for resources allows the generalists to not only survive but increase in numbers (Adams 2016). Garbage is an important food source for many urban generalists, particularly omnivores such as the wild boar; and humans are the principal garbage producers worldwide, promoting the transition of synurbic species from country to city living (Luniak 2004, Adams 2016, Reshamwala et al. 2018). Therefore, and according to this, populations of synurbic species can counteract the impact of urban-related threats such as environmental pollution or vehicle collisions (Zuberogoitia et al. 2014, Grilo et al. 2019), and tend to increase densities due to the availability of anthropogenic resources that provide an endless supply of easily attainable food (Adams 2016, Nyhus 2016, Townsend et al. 2019, Sütő et al. 2020). Furthermore, the action of providing supplemental food for urban wildlife (i.e., feeding feral or stray cats, pigeons and wild boars) has become a popular hobby in urban areas (Loss et al. 2012, Adams 2016, González-Crespo et al. 2018). Urbanization and associated human actions affect the behavior of wild co-existent species, where anthropogenic food supplies contribute to reduce the need for individual animals to move around in search of feeding sources (Luniak 2004, Parker and Nilon 2012). Once the minimum criteria for survival in the urban scene have been met, the next challenge is reproduction. Due to this process, genes are transmitted within the population and then tested on the ecosystem for fitness (Francis and Chadwick 2012). Then, those individuals with best-suited genetic adaptations lead to the dominant representation of the species (Focardi et al. 2015, Fulgione et al. 2016, Townsend et al. 2019). Applying the previously mentioned mechanisms, the effect of urbanization on synurbic populations is leading to smaller home ranges, behavioral changes, longer breeding seasons or traditional migration activity disappearance (Luniak 2004, Shochat et al. 2006, Parker and Nilon 2012, Francis and Chadwick 2012). This scenario is played out constantly and consistently in natural as well as in urban ecosystems. Due to that, wildlife adaptation to cities is becoming a fast-growing challenge for the society in the XXI century (Adams 2016, Nyhus 2016).
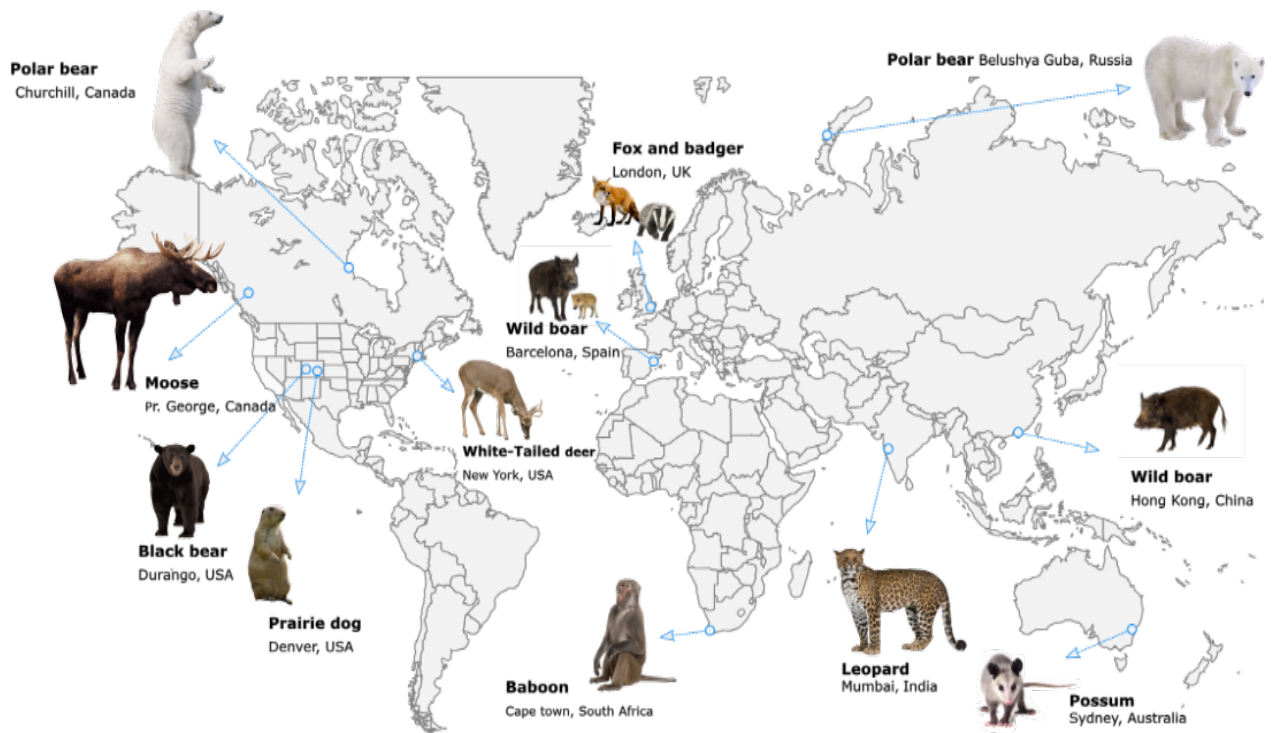
Figure 1. World distribution of some human-wildlife conflicts related to wild mammal presence in medium and big-size cities. Map based on a non-systematic literature review (Beckoff and Ickes 1999, Delahay et al. 2009, Hoffman et al. 2012, Macdonald et al. 2012, Cahill et al. 2012, Bhatia et al. 2013, Beaumont 2013, Seggos 2018, Johnson et al. 2018, Chor 2019, BBC News 2019, Heemskerk et al. 2020).

1.5. Human-wildlife interaction and conflict in urban areas

The current adaption of wildlife to urban landscapes and the close contact between humans and wildlife is raising the frequency of human-wildlife interactions (Soulsbury and White 2015, Poessel et al. 2017, Antoci et al. 2019). Those interactions vary in outcome from positive to negative, in impact from minor to severe, and in frequency from common to rare (Nyhus 2016). Therefore, human-wildlife coexistence in the urban interface sets the stage for a wide range of human-wildlife interactions, and consequent conflicts that had never existed before (Adams 2016). Current separation between people and natural landscapes during the childhood is promoting biophobia and, hence being detrimental for the human willingness to conserve nature (Zhang et al. 2014). Although the aesthetic value of wildlife species among society is recognized (Hess et al. 2014, Bencin et al. 2016), negative experiences induced by agonic encounters with wildlife lead to the growing social concern towards human-wildlife conflicts (Dickman 2010, Liordos et al. 2017).

On natural landscapes, wildlife damages are usually related to crop or livestock depredation, property loss, local biodiversity decline and growing risk of exposure for livestock, pets or humans to diseases arising from wildlife reservoirs (Ruiz-Fons et al. 2008, Meng et al. 2009, Wellington et al. 2013, Strohbach et al. 2014, Rakshya 2016, Torres et al. 2018, Carpio et al. 2021). Considering that approximately 60% of all globally emerging infectious diseases are zoonotic and the 70% originate in wildlife (Jones et al. 2008, Nyhus 2016), diseases carried by wildlife are highly relevant from a human and animal health perspective, as well as for biodiversity conservation (Daszak et al. 2002). Therefore, current synanthropization is creating unexplored and sometimes also unexpected wildlife-human interfaces that favor the occurrence of risks and hazards as interspecific transmission of pathogens (Bradley and Altizer 2007, Castillo-Contreras et al. 2022a and b, Gortázar et al. 2007, Mackenstedt et al. 2015, Fernández-Aguilar et al. 2018). However, in both rural and urban environments, vehicle collisions with large mammals are among the most conflictive occurrences for both humans and wildlife (Rodríguez-Morales et al. 2013, Zuberogoitia et al. 2019, Vanlaar et al. 2019, Carpio et al. 2021).

Conflict in one specific situation may not be perceived as such in another similar situation due to outputs, frequency, impact, culture, time and location, among other factors (Soulsbury and White 2015, Nyhus 2016). Indeed, perceived conflicts are highly influenced by human dimension factors, and are more influenced through social and cultural values than about actual impacts (Frank and Glickman 2019). In many cases, the human-wildlife conflict framework hides a human-human component. In urban areas, this conflict is often represented through disagreements between different stakeholders over different interests, including how to manage, protect and conserve wildlife (Nyhus 2016, Frank and Glickman 2019). By examining citizen attitudes towards wildlife presence in urban areas and the influence of human dimension drivers (emotions, previous lay-knowledge and personal past experiences), wildlife managers may obtain a static assessment of the human dimension. According to that, technicians can gain efficiency selecting the best locally fitted human-wildlife conflict mitigation measures, as well as choosing the most socially relevant contents when applying citizen awareness and/or educational campaigns (Bath 1998, Lindsey 2016).

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1.5.a. Life history and current situation of the wild boar

The wild boar (*Sus scrofa*) is an artiodactyl of the *Suidae* family, having the widest geographical range of all northern ungulates (Snow et al. 2017). The current increase of wild boar populations, both geographically and demographically, is being boosted by planetary-scale changes such as depopulation of rural areas, global warming, lack of predators and forest encroachment (Massei et al. 2015, Castillo-Contreras et al. 2018) as well as socioeconomic and ecological changes, such as natural forest regeneration, increased anthropogenic food resources, limited hunting and translocations (Sáez-Royuela and Tellería 1986, Massei et al. 2011, Snow et al. 2017).

In natural environments, wild boar is a gregarious species with a social hierarchy, in which elder and bigger sows occupy the higher positions (Újváry et al. 2012). The typical social organization of wild boar population is represented by family groups with overlapping generations of females, herd size is dependent on reproductive activities and litter size responds to environmental conditions like mast yield oak and weather (Kaminsky et al. 2005, Frauendorf et al. 2016, Toger et al. 2018). Females reach sexual maturity at a minimum weight of 35 kg and minimum age of 8 months (Herrero et al. 2008). When biological requirements are achieved, wild boar fecundity is extremely high when compared to other ungulate species (Fernández-Llario and Mateos-Quesada 1998).

As a generalist species, due to its movement ecology together with its diet plasticity and its high prolificacy, the wild boar can colonize and survive a wide range of habitats, including agro-ecosystems and urban areas, where (with suitable environmental conditions) the wild boar can reach very high densities (Podgórski et al. 2013, Snow et al. 2017, Vajas et al. 2020). Indeed, those abilities contribute to its spread (Morelle et al. 2015). The easy access to food and water and the expanding urbanization into forested areas is favoring wild boar intrusion into periurban and urban areas (Licoppe et al. 2013, González-Crespo et al. 2018). Rivers and roads act as corridors, which facilitate wild boar occurrence into urban areas (Licoppe et al. 2013, Castillo-Contreras et al. 2018). Because of that, the wild boar is easily becoming an urban dweller and is joining with success the current growing list of synantropic mammals in European cities, including Barcelona, Berlin, Budapest, Genova and Warsaw (Licoppe et al. 2013). In Spain, herds of urban wild boar packs have been recorded in almost all provinces, with special relevance in Barcelona, Asturias, Madrid, Galician and Basque Provinces, Malaga and Valencia (Cahill et al. 2012, Pontevedra 2019, Warner 2019, Serrano-Montes and Páez-Galiano 2020). Certainly, nowadays the wild boar is considered a potential invasive species by the IUCN, and the annual intensification of hunting pressure to control and reduce its populations has proven to be insufficient (Lowe et al. 2000, Bieber and Ruf 2005, Hearn et al. 2014, González-Crespo et al. 2018). Due to all those factors, the wild boar is considered a native invader, spreading within its historical range, reaching extreme abundances and producing severe effects on other species (Simberloff 2011, Carey et al. 2012).

Regarding pathogen circulation and health hazards, the wild boar plays an epidemiological role as reservoir for infectious diseases, and many of those are also shared with companion animals, livestock and humans (Ruíz-Fons et al. 2006, Meng et al. 2009, Navarro-González et al. 2013, Fernández-Aguilar et al. 2018, Castillo-Contreras et al. 2018, Wang et al. 2019, Klaumann et al. 2019). Into the rural and urban scene, the wild boar is a potential source for emerging diseases (Castillo-Contreras

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2021 & 2022, Darwich et al. 2021, Meng et al. 2009, Ruíz-Fons et al. 2006). Therefore, the wild boar can drive importantly economical livestock diseases such as African and Classical swine fevers, Tuberculosis (*Mycobacterium spp.*) and Brucellosis (*Brucella spp*); food-borne pathogens as *Salmonella enterica, Campylobacter spp.* and *Escherichia spp.*; diseases of public health concern as those caused by antibiotic-resistant bacteria and zoonotic viruses as the Hepatitis E virus (Ruíz-Fons et al. 2008, Meng et al. 2009, Mur et al. 2012, Navarro-González et al. 2013, Podgórsky et al. 2018, Wang et al. 2019). Due to urban landscape characteristics, wild boar synurbization process poses potential public health risk such as zoonotic pathogen transmission.

The wild boar is abundant in Collserola Natural Park (CNP), which is embedded in the metropolitan area of Barcelona -MAB- (Spain). In Barcelona, the wild boar seasonally enters the city through the urban edge with the CNP (Cahill et al. 2012, Castillo-Contreras et al. 2018), where the wild boar population was anecdotal in the 80s but has since then increased to reach a density over nine wild boar per 100 ha (Minuartia 2017). Urban wild boars gain access to urban areas using natural corridors and positively select fragmented urban landscapes, mainly during the seasonal periods of food scarcity in Mediterranean ecosystems (Castillo-Contreras et al. 2018). It is during those periods when the urban landscape provides additional resources such as anthropogenic food, water and shelter that result tempting for those wild boars getting closer to these settings (Amendolia et al. 2019).

Furthermore, recent models predict that this increasing trend will continue along time (González-Crespo et al. 2018), being favored by the extent of urbanization within the Collserola massif, and the associated anthropogenic food available for wild boar, namely domestic rubbish, vegetable material from parks and gardens, and pet food from stray cat colonies (Cahill et al. 2012, Castillo-Contreras et al. 2018). Since 2012, Barcelona city and the CNP are proffering a scenario where human-wild boar interactions occur along a natural-to-urban gradient (Cahill et al. 2012), being more intense in the intermediate levels of urbanization between the urban landscape and the CNP, in the urban edge (Castillo-Contreras et al. 2019, González-Crespo et al. 2020). In this scenario, human-wild boar coexistence and consequent interactions occur when the wild boar approach the urban environment looking for anthropogenic food sources and therefore habituating itself to the urban landscape as well as to the human presence (Baltasar et al. 2008, Cahill et al. 2012, Castillo-Contreras et al. 2019). In Barcelona, the occurrence of suitable environmental conditions, in conjunction with urban planning reasons unfeasible to revert, today it is normal to sight stable and habituated wild boars as common hosts in the suburban area (Cahill et al. 2012, Castillo-Contreras et al. 2018). Furthermore, hybridization between wild boar and different breeds of domestic pig (*Sus scrofa domesticus*), including the Vietnamese pot-bellied pig, has been observed in Barcelona (Figure 2, Delibes-Mateos and Delibes 2013, Lacolina et al. 2018). Vietnamese pot-bellied pigs are a common pet in Europe, but their recent decrease in popularity led to their abandonment, making them now well distributed throughout Spain, often found close to cities (Delibes-Mateos and Delibes 2013). Artificially domestic traits' introgression into wild populations seems to have been quite pervasive since domestication, which may alter the fertility and thus increase fitness in wild boar-hybrids (Lacolina et al. 2018).

Evidence about the urban life effect on wild boar populations has been provided. The wild boar in natural areas is diurnal when ranging in undisturbed environments, but a higher human pressure in general causes the wild boar to become more crepuscular or even nocturnal (Keuling et al. 2008, Podgórski et al. 2013, Johann et al.

2020, Wevers et al. 2020). When ranging within urban areas, wild boar populations have smaller home range and are less affected by seasonal conditions (Podgórski et al. 2013). Other significant differences were found in urban wild boar, regarding its behavior (feeding more often on anthopogenic sources), physiology (higher trigliyceride and lower creatinine serum concentrations) and morphometry (better body condition, larger body size and higher body mass; Castillo-Contreras et al. 2019). This behavioral plasticity led to an adaptation to urban environments originated by a higher wild boar tolerance towards human disturbances (Cahill et al. 2012). The "landscape of fear" describes a trade-off between access to food and predator avoidance on a spatial scale. This adaptation to the urban environment is accompanied by a modification of wild boar perception of the urban landscape of fear, with a resulting trade-off between foraging and human disturbance (Stillfried et al. 2017b). Furthermore, on-site observations show that both cultural and ecological behavioral patterns of suburban dwellers have generated a close proximity in specific hotspots and an increasing reciprocal habituation of humans and wild boar (Cahill et al. 2012, Arregui et al. submitted). All this research provided the first evidence on the synurbization process of wild boar populations arising new and broad unanswered questions.

The wild boar is adapting to and therefore surviving and reproducing in urban areas. However, there is little known about the possible detrimental effects on wild boar health and welfare of the urban lifestyle. A better wild boar fitness in the urban area population cannot be assumed without a successful test of gene transmission in the urban ecosystem. Due to that, we cannot confirm that wild boar population of Barcelona is greatly benefited from the availability of anthropogenic resources (Parker and Nilon, 2012). The high number of vehicle collisions with wild boar, dog attacks and poaching are among other potential risks and hazards in the urban foraging trade-off, which may also imply a higher probability of losing fitness, health and welfare. The complete success of synurbization process can only be reached if the best urban-adapted wild boar breeding sows lead offspring that contribute to increased individual recruitment into breeding herds.

Figure 2. Breeding wild boar sow with five pot-belied vietnamese hybrid piglets captured in the suburban area of Barcelona.

1.5.b. Human-Wild Boar Conflict in humanized landscapes

Over time and as a consequence of wild boar natural features and human-induced changes, the interaction between wild boar, humans, and the environment have increased and diversified and so has the discourse around them (Massei et al. 2011, Frank and Glickman 2019). Current Human-Wild Boar Conflict (HWBC) emerges when the needs and behavior of the wild boar impact negatively on the goals of humans (Madden, 2004) arising social sensitization towards coexistence. This happens as soon as incidents involving wild boar increase over time and those costs are more significant than benefits, suggesting that negative perceptions more strongly determine human values (Kansky and Knight 2014, Zhang et al. 2014, Lindsey 2016). The risks and disturbances associated with wild boar presence are crop damages, increased risk for shared diseases, altered food webs and damage to some plant and animal species. Despite quite neglected, public health hazards are by no means the least of the problems posed by wild boar synurbization, since wild boar share several diseases with both pets and humans (Meng et al. 2009, Ruiz-Fons 2017). It is not only about vehicle collisions, which are common in many countries, but more dangerous motorcycle and bicycle collisions with wild boar occur more frequently in suburban settings (Acevedo et al. 2013, Zuberogoitia et al. 2014, Massei et al. 2014, Pontevedra 2019, Warner 2019, Rivera 2021, Walters 2021, Trelinski 2021). Furthermore, in urban environments, wild boars imply disturbances such as damages to street furniture, parks and private gardens, ransacking of rubbish bins and containers and occasional attacks on pets and people (Massei et al. 2011, Cahill et al. 2012, Frank and Glickman 2019).

Although the death of a human being due to a direct attack by a wild boar is rare and normally only affects hunters or people living or working in agricultural lands, attacks on people and pet (non-hunting) dogs are underreported in the scientific literature but are reported in the media (Manipady et al. 2006, Ingendaay et al. 2008, Kose et al. 2011, Mayer et al. 2013). It is known that mostly in the rutting season and when provoked, wild boar attack ferociously and repeatedly with their sharp tusks. Thus, potentially fatal injuries can be inflicted commonly on lower parts of the body at the level of the thigh or calf (Manipady et al. 2006, Gunduz et al. 2007, Mayer et al. 2013). Hence, it cannot be neglected that wild boar is one of the biggest wildlife species that have proven to thrive in urban environments (Cahill et al. 2012), which together with its phenotypic plasticity confers this species a great harmful potential.

1.5.c. Human dimension of the urban wild boar phenomenon

As mentioned before, human-wildlife coexistence in urban areas is strongly determined by the willingness of humans to share urbanized landscapes with wildlife (Cretois et al. 2020). Wildlife management is understood as a process modulating human interaction between wildlife and its habitats, including studies on people's perception (Bruskotter and Vaske 2009, Lindsey 2016). This requires specific research on the influence of the so-called human dimension on the urban wild boar ecology. Although this new research scenario has nothing to do with wildlife at all, managing people nowadays becomes one of the most important things in managing wildlife (Bath 1998, Adams 2016, Hosaka et al. 2017). One way to expand understanding of people knowledge levels, expectations, attitudes and activities, namely the human dimension,

towards wildlife management is to collect representative data from desired human clusters through surveys (Bath 1998, Nilon 2014, Hostetler and Reed 2014).

In Barcelona, HWBC arise in peripheral districts, which are closer to CNP; namely, Les Corts (LC), Sarrià-Sant Gervasi (SSG), Gràcia (G), Horta-Guinardó (HG) and Nou Barris (NB). Citizens ranging in peripheral districts experience higher contact with urban wild boar, fostering citizen habituation or sensitization to the existing HWBC (Belaire et al. 2016; Bencin et al. 2016). On situations where human-wild boar coexistence and conflict is happening, there is often a mismatch between perceptions of risk, actual degree of risk and proportional response to risk (Nyhus 2016, Adams 2016). Whittaker et al. (2006) and Nyhus (2016) suggest that citizen values and norms towards current HWBC may differ depending on the action (wild boar translocation vs. culling), target (healthy vs. severe injured wild boar), context (aggressive wild boar vs. a sow with her litter) and location (urban area of Barcelona vs. in the CNP). According to that, non-conflictive interactions between citizens and the wild boar may give people an opportunity to connect locally and directly with nature and this can increase the value and appreciation of wild boar presence into the urban landscape (Soulsbury and White 2015, Lute and Gore 2019, Castillo-Contreras et al. 2022b).

1.6. Management of wild boar population in Barcelona

The urban adaptation of the wild boar is a more recent consequence of the generalized worldwide increase of wild boar populations (Toger et al. 2018, Castillo-Contreras et al. 2021). This phenomenon has led to the implementation of specific management measures, whose efficiency is necesary to achieve mitigation and prevention of attacks to humans, vehicle collisions or disease transmission risk.

Recommended management measures include the strict avoidance of supplementary feeding, shelter and water sources, as well as populaton control. In this respect, under good conditions (high availability of resources for wild boar), reducing juvenile survival will have the largest effect on wild boar population (González-Crespo et al. 2018); converserly, under poor conditions, strong hunting pressure on adult females will lead to most effective population control (Bieber and Ruf 2005). Currently applied management measures in Barcelona are aimed at 1) reducing the overload of wild boar population through lethal control in CNP, 2) tackling undesirable conflicts caused by the urban wild boar, 3) reducing the urban attractiveness for the wild boar and 4) applying citizen awareness campaigns. Apparently improved efficiency was achieved according to the mentioned aims through the following actions: 1) combining traditional drive hunts in autumn and winter with night stalks in spring and summer, which increased the yearly hunting bag of wild boar in CNP (González-Crespo et al. 2018); 2) capture of conflictive wild boars into the urban area by means of live capture methods (cage traps, corral traps, drop nets and/or teleanaesthesia) and pharmacological euthanasia (López-Olvera 2019, Torres-Blas et al. 2020); 3) Cattle grids were placed in paths leading to green-spaces and other wild boar-proof devices were installed to prevent acces to other potential anthropogenic food resources (e.g., containers, bins and stray cat feeding points); and (4) awareness campaigns focused on conflictive human clusters (e.g., stray-cat managers and pigeon feeders) were also carried out. However, it cannot be neglected that wild boar management in the urban scene faces to specific challenges derived of sociological component. A sounding part of the urbanite population considers that public safety and health are not important or menaced enough to accept lethal control and defends cohabitation with wild boar in

the urban environment. We argue that wild boar welfare may be a better argument to show this society sector and hypothesized that the urban environment is detrimental for wild boar health and welfare (Hess et al. 2014, Castillo-Contreras et al. 2021).

Short-term management of conflicts derived from wild boar presence in urban landscapes strongly relies on lethal control, which is up to date the only effective strategy to safeguard public safety (Keuling et al. 2016, Vajas et al. 2020). Regarding the surrounding forested landscapes of Barcelona, hunting is permitted in approximately 50% of the CNP (Cahill and Llimona 2004). However, in certain scenarios, such as the Barcelona urban areas (Figure 3), hunting is unfeasible or illegal due to safety constraints (Licoppe et al. 2013). Due to that, control and management actions of wild ungulate population including the capture of free-ranging individuals are part of the applied measures due to their efficiency and cost. In this respect, live trapping methods are widely used for ungulate capture and management (Iossa et al. 2007, López-Olvera et al. 2009) and animal welfare monitoring during the entire process is a key aspect (Barasona et al. 2013, Adams 2016). Current social concerns coupled with the ethical responsibility of wildlife managers make necessary assessing welfare of live-trapped wild boar (Carpio et al. 2020, Torres-Blas et al. 2020).

We counted on the participation of social scientists to address the human dimension of the HWBC. Namely, we studied the influence of citizen perception (Studies 1 and 2), attitudes (Study 2), and practical behavior in proximity to wild boar as potential triggers for reciprocal habituation (Study 2). Furthermore, we studied the inherent associated risks faced by the wild boar when ranging in the urban landscape (Study 3). Management measures mitigating HWBC claim to be feasible, efficient and socially accepted (Study 4), which also implies a change in citizen attitudes regarding the current HWBC. Understanding the influence of the human dimension, urban-related risks and management of the urban wild boar is a scientific and technical challenge for modern cities of the 21st century.
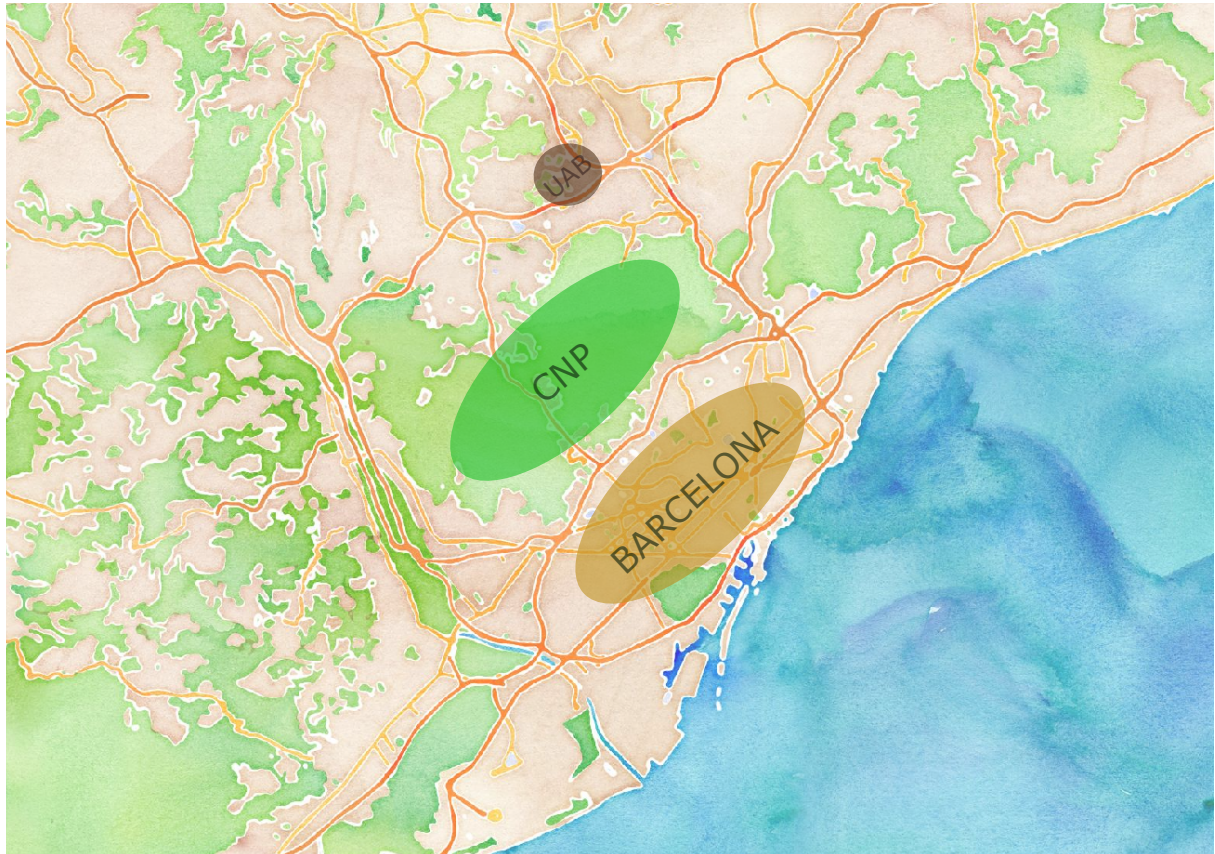
Figure 3. All studies included into this tesis were performed along the urban gradient between the Autonomous University of Barcelona (UAB), the Collserola Natural Park (CNP) and the urban area of Barcelona.

2. HYPOTHESES AND OBJECTIVES

The hypotheses of this thesis are:

Human dimension drivers influence citizen perception towards wild boar presence in urban areas (Studies 1 and 2).

Analyses through survey studies of human dimension factors influencing citizen perception can clarify which human factors best explain the attitude and behavior of local citizen facing the human-wild boar conflict in urban settlements (Studies 1 and 2).

Wild boar could be wrongly assessing the cost-benefit trade off when exploiting the urban environment, which implies the exposure to anthropogenic risks than can be detrimental for wild boar health and welfare (Study 3).

The Estrateko® remote controlled drop-net system is a selective and efficient trapping device for wild boar live-capture in urban areas capable of fulfilling humane trapping standards (Study 4).

Therefore, the objectives of this thesis are:

To determine which human dimension factors (citizen features, experiences, emotional motivations, previous lay-knowledge and current socio-economical context) drive citizen's wild boar perception and human-wild boar conflicts in urban areas (Studies 1 and 2).

To evaluate the impact on wild boar health and welfare of its current synurbization process in Barcelona (Study 3).

To assess humane trapping standards of a wild boar drop-net capture method -Estrateko®- (Study 4).

3. STUDIES

artist: Laura Gil (2018)

3.1. Study 1: Past experiences drive citizen perception of wild boar in urban areas

STUDY 1

3.1.a. Abstract

Wild boar (*Sus scrofa*) populations in urban environments have increased during the last decades. This has led to a new scenario where humans share the space with this recent colonizing species inside urban areas. Citizen perception on wild boar presence must be taken into account to assure the most suitable design, application and acceptance of management measures. In order to advance in the knowledge and comprehension of urban wild boar perception by citizens, we conducted 181 surveys to women and men representing all age classes. Our questions were focused on assessing citizen features, experiences and attitudes regarding wild boar presence in the urban area of La Floresta (Sant Cugat del Vallès, Barcelona, Spain). We used a recursive partitioning approach through regression trees to explore the relationship between a Wild Boar Perception Score (WBPS) and citizen profile, past and current experiences involving wild boars, contact with wild boars and acceptance of management measures. Our results show that the WBPS is mainly driven by previous incidents suffered by the respondent, independently of citizen profile, current experiences, level of contact and acceptance of management measures. The respondents answered that measures should be taken to minimize wild boar incidents (37%) and to help wild boars to return to their habitat (27%), whereas 16% chose to coexist with wild boars in the current conditions. Culling all the wild boars was not supported at all, even among the citizens with the most negative perception of wild boar. Citizens with positive perception of wild boar presence in urban areas contribute to reinforce the phenomenon by feeding wild boars. Our results verify that socio-demographic variables such as gender, education and public health concern are less important than past experiences to drive citizen perception and explain resident attitudes. Information campaigns on the causes, consequences and effective management options for urban wildlife could help to improve understanding and acceptance of the circumstances and currently non-socially accepted possible solutions. Evaluation of citizen perception and information campaigns should precede wildlife management measures, in order to gain acceptance by residents before being implemented.

3.1.b. Short Communication

Wild boar (*Sus scrofa)* has the widest geographical range of all northern wild ungulates and this range has been greatly expanded by planetary-scale changes such as depopulation of rural areas, mild winters, lack of predators and forest encroachment in some areas (Vetter et al. 2015, Massei et al. 2015). Wild boar is considered a potential invasive species and the annual intensification of hunting pressure in an attempt to control and reduce its populations has proven to be ineffective (Massei et al. 2015). The number of wild boar records in several European cities (for instance Berlin, Barcelona, Rome, Vilnius and Budapest, among others) has also increased in the last decades (Sáez-Royuela and Tellería 1986, Castillo-Contreras et al. 2018). This increase of wild boar in urban areas could be a consequence of exploiting anthropogenic food resources, such as refuses and waste material, food and water at public green areas and food provided by wild boar feeders (Kotulski and Koenig, 2008, Castillo-Contreras et al. 2018).

Inside urban areas, wild boars cause traffic accidents, damage to courtyards, green areas and street furniture. Minor attacks have been recorded on humans as well as domestic pets, and they have been reported to follow an increasing trend in some urban areas (Mayer, 2013, Fernández-Aguilar et al. 2018). Wild boar also pose a risk of pathogen transmission, such as Mycobacterium tuberculosis complex, *Salmonella enterica*, *Campylobacter spp.*, *Streptococcus suis*, *Rickettsia slovaca*, *Leptospira spp.* or *Chlamydophila spp.*; and they produce negative effects on plant and animal species richness and abundance (Jansen et al. 2007, Ortuño et al. 2007, Di Francesco et al. 2013, Navarro-González et al. 2013, Mentaberre et al. 2014, Fernández-Aguilar et al. 2018). Lethal measures such as culling have been proposed as successful wildlife management measures in order to deal with local overabundant populations, including the introduced American mink (*Neovison vison*) in southern England (Harrington et al. *2009*); stabilization of chronic wasting disease in white-tailed deer (*Odocoileus virginianus*) in Illinois (Manjerovic et al. 2014); mitigation of wild boar (*Sus scrofa*) overpopulation in Europe, Australia and the United States (Massei et al. 2011); control of bovine tuberculosis infection in European badger (*Meles meles*) in Ireland (Abdou et al. 2016) or introduced coypu (*Myocastor coypus*) populations in Italy (Panzacchi et al. 2007). In the particular case of growing Mediterranean wild boar populations, selective elimination (culling) of juvenile and young wild boars has been recently proposed as a more efficient measure than simply intensification of traditional non-selective hunting pressure to control population increase (González-Crespo et al. 2018). However, local attitudes towards wildlife are key for humans and wildlife coexistence (Bencin et al. 2016), and management measures acceptance varies according to different areas, human perception of the problem and different characteristics of the affected species (Liordos et al. 2017). Therefore, to implement management measures it is essential to assess public perception of the conflict and acceptance of the measures. Wildlife presence in urban areas can modify resident perception on a cost-benefit trade-off, depending on positive or negative past experiences with the particular species (Belaire et al. 2016, Sekhar, 2003, Bencin et al. 2016, Brook and van Beest, 2014). People are part of all human-wildlife conflicts, so social research methods are essential for finding solutions. Conflicts arise when the costs that wildlife causes to residents are more significant than benefits, suggesting that negative perceptions more strongly determine human attitudes (Kansky and Knight, 2014). The objective of this study is to obtain information about the factors driving citizen perception of wild boar presence in urban environments, providing information and tools for managers to deal with wild boar-related conflicts according to citizen perception and acceptance of management measures. We interviewed 181 citizens, 85 women and 96 men classified into five age groups: "under 18 years old" (n = 22), "18 to 30 years old" (n = 46), "31 to 45 years old" (n = 67), "46 to 60 years old" (n = 39) and "over 60 years old (n = 7)", in La Floresta (Sant Cugat del Vallès, Barcelona, Spain) during June and July 2015. La Floresta (UTM31 N/ETRS89 X: 422564, Y: 4589101) is a neighborhood of 4430 inhabitants in Sant Cugat del Vallès, a municipality of the metropolitan area of Barcelona. The entire neighborhood lies on the northwestern slope of Collserola Natural Park (CNP) within the Collserola massif. The urban area of La Floresta is hilly, poorly planned and structured, mostly made up of family dwellings interspersed with scrubland and forest patches. Due to sociological, environmental and urban planning reasons, a stable and habituated wild boar population openly thrives throughout the urban area (Cahill et al. 2012). This provides

an exceptional scenario of increased interaction between human and wild boars to study citizen perception of urban wild boar.

The questionnaire (Electronic supplementary material 1 -ESM1-, Table 1 and Figure 4) had 20 questions divided into two sections, the first one aimed at characterizing the individual traits of the surveyed inhabitant and the second one focused on issues related to wild boar presence inside the neighborhood. Five questions from the second section (PS1, PS2, PS3, PS4, and PS5) were used to calculate the Wild Boar Perception Score (WBPS) using the formula WBPS = PS1+PS2+PS3+PS4+PS5, positively correlated with a positive perception of wild boar (the higher the WBPS, the better the perception of wild boar). On the other hand, questions number 12, 14 and 16 served as a proxy for urban wild boar feeders (WBfeed), people who consume wild boar (WBconsumer) and people who had previously suffered incidents with wild boar (WBinc), respectively. In order to assess the relationship between citizen profile and wild boar perception in urban areas, WBPS values were used as a continuous response variable and citizen profile variables as either continuous or categorical explanatory variables to construct a regression tree (ESM1 Tables 2 and 3) using a cross-validation method considering calibration and validation errors. Models were run in the R software version 3.5.0 (R Development Core Team, 2018), using "rpart" (Therneau et al. 2015), "gplots" (Warnes et al. 2016), and "rpart.plot" (Milborrow, 2016) packages. Most of the respondents (93%) liked seeing wild boar in urban areas (question number -Q- 11, PS1), and perceived wild boar presence as a positive distinction for the neighborhood (51%; Q17, PS4), feeling respect (61%) and friendship (31%) for wild boars (Q13, PS2). A small proportion of citizens also found wild boar presence in urban areas positive as a local and organic protein source (6%), contributing to less presence of stray dogs (5%) and beneficial for children as they can play together (3%, see Q17, PS4). Overall, wild boar presence in urban areas was not perceived as negative at all by 37% of the citizens (Q18, PS5) whereas 31% affirmed that wild boars cause some minor problems and 25% not problems at all (Q15, PS3). Conversely, 15% of the participants agreed that wild boar presence in urban areas was not beneficial at all (Q17, PS4) and 27% of the participants thought that wild boars should live in the forest (Q20). The major negative concern about wild boar presence was vehicle collision risk (17%), followed by damage to urban zones (16%) and risk towards pets (7%). Finally, 7% of the participants were worried about the risk for people related to health issues (Q18, PS5). On Q20, regarding the potential need for management measures to be undertaken, 37% of the answers pointed that measures should be taken to minimize wild boar incidents in urban areas for a better coexistence. The most popular option was helping the wild boars to return to their habitat (27%), followed by coexisting with wild boars in the current conditions (16%). No culling of wild boars at all was supported by 13% of the participants, while 7% agreed on the use of contraception and 1% proposed that people should feed wild boars. Nobody supported culling all wild boars as an option. Our regression tree analysis explained 12.2% of the observed WBPS variability and 10% after our cross-validation procedure (Figure 4). The citizens with the highest WBPS (3.6) were those scoring less than 0.5 points in incidents suffered (Q16, WBinc) and usual or occasional feeders of wild boars. Therefore, citizens with positive perception of wild boar presence in urban areas contributed to reinforce the phenomenon by habituating the wild boar to consume anthropogenic food. In this case, awareness campaigns focused on the reduction of wild boar direct feeding can contribute to minimize their presence in urban areas. Conversely, citizens with a WBinc value of 0.5 or more, who "always" or "never" feed wild boars and have the

highest education level, showed the lowest WBPS value (−0.18). This suggests that negative incidents determine negative perception for habitual feeders, who have an increased chance of having negative interactions, as well as for citizens not particularly prone to interact with wild boar.
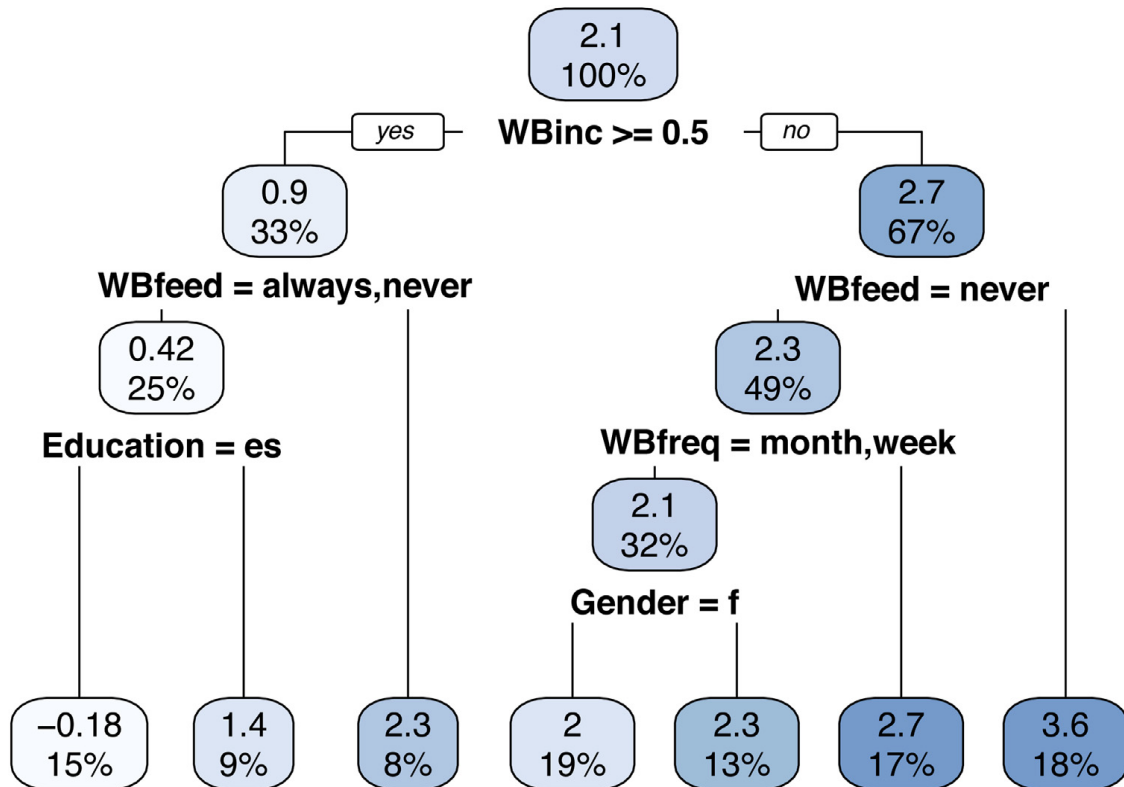
Figure 4. Regression tree model predicting the Wild Boar Perception Score (WBPS) according to five explanatory variables detailed below. The text in each split shows the variable used to divide the dataset according to a value or category from that variable (Electronic supplementary material, Tables 2 and 3). The value at the top of each node indicates the predicted WBPS value for the citizens accomplishing the conditions leading to that node. The percentage indicates the proportion of observations included in the node. In each node the sample is split into two subgroups; the observations agreeing with the node condition are included in the left branch, whereas the ones failing to comply with the condition are included in the right branch. The first explanatory variable selected by the tree model is wild boar incidents (WBinc, Question 16). Descending left from the first node (overall WBPS = 2.1), citizens with a WBinc score of 0.5 or higher are more likely to show a lower value in WBPS (0.9) than citizens who have not suffered incidents with wild boar (WBinc < 0.5, WBPS = 2.7). Citizens with WBinc ≥0.5 who "always" or "never" feed the wild boar are more likely to show a lower value in WBPS (0.42) than the citizens into the same category who "occasionally" feed the wild boar (2.3). Among the citizens with WBinc ≥0.5 and who "always" or "never" feed wild boar, WBPS is lower (-0.18) in citizens with superior studies than without them (1.4). Citizens with WBinc <0.5 who never feed wild boar are more likely to show a lower WBPS (2.3) than the citizens who "always" or "sometimes" feed wild boar (3.6). Then, citizens with WBinc <0.5 who do not feed wild boar and see them "monthly" or "weekly" show a lower WBPS (2.1) than citizens who see wild boars "daily" or "never" (2.7). Within this node (WBfreq = "month" and "week"), female citizens show a lower WBPS value (2) than male citizens (2.3).

Hence, our model shows that wild boar perception in urban areas is influenced by the past negative experiences suffered by the citizens. Previous studies already pointed out that negative attitudes towards wildlife are associated with negative experiences (Bencin et al. 2016). Furthermore, people who have suffered direct experiences are more likely to have stable, difficult-to-change attitudes (Browne-Nuñez et al. 2014), and direct contact leading to negative experiences involving wild boar which could provoke anxiety or fear in people (Baltasar et al. 2008). Thus, the negative perception of wild boar presence in urban areas is expected to rise with increasing negative incidents related to wild boar (Baltasar et al. 2008, Liordos et al. 2017). The close contact between wild boars and humans in our study area (Cahill et al. 2012) could therefore lead to an increasing negative perception of urban wild boar. However, our results reveal a substantial level of tolerance towards wild boar in our study area (ESM1 Table 1, section 2, Q11, Q15 and Q18), a determinant key for sustainable coexistence between humans and wildlife (Bruskotter et al. 2009, Treves and Bruskotter, 2014, Bencin et al. 2016). This tolerance for wildlife is a common topic of research and a management objective in wildlife conservation to decrease conflict, and there is ongoing debate on how to conceptualize this concept when conducting human dimension research (Browne-Nuñez et al. 2014). As in other published studies, our results verify again that socio-demographic variables such as gender, education and public health concern are less important than past experiences to explain resident attitudes (Kansky and Knight, 2014). Living in a more pleasant residential environment in contact with nature is one of the reasons for suburban human migration (Ford, 1999). Altogether with the biased features of the sample population, with predominance of higher educated (66%) and pet owners (74%), could explain this positive perception of wild boar in La Floresta in spite of the close contact. The concern about threats and risks caused by wildlife, particularly those related to human safety, cause negative perception among residents (ESM1 Table 1, section 2, Q18, Browne-Nuñez et al. 2014, Sakurai et al. 2013) and may more strongly determine attitudes than positive perceptions (Kansky and Knight, 2014). The relative importance of costs versus benefits in determining attitudes to different wildlife species would usefully inform about the benefits needed in order to counter the costs of living with wildlife (Kansky and Knight, 2014). In this specific scenario, increased tolerance may be related to human attitudes that worsen the problem. Tolerant citizens in front of wild boar presence are commonly those directly feeding wild boar, which contributes to wild boar habituation to human presence. This human behavior fosters the persistence of wild boar in urban areas and increases the human-wildlife conflict. The respondents of this survey reported traffic accidents (5%) and aggressiveness towards humans (5%) and pets (12%) as negative experiences involving wild boars. The danger posed by wild boar presence in urban areas is higher than the danger posed by other species ranging in the same conditions due to its size, weight, strength and tusks. The reported incidents suggest that the sustainable coexistence with wild boar may differ from that suitable for other urban species with less harmful potential. Because of the aforementioned problems, a variety of management approaches are being considered to regulate wildlife populations, ranging from attempts of complete local eradication to reduction of urban population once number or damage thresholds are exceeded (González-Crespo et al. 2018, Toger et al. 2018). However, resident values and attitudes must be considered if wildlife management programs are to be successful and sustainable (Sakurai et al. 2013). As in other studies, public preferences for urban wildlife management were controversial in La Floresta, and the most effective methods

for reducing conflict are not always accepted (Liordos et al. 2017). Attempts to decrease wild boar abundance by culling individuals could lead to public opposition (Toger et al. 2018), since lethal wildlife managing methods were not widely accepted in La Floresta (ESM1 Table 1, Q15 to Q20). However, only 13% of the population supported no killing at all, which means that the remaining 87% could accept some forms of culling. The questionnaire aimed at detecting extreme attitudes towards culling (e.g., no culling acceptance at all or culling all the wild boars), but fine-tuning questions about culling acceptance in certain cases and under specific conditions could help managers to design socially accepted management protocols including partial culling as a measure. Information campaigns on the causes, consequences and effective management options for urban wildlife could help to improve understanding and acceptance of the circumstances and possible solutions, but communication programs conducted by wildlife management organisms can be ineffective if people have distrust in public managers (Sakurai et al. 2013). Our findings suggest that sustainable coexistence in La Floresta can be maintained if incidents are prevented by culling aggressive individuals and restricting wild boar access to anthropogenic resources. Evaluation of citizen perception and information campaigns should precede the application of any wildlife management measure in humanized areas (either human or rural, for wild boar or for any other potentially conflictive species), in order to gain acceptance by residents before being implemented. The measures are then more understandable, feasible and more likely to succeed. By analyzing citizen perception, it is possible to determine the human social groups perpetuating the conflict. Authorities can gain feasibility concentrating efforts on those specific groups. Awareness and information campaigns focused on preventive measures to counter the risk posed by wild boar presence can contribute to allow the current non-socially accepted measures to be more acceptable. Such campaigns should be carried out to promote this change in attitude through knowledge rather than fear, in order to keep a sustainable coexistence between humans and wildlife.

3.1.c. Electronic supplementary material 1

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.mambio.2019. 04.002.

Table 1: Citizen survey and results. Our questions were focused on assessing citizen features, experiences and attitudes regarding wild boar presence in the urban area of La Floresta (Sant Cugat del Vallès, Barcelona, Spain). We used a recursive partitioning approach through regression trees to explore the relationships between a Wild Boar Perception Score (WBPS) and citizen profile (section 1), past and current experiences involving the wild boar, degree of contact with the wild boar and acceptance of management measures (section 2, wild boar perception). The results obtained from the questionnaire regarding past and current experiences involving the wild boar, degree of contact with the wild boar and acceptance of management measures. Questions 11, 13, 15, 16, 17, 18 were used to calculate the Wild Boar Perception Score (WBPS). Section 1. Citizen profile results obtained from the questionnaire regarding citizen profile.

Question	Options	Total N	Percentage %
1. Sex			
	Male	96	53.04
	Female	85	46.96
2. Age			
	<18	22	12.15
	18-30	46	25.41
	31-45	67	37.02
	46-60	39	21.55
	>60	7	3.87
3. Characteristics of birthplace (as defined by the citizen):			
	Town	80	44.20
	City	101	55.80
4. Education			
	Primary school	12	6.63
	High school	49	27.07
	Higher education	120	66.30
6. Pets			
	Dog	79	37.09
	Cat	65	30.52
	Birds	7	3.29
	Chickens	7	3.29
	Exotic animals	3	1.41
	Reptiles	4	1.88
	None	48	22.54
9. Urban qualification of La Floresta			
	It is a Natural Park	36	19.35
	Urban area inside the forest	137	73.66
	Urban area outside the forest	13	6.99

STUDY 1

Section 2. Wild boar perception.

Question	Options	Total N	Percentage %
10. How often do you see wild boars?			
	Every day	73	40.33
	Less than once per week	82	45.30
	More than once per week	25	13.81
	Never	1	0.55
11 (PS1) Do you like to see wild boars?			
	Indifferent (+0 WBPS)	3	1.66
	Yes (+1 WBPS)	168	92.82
	No (-1 WBPS)	10	5.52
12 (WBfeed). Have you ever fed wild boars?			
	Never	132	72.93
	Sometimes	42	23.20
	Always	7	3.87
13 (PS2). What do you feel when you see a wild boar?			
	Indifference (+0 WBPS)	12	5.77
	Friendship (+1 WBPS)	65	31.25
	Respect (+1 WBPS)	126	60.58
	Fear (-1 WBPS)	5	2.40
14 (WBeater). Have you ever eaten wild boar from La Floresta?			
	Never	146	80.66
	Only on a few occasions	32	17.68
	It is an habitual practice	3	1.66
15 (PS3). Do you think the presence of wild boar in urban areas is a problem?			
	It is not a problem at all (+3 WBPS)	48	25.26
	It causes some problems but I do not care (+2 WBPS)	59	31.05
	If they were being managed, they would not cause problems (+1 WBPS)	57	30
	They represent a threat in urban areas, they should live in the forest (-1 WBPS)	26	13.68
	WB is a plague and we should exterminate them (-2 WBPS)	0	0
16 (WBinc). Have you ever had any incident with wild boar?			
	No, never (+0 WBinc)	119	60.71
	They enter into my home (+1 WBinc)	29	14.80
	Aggressiveness towards my pet (+1 WBinc)	24	12.24
	Aggressiveness towards myself (+2 WBinc)	10	5.10
	Traffic accident (+1 WBinc)	11	5.61
	They spread waste on the street (+1 WBinc)	1	0.51
	They damage my garden (+1 WBinc)	2	1.02

Question	Options	Total N	Percentage %
17 (PS4). Do you think the presence of wild boar is beneficial for La Floresta?			
	WB presence is not beneficial at all (-1 WBPS)	28	15.14
	There are less stray dogs in the street (+1 WBPS)	9	4.86
	Their presence is a great distinction for the neighborhood (+1 WBPS)	95	51.35
	It is good that the kids can play with them (+1 WBPS)	5	2.70
	It is an organic/local source of protein (+1 WBPS)	12	6.49
	It is their natural environment and they increase the biodiversity (+1 WBPS)	17	9.19
	It is beneficial for other reasons (+1 WBPS)	5	2.70
	I do not know (+0 WBPS)	14	7.57
18 (PS5). Do you think the presence of wild boar is negative for La Floresta?			
	WB presence is not negative at all (+1 WBPS)	80	37.04
	They represent a threat towards vehicles (-1 WBPS)	37	17.13
	They damage urban areas (-1 WBPS)	35	16.20
	They represent a threat towards pets (-1 WBPS)	16	7.41
	They are infectious and parasitic disease carriers (-1 WBPS)	16	7.41
	They represent a threat for people (-1 WBPS)	11	5.09
	It is negative for other reasons (-1 WBPS)	2	0.93
	I do not know (+0 WBPS)	19	8.80
19. Why do you think wild boars have "colonized" La Floresta?			
	They lost their natural habitat	99	30.94
	There are bush areas that they use as resting sites	63	19.69
	They do not have enough food in the forest	61	19.06
	They prefer the food that they get from rubbish bins and people	71	22.19
	There are so many wild boars that there is not enough space in the forest	17	5.31
	Other reasons	0	0.00
	I do not know	9	2.81

Question	Options	Total N	Percentage %
20. Do you think we should do something regarding wild boar presence in urban areas?			
	We have to live with them in the current conditions	44	15.66
	We should undertake measures for a better coexistence	105	37.37
	We have to cull all wild boars	0	0.00
	We should not cull any wild boar	36	12.81
	We should use contraception methods such as sterilization	19	6.76
	We have to help them to return to the forest	75	26.69
	We should feed them	2	0.71

Table 2: This table includes the explanatory variables used to determine the Wild Boar Perception Score (WBPS) and included in the tree model (Figure 4). The first column contains the variable name, the second column contains the abbreviation used in the tree and the third column contains the definition and categories of each variable.

Variable	Abbreviation	Definition
Wild boar incidents	WBinc	Score ranging from 0 to 4 according to the number and type of wild boar incident suffered by the respondent.
Wild boar feeding	WBfeed	Variable used to assess how frequently the citizens surveyed feed the wild boar. The categories are always, sometimes and never.
Gender	Gender	Gender of surveyed citizen, male (m) or female (f).
Wild boar frequency	WBfreq	Variable categorizing how often the citizen encounters wild boar in the neighborhood. The categories are daily, weekly, monthly and never.
Education	Educatio	Level of citizen education, primary school (p), high school (s) or higher education (es).

Table 3: Classification and Regression Tree (Figure 4) related information. Node number, condition of each split (Split), total number of observations in each node (Total N), total sum of squares within the node divided by Total N (Variance) and mean value of the response variable (WBPS) within that node (Yval). The asterisk (*) indicates a terminal node.

Node number	Split	Total N	Variance	Yval
1	root	181	5.45	2.08
2	WBinc >=0.5	60	7.12	0.90
4	WBfeed=always, never	45	7.53	0.42
8	Educatio=es	28	6.58	-0.18 *
9	Educatio=p,s	17	7.54	1.41 *
5	WBfeed=sometimes	15	3.16	2.33 *
3	WBinc< 0.5	121	3.6	2.66
6	WBfeed=never	89	3.3	2.32
12	WBfreq=month, week	58	2.57	2.14
24	Gender=f	35	2.91	2.00 *
25	Gender=m	23	1.97	2.34 *
13	WBfreq=day, never	31	4.48	2.67 *
7	WBfeed=always, sometimes	32	3.24	3.59 *

3.2. Study 2. Between Conflict and Reciprocal habituation: A Study of Human-Wild Boar Coexistence in Suburban Areas
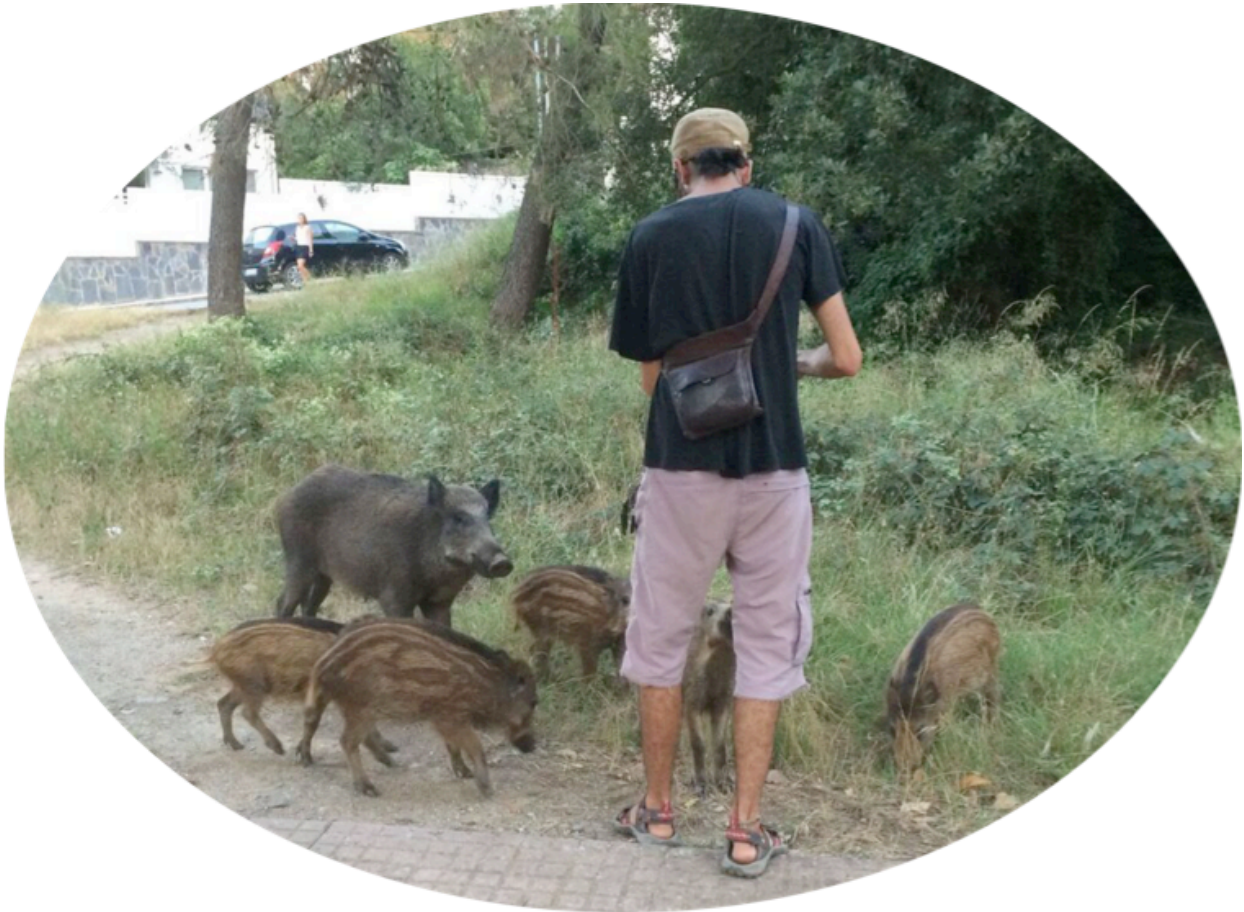
Figure 5. Voluntary feeding is becoming a common practice in suburban landscapes. This activity promotes a process of reciprocal habituation between humans and wild boars, boosting the occurrence of conflicts for both species.

STUDY 2

3.2.a. Abstract

The habituation of wild boar (*Sus scrofa*) to anthropogenic contexts and resources has driven to a common presence of wild boar in suburban areas of the Metropolitan Area of Barcelona (MAB). In this scenario, not only wild boar loses fear to human presence: determinant processes of habituation, conflict or sensitization occur on the human side as well.

In this process of "reciprocal habituation" that we document for the first time citizens familiarize with wild boar presence because of repeated encounters, which result in a lower perception of conflicts and the acceptance of wild boar presence in urban settings. In contrast, conflicts may cause negative perceptions and reduce tolerance towards these animals. Since citizen attitudes (habituation or sensitization) can either facilitate or hinder control measures, we aim at analyzing human drivers of these attitudes in order to better adjust the management of wild boar population to specific cultural and socio-ecological contexts. We conducted 1956 face-to-face questionnaires to passers-by from Barcelona and grouped the response variables to score citizen and urban characteristics, as well as citizen experiences, emotions, and lay-knowledge related to wild boar.

According to our results, citizen perception of human-wild boar conflict (HWBC) depended on a combination of the emotions, lay-knowledge about the wild boar and previous experiences of human-wild boar coexistence. The diversity of citizen attitudes towards wild boar should be considered when designing awareness campaigns seeking to reduce behaviors promoting wild boar presence (e.g., feeding). Likewise, our study of the tensions between conflict and reciprocal habituation can help to understand why some management measures (e.g., the capture of specific individuals or sounders) are rejected by the public, even when these animals are endangering suburban residents and becoming themselves more vulnerable in an urban context.

Keywords: Attitude; Perception; Coexistence; Human-Wildlife Conflict; Urban Wildlife; Wildlife Management; Socio-Ecology.

3.2.b. Introduction

Synantropic mammal species take profit from human space and food, resulting in human-wildlife conflicts responsibles for economic and material costs associated with mitigation and prevention, such as damage to landscape and gardens, fouling of public spaces and noise, and raiding of garbage bins (Luniak 2004, Nyhus 2016). The wild boar (*Sus scrofa*) has expanded its distribution range and abundance in the last decades due to the lack of predators, human depopulation of rural areas and consequent forest encroachment, among other factors (Massei et al. 2015). 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 (Cahill et al. 2012, Licoppe et al. 2013, Stillfried et al. 2017a and b, Castillo-Contreras et al. 2018). The Metropolitan Area of Barcelona (MAB), in Spain, is a densely populated area -~ 16,149 human inhabitants/km² (Idescat 2019)- that includes the Collserola Natural Park (CNP), a natural area hosting an increasing wild boar population (González-Crespo et al. 2018). Wild boar behavioral plasticity, food availability and environmental and urban planning have favored the wild boar presence in the urban area of Barcelona. Consequently, contacts between humans and wild boars have become frequent in the suburban areas of Barcelona (Cahill et al. 2012, González-Crespo 2018, Conejero et al. 2016).

Human-wildlife interactions contribute to define coexistence and human perception of wildlife-related conflicts (Nyhus 2016, Conejero et al. 2019a). Non-traumatic contact with wild boar minimizes the perception of human-wild boar conflict (HWBC), increasing the habituation of citizens themselves, which is expressed in an increasing tolerance towards wild boar presence in a complex context of human-animal relations (Dickman 2010, Conejero et al. 2019a). On the other hand, citizen tolerance towards wild boar is negatively correlated with the number of wild boar-related incidents suffered by the citizen (e.g., traffic accidents, attack on pets and people). When incidents involving wild boar increase over time and costs become more significant than eventual benefits, negative perceptions would strongly determine human attitudes: the more incidents suffered or experienced, the more negatively is perceived the wild boar presence (Kansky and Knight 2014, Conejero et al. 2019a). In Barcelona, HWBC is more likely to arise in the districts bordering CNP, as the inhabitants and users of these districts possibly experience more direct and frequent contact with the urban wild boar (González-Crespo et al. 2018, Castillo-Contreras et al. 2018).

Addressing and managing HWBC and other hazards posed by urban wildlife in human-densely populated areas are essential. However, people attitudes may determine public acceptance of crucial management actions (Whittaker et al. 2006) and must therefore be considered by managers and policymakers when establishing management plans. As part of contemporary human-wildlife conflicts, suburban residents and citizens in general may have a negative perception of actual control measures, thus adding social difficulties and technical hurdles to the success and efficiency of conflict management (Jackobson et al. 2014). 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 (Scheele et al. 2015, Benvenuti 2016, Torres-Blas et al. 2020), even when these measures are oriented to reduce the vulnerability that the urban population of wild boar, as a whole, sees increased by uncontrolled demographic growth, hybridization with feral domestic pigs, exposure to

toxic chemical, suburban poachers, or traffic accidents (Delibes-Mateos and Delibes 2013, Lacolina et al. 2018, González-Crespo et al. 2018, Castillo-Contreras et al. 2021, Colomer et al. 2021). This is challenging traditional approaches to wildlife management in urban environments (Manfredo et al. 2019, Nettles et al. 2021). Management actions including sensitization and conservation policies focusing solely on reeducation of lay knowledge regarding wild boar is likely to fail in gaining public acceptance (Emre Can and Macdonald 2018). Descriptive studies can identify public attitudes, but information about people's underlying cultural, social and emotional drivers may better forecast potential controversies as well as fostering the understanding and acceptance of specific management measures (Nyhus 2016).

The objective of this study is analyzing the tensions between perceived conflict and reciprocal habituation of humans and wild boar in an urban setting. While studies describing habituation of wild boar to urban settings are currently available (Cahill et al. 2012, Stillfried et al. 2017c, Ikeda et al. 2019), to date there is a lack of research considering habituation as a bidirectional process, involving changes in human relational habits as well.

As an interdisciplinary team of veterinary, natural and social scientists, we document this process of reciprocal habituation for the first time and analyze citizen perception of wild boar presence and HWBC in the city of Barcelona. Our goal is to understand the motivations behind public attitudes and forecast the potential social acceptance of management measures. The results of this study will allow to better adapt management measures to specific cultural and socio-ecological contexts, which should improve urban wild boar population management, minimize HWBC in Barcelona, and reduce the mutual vulnerability of both humans and wild boar who share an urban space. Both the methodology used and the results obtained may also be applicable in other human-wildlife conflict scenarios.

3.2.c. Materials and methods

3.2.c.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 1,600,000 inhabitants (Idescat 2019). 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 (Figure 6). Those Peripheral Districts (PD, from now on), are frequented by wild boar, which coexist with citizens. The remaining five districts of Barcelona (Core Districts -CD-, from now on), namely Sant Andreu (S A), Sant Martí (StM), Ciutat Vella (CV), Eixample (E) and Sants-Montjuïc (SM), conversely, do not border CNP and are less visited by wild boar (Castillo-Contreras et al. 2018). The CNP

is an 8,295 ha protected area (Figure 6) that hosts an increasing wild boar population (González-Crespo et al. 2018).
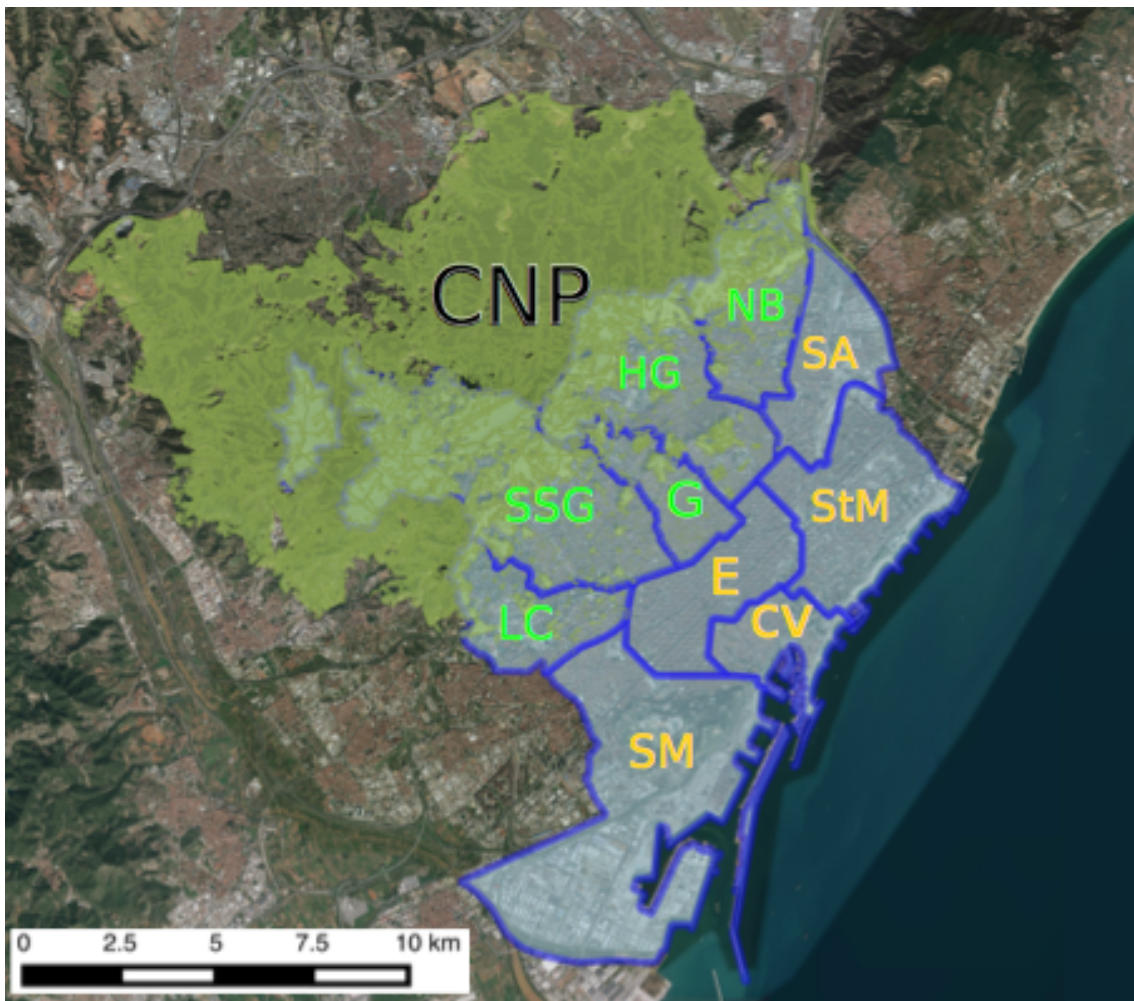
Figure 6. Study area. Collserola Natural Park (CNP) surface is shown in green color; area and edges of the ten districts of Barcelona appear in blue; Peripheral Districts (PD), namely Nou Barris (NB), Horta-Guinardó (HG), Gràcia (G), Sarrià-Sant Gervasi (SSG) and Les Corts (LC) are labelled in bright green characters; 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.

3.2.c.2. Questionnaire design and scores

A standardized survey was designed to obtain data on citizen characterization, behavioral reactions towards wild boar, citizen home range, experience on coexistence with wild boar, assumed wild boar-related emotions and previous lay-knowledge, as well as their public perception and attitude towards wild boar, HWBC and management measures (see the complete questionnaire in Supplementary Material 2 -ESM2-). The following scores were calculated from the data obtained: perception of incidents related with wild boar (sum of incidents suffered by the citizen), namely Perception of Incidence Score (PIS) and citizen habituation to wild boar presence (ratio between sighting frequency and HWBC perception), see ESM2. Therefore, each survey characterized each citizen with 52 variables: 30 citizen responses to questions, two citizen scores and 20 characteristics of the district where the questionnaire took place (ESM2, Table 4, Idescat 2019).

3.2.c.3. Data collection

From May 4th to July 23rd, 2018, eight trained pollsters interviewed 1,956 passers-by across the ten metropolitan districts of Barcelona. The number of telephone calls reporting wild boar presences in the urban area of Barcelona received by the local police (wild boar-related incidents), the veterinary interventions reacting to these wild boar presences, and the number of wild boars captured in the urban area were based on data specific to each district from January 1st until December 31st, 2018. Local socio-economic and landscape-related variables (unemployment rate, At Risk of Poverty or Exclusion Rate -AROPE-, number of residents, human density and different land uses) of each district were obtained from public statistics (ESM2, Idescat 2019, Table 4).

Table 4. Mean values of citizen habituation score, cost of wild boar management measures, use of the ground and socio-economic variables in Barcelona (BCN) and its districts, namely Ciutat Vella (CV), Eixample (E), Sants-Montjuïc (SM), Les Corts (LC), Sarrià-Sant Gervasi (SSG), Gràcia (G), Horta-Guinardó (HG), Nou Barris (NB), Sant Andreu (SA) and Sant Martí (StM).

Variables		Districts										
Category		BCN	CV	E	SM	LC	SSG	G	HG	NB	SA	StM
Citizen[†]	Habituation	0.7	0.47	0.57	0.56	0.61	1.02	0.71	0.92	0.95	0.65	0.58
District[†]	Cost of WB management measures[1]											
	Captured WB	46	0	0	0	1	24	1	19	0	1	0
	Veterinary interventions	31	0	0	0	1	16	1	10	1	2	0
	WB-related incidents	478	1	1	2	37	128	47	201	50	10	1
	Landscape features[2]											
	Residential	27.3	31.6	11.7	11.1	29.6	30.7	48.1	24.4	28.9	28.9	27.8
	Forestry	10.7	0.0	0.0	0.0	7.7	44.5	3.0	31.7	20.3	0.0	0.0
	Urban parks	14.6	16.8	19.1	19.1	11.2	5.0	12.4	15.0	15.4	14.7	17.8
	Sociodemographic variables[2]											
	Unemployment	7.1	9.0	5.7	7.4	5.7	3.9	6.1	7.5	9.8	7.9	7.7
	AROPE	25.1	37.2	19.8	29.1	20.2	10.4	17.6	23.3	43.3	25.9	24.2
	Human density	641	777	712	721	459	244	601	582	721	777	816
	Population (in miles)	1620	101	265	181	82	149	121	170	168	148	236

[†]Mean value for each district; [1]own data for each district from January 1st until December 31st (2018) and Ajuntament de Barcelona (2020b); [2]Institut d'Estadística de Catalunya (2020); AROPE = People rate at risk of poverty or social exclusion.

3.2.c.4. Statistical analysis

In order to identify the drivers of citizen attitudes towards the wild boar, correlations were used 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. We applied a Principal Component Analysis (PCA) to create and sort the principal factors determining citizen attitudes towards the wild boar (Macci et al. 2012), using a correlation matrix (n=1,956). Missing values on the dataset were replaced by the median of the corresponding variable. We selected 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 (ratio between wild boar sighting frequency and problem perception score) as the six active variables used to characterize citizen attitudes. In order to detect citizen clusters regarding attitudes towards wild boar, the PCA output was grouped into nesting clusters by performing a Hierarchical Clustering on Principal Components (HCPC). 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. 2010a and b).

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. 2019). The packages ggplot2 (Wickham 2016) and "GGally" (Barret Schloerke et al. 2018) were used in the correlation analyses. The Catdes function of the FactoMineR package (Lê et al. 2008) was used to detect differences (at a 90% confidence level) on categorical variables between district categories. The PCA was performed through the PCA function of the same FactoMinerR package. The "fviz" function from the "factoextra" package (Kassambara and Mundt 2019) 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.

3.2.d. Results

3.2.d.1. Citizen characteristics, experiences towards wild boar and acceptance of lethal and nonlethal 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%). Regarding coexistence, almost three quarters of the respondents had never (48.1%) or only once (25.0%) seen a wild boar, while 5.6% of the respondents claimed seeing wild boar daily or weekly. Forty-two out of 1,956 citizens (2.2%) confirmed that they had fed wild boar at least once, and four (0.2%) admitted to feeding wild boar frequently.

Seven citizens (0.4%) living in the PD were identified as wild boar hunters. While most of the passers-by answered that wild boar cause problems because their

population is not adequately managed (45.5%) or that wild boar represents a threat in urban areas (35.6%), only 75 of the surveyed citizens (3.9%) perceived the wild boar as a threat for themselves. Most of the passers-by (95.2%) scored a PIS equal to 0, which means they never had an incident related to wild boar. A much smaller proportion, 86 citizens (4.4%), had a PIS ranging between 1 and 2, and only three citizens (0.2%) had a PIS over 3 (e.g., more than three different types of negative interactions with wild boar). The most frequently reported incidents with wild boar were traffic accidents (1.5%), intromission in property (1.0%) and attacks on pets (0.6%) or people (0.7%). According to our correlation results, PIS was positively correlated with citizen habituation and voluntary feeding in urban areas (Figure 7). In addition, frequent wild boar feeders were strongly influenced by their emotions and lay-knowledge, as they perceived the wild boar as likable with pleasant aesthetic value, without considering the physical and health-related threats associated to wild boar proximity to people (Figures 5, 7 and 8).

Nearly a 44% of the passers-by did not approve management measures based on lethal methods, while approximately one third (37.7%) proposed maintaining (not increasing nor reducing) the wild boar population, a quarter (25.2%) would accept ethical sacrifice but not hunting, and the remaining 11.1% would support the complete eradication of urban wild boar population. The complete results of the surveys are presented in Electronic Supplementary Material 2 (ESM2).
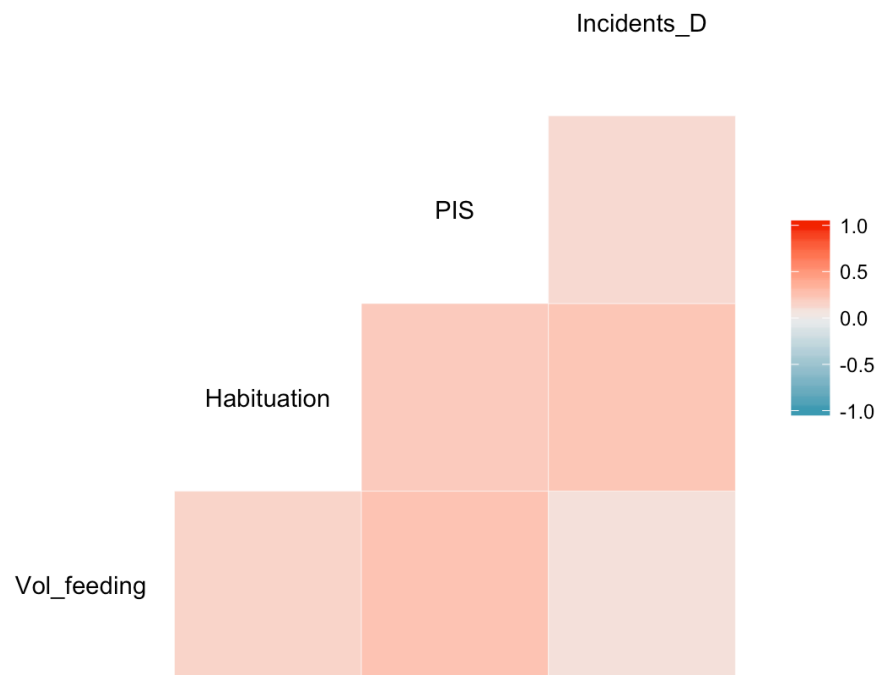
Figure 7. Correlation plot of variables including voluntary feeding (Vol_feeding), citizen habituation to wild boar presence (Habituation), total perception of wild boar-related incidents suffered by the passer-by (PIS) and number of calls to the district emergency number due to wild-boar related incidents (Incidents_D). The color scale represents the correlation coefficient among variables.

STUDY 2

Table 5.1. Quantitative variables characterizing the Peripheral (PD) and Core (CD) districts. SD = Standard deviation; PIS = Perception of Incident Score; AROPE = People rate at risk of poverty or social exclusion.

Variables	Total	Peripheral districts (PD)		Core districts (CD)	
	Mean (SD)	Mean (SD)	v.test	Mean (SD)	v.test
Citizen					
Characteristics					
Age	3.72 (1.12)	3.51 (1.10)	-07.27**	3.88 (1.11)	07.27**
Formation	3.08 (0.89)	3.22 (0.82)	06.34**	2.96 (0.92)	-06.34**
Eating habits	2.02 (0.96)	2.09 (0.98)	03.15**	1.96 (0.93)	-03.15**
Experiences					
WB sighting	1.98 (1.23)	2.40 (1.41)	13.32**	1.65 (0.95)	-13.32**
Habituation	0.70 (0.60)	0.87 (0.74)	10.87**	0.57 (0.42)	-10.87**
Voluntary feeding	0.02 (0.17)	0.04 (0.24)	04.35**	0.01 (0.09)	-04.35**
WB feeding in city sighting	0.26 (0.44)	0.35 (0.48)	07.77**	0.2 (0.4)	-07.77**
PIS	0.08 (0.4)	0.14 (0.52)	05.64**	0.04 (0.27)	-05.64**
Incidents	0.03 (0.18)	0.05 (0.22)	04.65**	0.02 (0.12)	-04.65**
Home garden	0.01 (0.10)	0.02 (0.13)	03.11**	0.00 (0.06)	-03.11**
Attack	0.01 (0.06)	0.01 (0.08)	02.78**	0.00 (0.00)	-02.78**
Aggressiveness to pets	0.01 (0.07)	0.01 (0.11)	03.16**	0.00 (0.03)	-03.16**
Traffic incident	0.01 (0.12)	0.02 (0.15)	02.39*	0.01 (0.10)	-02.38*
Other incidents	0.01 (0.11)	0.02 (0.15)	04.62**	0.00 (0.04)	-04.62**
Attitudes					
WB problem	3.19 (0.85)	3.14 (0.84)	-02.47*	3.24 (0.86)	02.47*
District					
Cost of WB management measures[1]					
Captured WB	4.51 (8.54)	10.13 (10.51)	25.66**	0.14 (0.35)	-25.66**
WB veterinary interventions	2.97 (5.14)	6.44 (6.21)	26.28**	0.28 (0.69)	-26.28**
WB-related incidents	46.17 (65.81)	102.34 (65.38)	33.29**	2.46 (3.05)	-33.29**
Use of the ground percentages[2]					
Residential	25.26 (9.99)	31.35 (7.72)	23.77**	20.52 (8.93)	-23.77**
Forested land	10.51 (15.29)	24.01 (14.49)	34.45**	0.00 (0.00)	-34.45**
Urban parks	15.36 (4.05)	12.10 (3.96)	-31.36**	17.89 (1.51)	31.36**
Sociodemographic variables[2]					
Unemployment	7.36 (1.50)	6.90 (2.11)	-12.15**	7.73 (0.48)	12.15**
District AROPE	26.52 (8.63)	24.46 (12.01)	-09.32**	28.13 (3.79)	09.32**
Human density	662.60 (162.03)	535.04 (170.01)	-30.71**	761.86 (40.94)	30.71**
Population	167512.83 (40721.43)	146724.07 (29028.54)	-19.91**	183690.28 (41168.98)	19.91**

Statistical values are given by v.test-value; *p<0.05, **p<0.01; [1]Ajuntament de Barcelona (2020b), [2]Institut d'Estadística de Catalunya (2020).

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Table 5.2. Categorical variables for the Peripheral (PD) and Core (CD) districts. HBWC: human-wild boar conflict.

Variables and categories	TS	PD		CD	
	% TS in Cat	% PD in Cat	v.test	% CD in Cat	v.test
Characteristics					
Sex					
Female	54.60	57.83	02.53*	52.09	-02.53*
Male	45.35	42.06	-02.58**	47.91	02.58**
Student					
No	82.11	80.02	-02.11*	83.73	02.11*
Yes	17.89	19.98	02.11*	16.27	-02.11*
Working Area					
Student	11.61	13.79	02.64**	9.91	-02.64**
Services	26.48	30.02	03.12**	23.73	-03.12**
Retired	36.55	27.10	-07.71**	43.91	07.71**
Public administration	4.24	5.96	03.29**	2.91	-03.29**
Attitudes					
Ideal solution towards HWBC					
Eliminate	11.09	8.18	-03.66**	13.36	03.66**
Maintain	37.63	40.19	02.06*	35.64	-02.06*

Statistical values are given by v.test-value; *p<0.05;**p<0.01.

3.2.c.2. District characteristics, citizen habituation score, voluntary feeding and PIS

Citizens surveyed in PD were younger (p<0.001) and students (p<0.001), people working in the service-sector (p<0.001) or in the public administration (p=1.018*10^{-3}). Overall, the preferred strategy to manage wild boar by respondents in PD was to maintain the population (p<0.05). Citizens surveyed in CD were older (p<0.001), lived in neighborhoods with higher AROPE rate (p<0.001) and were more prone to choose eliminating wild boar as the best management option to mitigate HWBC (p<0.001). Voluntary feeding, the score of citizen habituation to wild boar presence, PIS, and number of calls to the local emergency number were positively correlated (p<0.05, Figure 7). Habituated citizen profiles (high wild boar contact, high PIS, and low problem perception) were more frequent in PD (p<0.001), as opposed to the sensitized profile (low presence of wild boar, low PIS, and high problem perception), which were more frequent in the CD. Citizens from the PD saw wild boar (p<0.001) more frequently, called more times to the emergency number due to wild boar presence (p<0.001), obtained higher PIS (p<0.001), and were more habituated to wild boar presence (p<0.001) than the citizens from CD. Accordingly, voluntary feeding was more often associated with citizens surveyed in the PD (p<0.001), mostly with citizens with a problem perception score below 3. The comparison of quantitative and categorical variables between PD and CD (Figure 8) are shown in tables 5.1 and 5.2.
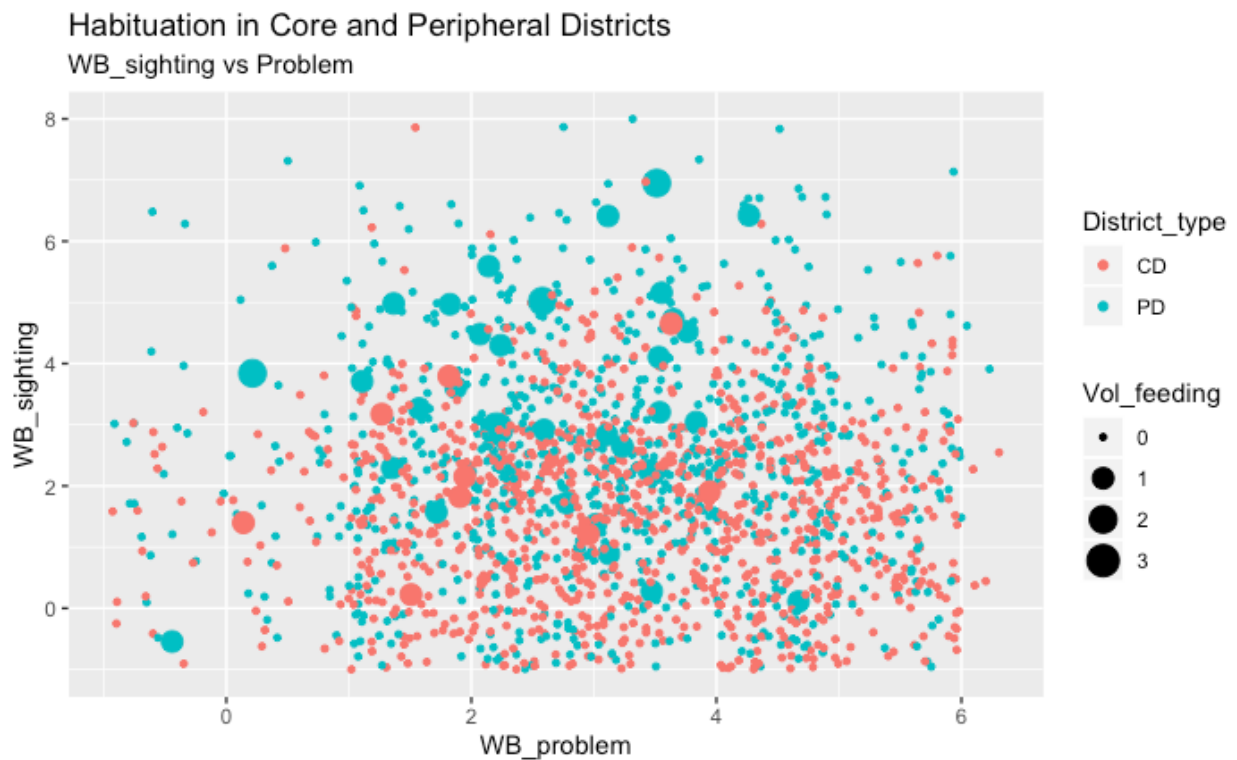
Figure 8. Graph of habituation score towards wild boar presence in urban areas. The *x* axis is the perception of the wild boar problem by the citizen and the *y* axis is representing the wild boar sighting frequency. Citizens surveyed in peripheral districts (PD) are represented in blue and citizens surveyed in core districts (CD) are represented in red. Bubble size shows the citizen voluntary feeding behavior, from "I never fed a wild boar" (0) to "If I can, I always feed the wild boar" (4). Most habituated citizen profiles correspond to citizens showing the lowest wild boar-related problem perception and the highest wild boar sighting frequency.

The most significant differences among the PD districts were the number of wild boar interventions ($p<0.001$) and captured wild boar ($p<0.001$), number of citizen calls to the municipal services due to wild boar incidents ($p<0.001$), population density ($p<0.001$), and AROPE rate ($p<0.001$). The highest AROPE rate was found in NB ($p<0.001$), while lower AROPE rates were found in G ($p<0.001$), LC ($p<0.001$) and SSG ($p<0.001$). A higher school education level was found in G ($p<0.001$) and SSG ($p<0.001$). The highest activity of wild boar feeding by people was found in SSG ($p<0.05$). Higher costs associated to HWBC mitigation measures were recorded in SSG and HG (Table 6.1), which together with NB were the districts with highest score in habituation towards wild boar presence in urban areas. Regarding the ideal management solution, eradicating the urban wild boar population was mostly accepted by citizens in LC ($p<0.001$), while reducing the wild boar population was supported by G citizens ($p<0.001$). On the contrary, HG citizens supported maintaining the actual wild boar population ($p<0.001$) and some among these (HG citizens) were rejecting the reduction of WB population ($p<0.001$). Further comparisons among quantitative and categorical variables among the PD can be found in tables 6.1 and 6.2.

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Table 6.1: Quantitative variables characterizing each one of the Peripheral districts (PD): Les Corts (LC), Sarrià-Sant Gervasi (SSG), Gràcia (G), Horta-Guinardó (HG) and Nou Barris (NB). SD = Standard deviation; PIS = Perception of Incidence Score; AROPE = People rate at risk of poverty or social exclusion.

Variables	Total	LC		SSG		G		HG		NB	
	Mean (SD)	Mean (SD)	v.test	Mean (SD)	v.test	Mean (SD)	v.test	Mean (SD)	v.test	Mean (SD)	v.test
Citizen											
Characteristics											
Animal affinity	7.76 (2.14)									7.49 (2.16)	-02.24*
Age	3.51 (1.1)							3.36 (1.08)	-02.19*	3.64 (1.05)	02.09*
Eating habits	2.09 (0.98)	1.90 (0.90)	-02.11*	2.21 (0.99)	01.77*						
Formation	3.22 (0.82)			3.43 (0.71)	03.93**	3.36 (0.83)	02.17*			2.98 (0.85)	-05.01**
Experiences											
WB sighting	2.40 (1.41)	1.86 (1.08)	-04.05**			2.09 (1.27)	-02.86**	2.7 (1.46)	03.53**	2.55 (1.48)	01.88*
Habituation	0.87 (0.74)	0.61 (0.64)	-03.71**	1.01 (0.92)	02.76**	0.70 (0.55)	-02.96**			0.95 (0.82)	01.73*
WB voluntary feeding	0.04 (0.24)			0.08 (0.27)	02.18*						
WB feeding in city sighting	0.35 (0.48)	0.25 (0.43)	-02.19*			0.23 (0.42)	-03.27**	0.48 (0.5)	04.42**		
Feeling threatened by WB	0.05 (0.21)					0.01 (0.12)	-01.97*				
Trying to hunt WB	0.00 (0.05)					0.01 (0.12)	03.21**				
PIS	0.14 (0.52)	0.05 (0.26)	-01.79*	0.20 (0.58)	01.77*						
Incidents	0.05 (0.22)			0.10 (0.31)	03.53**					0.03 (0.16)	-01.98*
Attack	0.01 (0.08)			0.02 (0.13)	01.73*						
Home garden	0.02 (0.13)			0.03 (0.18)	01.79*					0.00 (0.07)	-01.72*
Other incidents	0.02 (0.15)	0.00 (0.00)	-01.68*	0.01 (0.07)	-01.87*					0.05 (0.21)	02.29*
Attitudes towards WB											
Hunting perception	1.86 (0.90)	2.04 (1.04)	02.09*					1.71 (0.83)	-02.88**		
Problem level	3.14 (0.84)	3.42 (0.77)	03.57**	2.87 (0.91)	-04.82**						
Emotions towards WB											
Sympathy	3.02 (1.32)			2.87 (1.41)	-01.69*			2.80 (1.28)	-02.77**	3.36 (1.35)	04.38**
Contact with nature	3.49 (1.43)	4.11 (1.1)	04.59**	3.28 (1.44)	-02.25*			3.22 (1.56)	-03.22**	3.66 (1.38)	02.01*
Aesthetics	3.71 (1.25)	3.94 (1.1)	01.90*	3.53 (1.33)	-02.28*						

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Variables	Total Mean (SD)	LC Mean (SD)	v.test	SSG Mean (SD)	v.test	G Mean (SD)	v.test	HG Mean (SD)	v.test	NB Mean (SD)	v.test
Beliefs towards WB											
Risk for health/security	2.19 (1.24)	1.96 (1.15)	-01.94*			2.42 (1.35)	02.39*			2.00 (1.23)	-02.61**
Fouling city	2.11 (1.15)					2.43 (1.24)	03.59**			1.91 (1.10)	-02.93**
District											
Cost of WB management measures[1]											
Captured WB	10.13 (10.51)	1	-09.19**	24	20.06**	1	-11.19**	19	14.25**	0	-16.69**
WB veterinary interventions	6.44 (6.21)	1	-09.27**	16	23.41**	1	-11.29**	10	09.69**	1	-15.17**
WB-related incidents	102.34 (65.38)	37	-10.57**	128	05.96**	47	-10.90**	201	25.47**	50	-13.85**
Sociodemographic variables[2]											
AROPE	24.46 (12.01)	20.2	-03.75**	10.4	-17.79**	17.6	-07.36**			43.3	27.15**
Density	535.04 (170.01)	459	-04.73**	244	-26.01**	601	04.99**	582	04.66**	721	18.93**
Borough											
Cost of WB management measures[1]											
WB-related incidents	13.27 (19.56)	7.44 (8.41)	-03.15**	22.36 (18.69)	07.07**	7.12 (15.94)	-04.04**	22.47 (26.85)	07.94**	3.38 (4.14)	-08.75**

Statistical values are given by v.test-value; *p<0.05, **p<0.01; [1]Ajuntament de Barcelona (2020b), [2]Institut d'Estadística de Catalunya (2020).

Table 6.2: Categorical variables characterizing each one of the Peripheral districts (PD): Les Corts (LC). Sarrià-Sant Gervasi (SSG), Gràcia (G). Horta-Guinardó (HG) and Nou Barris (NB). HBWC: human-wild boar conflict.

Variables and categories	Total (%)	LC		SSG		G		HG		NB	
		%	v.test	%	v.test	%	v.test	%	v.test	%	v.test
Characteristics											
Sex											
Female	57.83					64.75	1.81*				
Male	42.06					35.25	-1.78*				
Growth environment											
Rural	28.39	37.37	2.06*					22.90	-2.07*		
Urban	70.68	61.62	-2.06*					75.70	1.87*		
Working Area											
Student	13.79			18.68	2.09*						
Retired	27.10	35.35	1.92*	20.33	-2.35*			21.03	-2.33*	36.04	3.41**
Unemployed	4.67	1.01	-1.97*	1.65	-2.31*					8.11	2.65**
House-maker	3.27	0.00	-2.17*					5.14	1.69*		
Industry	2.22	0.00	-1.67*								
Commerce	6.54	1.01	-2.66**	9.89	01.96*	10.79	02.08*				
Construction	1.64			3.30	01.80*						
Public administration	5.96					9.35	01.75*			2.70	-2.49*
Services	30.02	39.39	2.11*								
Not answered	4.32									1.80	-2.24*
Attitudes											
Ideal solution towards HWBC											
Eliminate	8.18	24.24	5.28**			2.16	-3.12**				
Reduce	46.26					64.03	4.58**	36.45	-3.33**		
Maintain	40.19	26.26	-03.05**	46.70	02.01*	28.06	-3.23**	50.00	3.35**		
Do not control	4.91	0.00	-02.81**								
Not answered	0.35					1.44	1.78*				

Statistical values are given by v.test-value; *p<0.05. **p<0.01.

3.2.c.3. Citizen emotions, lay-knowledge and habituation driving clustering attitudes towards wild boar presence in Barcelona

Regarding positive emotions towards wild boar, less than a third of the respondents perceived the wild boar as sympathetic (32.0%), with pleasant aesthetic value (16.0%), and stated that wild boar made them feel closer to nature (23.5%). In contrast, most of the respondents believed that the wild boar has no aesthetic value (59.2%), poses a threat for safety and public health (66.1%), fouls and/or damages the city (63.1%), does not bring them closer to nature (54.8%), and a third perceived the wild boar as unfriendly (34.1%,-ESM2-).

The PCA provided six Principal Components (Dim) based on human-wild boar coexistence, citizen emotions and lay-knowledge of wild boar (Table 7, Figure 9). The first component (Dim1, eigenvalue = 2.49) explained 41.49% of the variance, with higher contributions from two personal perceptions of lay-knowledge, namely considering wild boar detrimental for the city (Corr.=-0.62, p<0.001) and as a threat for public health and safety (Corr.=0.37, $p=3.71*10^{-205}$). Citizen emotions such as "aesthetics" (Corr.=0.75, p<0.001), "closeness to nature" (Corr.=0.73, p<0.001) and "sympathy" (Corr.=0.70, p<0.001) towards wild boar were correlated with Dim1. This component was also correlated with citizen perception of wild boar as a problem (p<0.001), approval of lethal management measures (p<0.001), citizen age (p<0.001), and socio-economic variables (unemployment rate, p<0.001; and district AROPE, p<0.001). Variables characterizing the borough (r2=0.14, p<0.001) and the district (r2=0.02, p<0.001) where the passer-by was surveyed, as well as the district where the citizen worked (r2=0.05, p<0.001) and inhabited (r2=0.02, p<0.001) were also correlated with Dim1. Finally, Dim1 was correlated with the proposed solutions (r2=0.17, p<0.001), mainly eliminating wild boar (p<0.001) and reducing wild boar population (p<0.001), and with being a student (r2=0.01, p<0.001). Dim2 had an eigenvalue of 1.03, explained 17.2% of the variance and was negatively correlated with the score in habituation to wild boar presence (Corr.=-0.65, p<0.001), wild boar aesthetics (Corr.= 0.21, p<0.001), and wild boar sympathy (Corr.=0.18, p<0.001). Dim2 was also correlated with the borough (r^2 = 0.21, p<0.001), type -being positively correlated with CD surveys (r^2=0.02, p<0.001)- and name of the district (r^2=0.05, p<0.001) where the passer-by was surveyed, and with the district where the citizen worked (r^2=0.05, p<0.001) and lived (r^2=0.07, p<0.001).

Table 7. Quantitative and qualitative variables describing Dim1 and Dim2. Correlation coefficients (Corr.) are given for the quantitative variables and r-square (r2) for the qualitative variables. WB = wild boar; HWBC = human-wild boar conflict; PD=Peripheral district; CD=Core district.

Quantitative variables	Dim1	Dim2	Qualitative variables	Dim1	Dim2
	Corr.	Corr.		r2	r2
Aesthetics	0.76**	0.21**	Ideal solution towards 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**			
Sight WB eating in city	-0.05*	-0.34**			
District forested land	-0.07**	-0.19**			
WB-related incidents	-0.08**	-0.16**			
Captured WB	-0.10**	-0.15**			
WB veterinary interventions	-0.10**	-0.15**			
WB voluntary feeding	-0.11**	-0.09**			
WB 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**			

*p<0.05; **p<0.01.
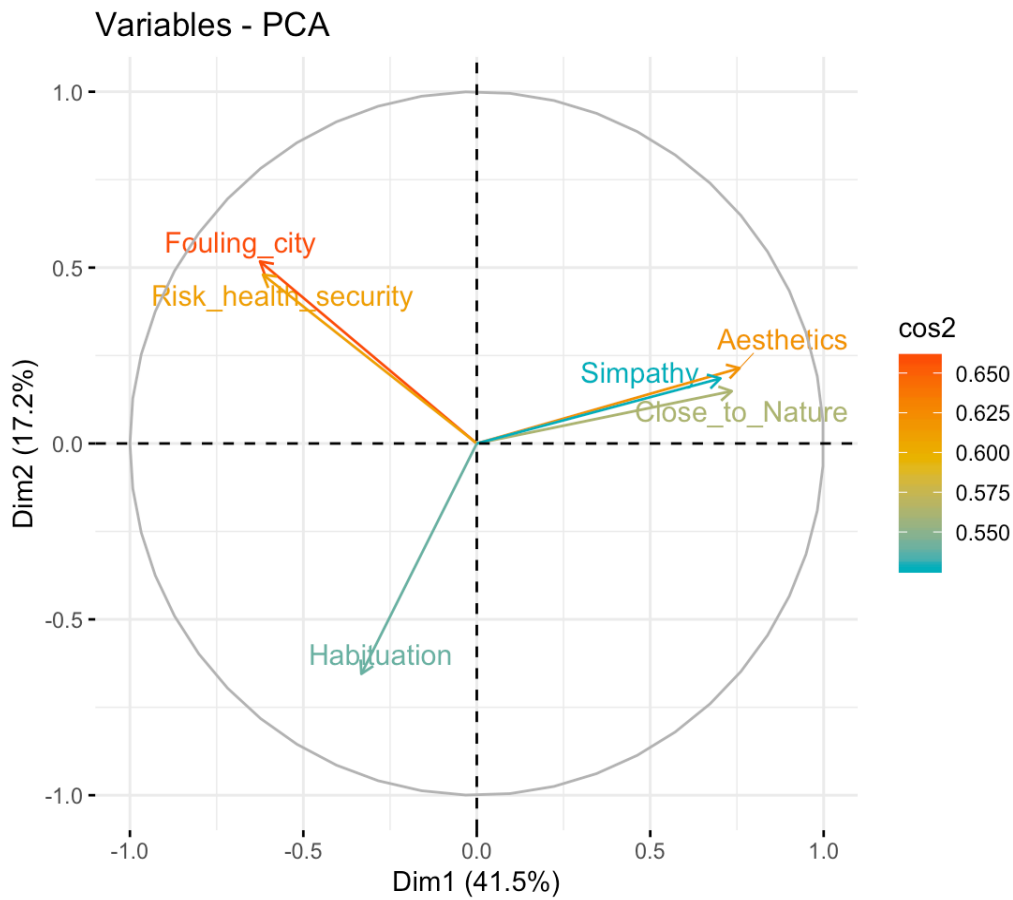
Figure 9. Correlation circle on principal components (Dim) with the active variables used for the Principal Component Analysis (PCA). The color scale according Cos2 indicates the quality of representation of the variable on the Dim. The x axis is Dim1 and the y axis is Dim2. Citizen emotions, lay-knowledge and habituation score towards the wild boar are forming a proportionally correlated triangle star on three axes.
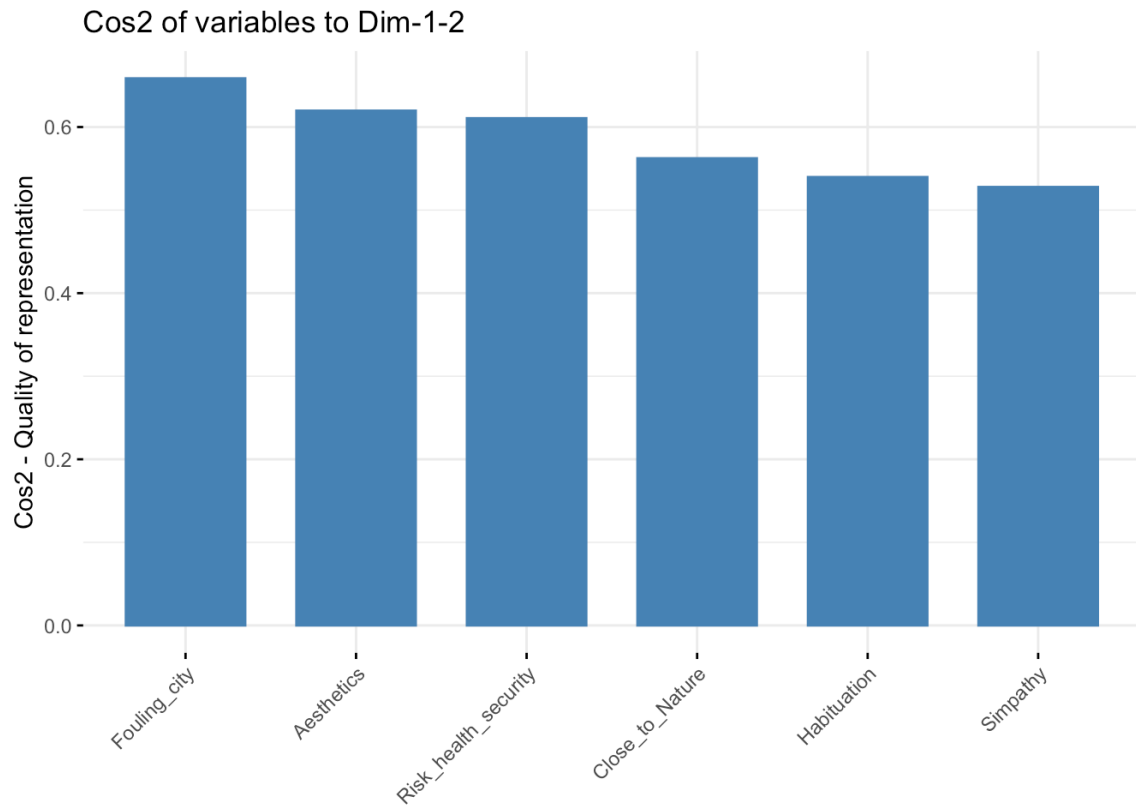
Figure 10. Active variable contribution (Cos²) in Dim1 and Dim2 resulting from the Principal Component Analysis conducted on citizen emotions, lay-knowledge and habituation towards the wild boar.

The HCPC performed on the PCA results identified five citizen clusters according to their emotions, lay-knowledge and habituation score towards wild boar presence in urban areas (Tables 8.1, 8.2 and Figures 9 and 11). The following is a depiction of the citizen clustering according to their perception, starting with the most sensitized (Cluster 5) and ending with the most habituated to the presence of wild boar in urban areas (Clusters 1 and 2).

Cluster 5 included a 40.1% of the passers-by surveyed and contained half of the NB residents surveyed (51.61%, $p < 0.001$). The citizens in cluster 5 were the most sensitized to HWBC, accepted lethal methods as a wild boar management option, and perceived the wild boar as an unnatural ($p < 0.001$), ugly ($p < 0.001$), unfriendly ($p < 0.001$) and dirty ($p < 0.001$) animal. These citizens also believed that wild boar poses a risk for human health and safety ($p < 0.001$). A previous experience of a vehicle collision with wild boar ($p < 0.05$) was also significant into cluster 5.

Cluster 4 (19.8% of passers-by) contained a 27.8% of all the foreign citizens surveyed ($p = 0.002$) and a 24.4% of StM inhabitants ($p = 0.048$). They were highly sensitized to wild boar presence ($p < 0.001$), meaning that they had a high perception of potential problems with wild boar despite distance and low degree of coexistence. Some citizens in this cluster, however, declared themselves as animal lovers ($p < 0.001$) and perceived the wild boar as a likable ($p < 0.001$) animal that made them feel closer to nature ($p < 0.001$). Neither cluster 3 or 4 had extreme attitudes against lethal control measures.

Cluster 3 included a fourth of the passers-by (25.5%), containing a 29.1% of the citizens surveyed in the CD ($p < 0.001$) and a 27.8% of the citizens who selected the reduction of the wild boar population as the preferred management option of human-wild boar conflicts ($p < 0.05$). Cluster 3 was mainly composed by elderly citizens ($p < 0.001$), who did not coexist with wild boar ($p < 0.001$) and perceived wild boar as a safe ($p < 0.001$) and clean ($p < 0.001$) animal.

Cluster 2 included the smallest proportion of passers-by surveyed (3.3%), but it was also more frequent among the PD inhabitants ($p < 0.001$), most of them surveyed in neighborhoods with lower human density ($p < 0.001$). Those citizens were the most habituated to wild boar presence ($p < 0.001$), approved of maintaining the wild boar population ($p < 0.001$) as the appropriate method to mitigate HWBC, exhibited the highest rate of urban wild boar voluntary feeding ($p < 0.001$) and experienced the highest proportion of wild boar incursions into their properties ($p < 0.001$).

Cluster 1 included a small proportion (11.3%) of the citizens surveyed. They declared themselves as animal lovers ($p < 0.001$) and preferred to maintain the wild boar population ($p < 0.001$) in Barcelona, rejecting any kind of lethal control ($p < 0.001$), even if this would be required for public health or safety concerns ($p < 0.001$). According to their emotions and lay-knowledge, cluster 1 saw wild boar as an aesthetically likable ($p < 0.001$), sympathetic ($p < 0.001$), not dangerous ($p < 0.001$), and clean ($p < 0.001$) animal.

Significant relationships were found between the citizen clustering and wild boar voluntary feeding, citizen habituation to wild boar presence, and number of wild boar veterinary interventions. Voluntary feeding was negatively associated with cluster 5 ($p < 0.001$) and positively associated with clusters 1 ($p < 0.05$) and 2 ($p < 0.001$). Although a higher degree of human-wild boar coexistence was only found in cluster 2 citizens ($p < 0.001$), citizen habituation to this coexistence was positively associated with both clusters 1 ($p < 0.05$) and 2 ($p < 0.001$), and negatively associated with clusters 3 ($p < 0.001$), 4 ($p < 0.05$) 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 culled wild boar was associated with cluster 3 (p<0.001) surveyed districts. More information about quantitative and categorical variables characterizing each cluster can be found in tables 8.1 and 8.2.
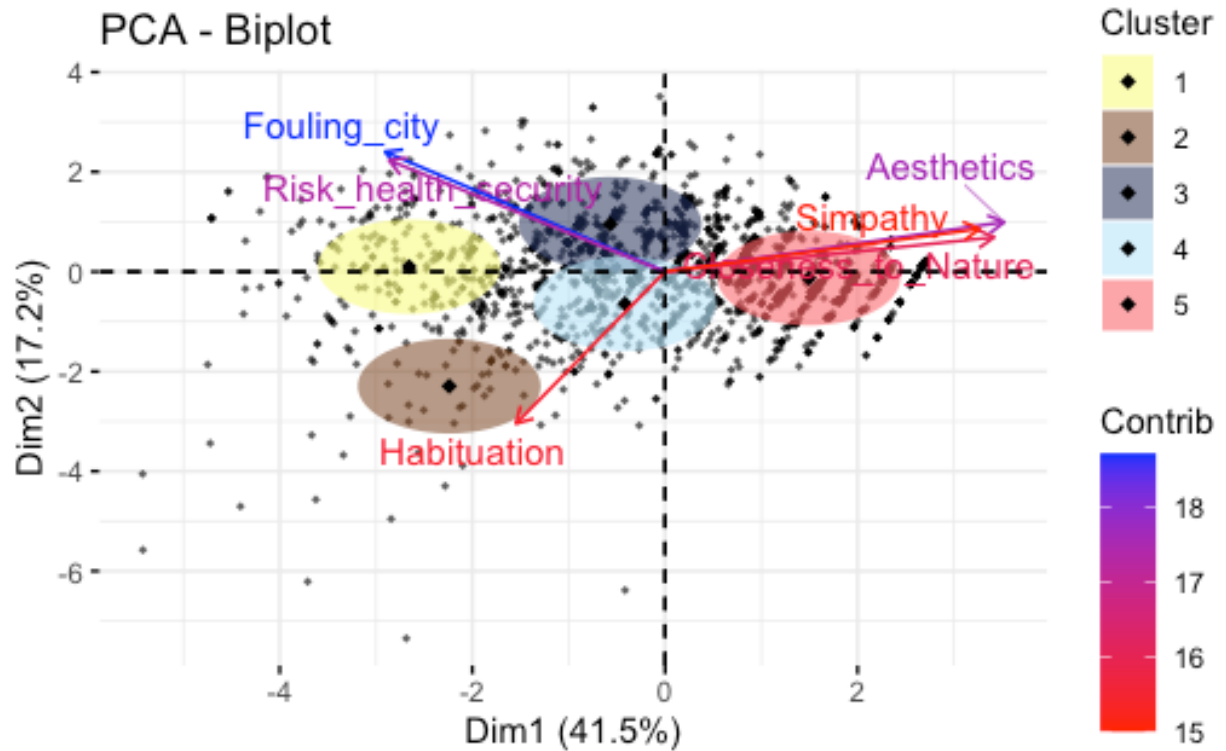
Figure 11. Hierarchical Clustering on Principal Components (HCPC) on PCA results. Cluster 4 was not polarized on attitudes nor habituated towards the wild boar, while clusters 1 and 5 showed opposite attitudes towards wild boar. Cluster 3 was the most sensitized to wild boar presence, whereas cluster 2 was the most habituated to wild boar presence. The x axis is Dim1 and the y axis is Dim2. The color scale indicates the contribution (Contrib) of the active variable on the Dim, higher contributions are displayed in blue.

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Table 8.1. Quantitative variables describing the five clusters identified. SD = standard deviation; WB = wild boar; PIS = perception of incidence score; AROPE = At Risk Of Poverty and/or Exclusion index.

Variables and categories	Total	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	Mean (SD)	Mean (SD)	v.test	Mean (SD)	v.test	Mean (SD)	v.test	Mean (SD)	v.test	Mean (SD)	v.test
Citizen											
Characteristics											
Animal affinity	7.71 (2.14)	8.88 (1.64)	08.62**	8.44 (1.84)	02.76**	7.28 (2.12)	-05.26**	8.09 (1.93)	03.86**	7.42 (2.22)	-05.02**
Age	3.72 (1.12)	3.33 (1.04)	-05.46**			3.92 (1.13)	04.71**				
Formation	3.08 (0.89)	3.20 (0.76)	02.11*	3.34 (0.73)	02.45*	2.94 (0.90)	-03.96**				
Experiences with WB											
WB sighting	1.98 (1.23)			3.83 (1.57)	12.18**	1.76 (0.97)	-04.52**				
Habituation	0.70 (0.60)	0.82 (0.47)	03.17**	2.90 (1.20)	29.57**	0.59 (0.35)	-04.91**	0.64 (0.39)	-02.33*	0.59 (0.40)	-06.52**
WB voluntary feeding	0.02 (0.17)	0.05 (0.24)	02.38*	0.11 (0.36)	04.03**					0.01 (0.11)	-03.18**
WB eating in city sighting	0.26 (0.44)			0.64 (0.48)	06.95**	0.19 (0.39)	-04.19**				
PIS	0.08 (0.40)			0.20 (0.69)	02.51*					0.10 (0.45)	01.97*
Incidents	0.03 (0.18)			0.09 (0.29)	02.88**						
Home garden	0.01 (0.10)			0.08 (0.27)	05.67**						
Traffic incident	0.01 (0.12)									0.02 (0.15)	02.44*
Attitudes towards WB											
Hunting perception	1.91 (0.97)	1.49 (0.84)	-06.79**							2.10 (1.04)	07.13**
Problem level	3.19 (0.85)	2.7 (0.86)	-09.21**	1.42 (0.70)	-16.90**					3.47 (0.71)	11.76**
Emotions towards WB											
Sympathy	3.00 (1.24)	1.49 (0.72)	-19.22**	2.14 (1.13)	-05.65**			2.27 (0.94)	-13.06**	3.83 (0.98)	23.97**
Close to nature	3.53 (1.34)	1.77 (1.00)	-20.60**	2.55 (1.38)	-05.94**			2.69 (1.18)	-13.80**	4.50 (0.72)	26.36**
Aesthetics	3.67 (1.2)	1.92 (1.01)	-22.90**	2.58 (1.20)	-07.38**			3.13 (1.11)	-09.84**	4.49 (0.64)	24.77**
Beliefs towards WB											
Risk for health/security	2.15 (1.19)	3.31 (1.19)	15.40**	2.98 (1.21)	05.70**	3.11 (1.02)	20.84**	1.60 (0.68)	-10.20**	1.42 (0.64)	-22.23**
Fouling the city	2.15 (1.13)	3.22 (1.20)	15.07**	2.47 (1.24)	02.34*	3.10 (0.91)	21.87**	1.71 (0.67)	-08.43**	1.43 (0.60)	-23.15**
District											
Cost of WB management measures1											
Captured WB	4.51 (8.54)	6.91 (9.78)	04.42**	8.56 (10.92)	03.86**	3.05 (7.22)	-04.43**				
WB veterinary interventions	2.97 (5.14)	4.38 (5.82)	04.31**	5.75 (6.81)	04.39**	2.13 (4.41)	-04.25**				

STUDY 2

Variables and categories	Total Mean (SD)	Cluster 1 Mean (SD)	Cluster 1 v.test	Cluster 2 Mean (SD)	Cluster 2 v.test	Cluster 3 Mean (SD)	Cluster 3 v.test	Cluster 4 Mean (SD)	Cluster 4 v.test	Cluster 5 Mean (SD)	Cluster 5 v.test
WB-related incidents	46.17 (65.81)	64.60 (77.10)	04.41**	70.55 (66.81)	03.01**	33.56 (55.16)	-04.96**				
Landscape features											
Residential	25.26 (9.99)	26.66 (9.20)	02.20*			24.04 (11.23)	-03.15**				
Forested land	10.51 (15.29)	13.95 (17.09)	03.54**	20.32 (17.91)	05.22**	7.37 (13.40)	-05.32**				
Urban parks	15.36 (4.05)	14.67 (4.27)	-02.66**	13.13 (5.16)	-04.48**	15.85 (3.83)	03.14**				
Sociodemographic variables2											
AROPE	26.52 (8.63)	25.33 (8.77)	-02.17*								
Density	662.6 (162.03)			591.22 (223.64)	-03.58**	676.57 (144.94)	02.23*				
Borough											
Cost of WB management measures1											
WB-related incidents	5.95 (14.47)	7.83 (17.41)	02.04*	11.08 (15.84)	02.88**	3.98 (11.12)	-03.53**				
Landscape features											
Residential	37.59 (15.37)			33.81 (15.46)	-02.00*	39.62 (14.78)	03.41**				
Forested land	4.36 (13.3)			7.99 (17.14)	02.22*	2.23 (8.99)	-04.15**				
Sociodemographic variables2											
Unemployment	1238.98 (686.21)	1108.26 (704.74)	-03.00**	784.08 (405.42)	-05.39**					1305.28 (683.80)	03.50**
Density	709.95 (248.55)			582.67 (249.93)	-04.16**	739.03 (233.45)	03.03**				
Population	27615.34 (14513.25)	25152.5 (14592.03)	-02.67**	19165.73 (9769.49)	-04.73**					28964.24 (14557.16)	03.36**

Statistical values are given by v.test-value (v.test); *p < 0.05; **p < 0.01; [1]Ajuntament de Barcelona (2020); [2]Institut d'Estadística de Catalunya (2020).

STUDY 2

Table 8.2. Categorical variables describing the five clusters identified. HBWC: human-wild boar conflict.

Variables and categories	Total	Cluster 1		Cluster 2		Cluster 3		Cluster 4		Cluster 5	
	%	%	v.test	%	v.test	%	v.test	%	v.test	%	v.test
Characteristics											
Sex											
Female	54.60			39.06	-02.52*						
Male	45.35			60.94	02.52*						
Growth environment											
Rural	26.43					22.04	-02.60**			29.68	02.66**
Urban	72.90					76.75	02.26*			69.94	-02.41*
Student											
No	82.11	75.91	-02.46*					77.06	-02.83**	84.59	02.35*
Yes	17.89	24.09	02.46*					22.94	02.83**	15.41	-02.35*
Working Area											
Student	11.61									9.30	-02.63**
Retired	36.55	18.18	-06.27**	25.00	-01.97*	42.89	03.38**				
Unemployed	4.86	7.73	01.98*	12.50	02.46*	3.21	-02.04*			3.69	-01.97*
Commerce	5.88	11.82	03.59**								
Construction	1.43					0.20	-02.98**	2.58	01.96*		
Services	26.48							22.42	-02.04*	29.30	02.30*
Not answered	3.99									2.04	-03.72**
Attitudes											
Ideal solution towards HWBC mitigation											
Eliminate	11.09	0.91	-06.19**			3.01	-07.41**	7.99	-02.23*	21.02	11.39**
Reduce	46.11	25.00	-06.81**			50.30	02.17*			51.21	03.70**
Maintain	37.63	66.82	09.30**	57.81	03.30**			44.33	03.02**	22.68	-11.36**
Do not control	4.91							2.84	-02.19*		
Range											
Type of district											
Peripheral district	43.76	50.00	01.97*	65.63	03.55**	35.87	-04.14**				
Core district	56.24	50.00	-01.97*	34.38	-03.55**						

Statistical values are given by v.test-value (v.test); *p<0.05, **p<0.01.

3.2.e. Discussion

3.2.e.1. Influence of human emotions, previous experiences and lay-knowledge on citizen attitude towards wild boar in Barcelona

Our results (Figures 8 to 11; Tables 5.1, 6.1 and 8.1). show that human attitudes towards the wild boar, and the derived human-wildlife conflicts are determined by emotions, lay-knowledge and past experiences. These attitudes are driven by both emotional processes and personal decisions, and are further linked to perceived risk, cultural perceptions, socio-economic differences and demographic factors (Soulsbury and White 2015, Adams 2016, Emre Can and Macdonald 2018, Jacobs and Vaske 2019, Lute and Gore 2019, Nettles et al. 2021, Batavia et al. 2021). According to our results, the gradient of human-wild boar coexistence along the urban scene and its consequent citizen habituation or sensitization is an important driver of public attitudes towards the wild boar (Arreguín-González 2013, Adams 2016, Zhang et al. 2014). We identified five different citizen clusters diverging on their experiences, emotions and personal perceptions, which influenced the attitudes towards wild boar and determined the acceptance of measures as is the capture and euthanasia of wild boar (Jackobson et al. 2014, Bencin et al. 2016).

In Barcelona, the human-wild boar gradient of spatial coexistence determined the difference in citizen attitudes between the CD, where there is low contact with wild boar and attitudes were based solely on the present lay-knowledge and emotions; and the PD, where there are contact and therefore interaction with wild boar and hence adding the influence of experiences to the formation of specific attitudes (Soulsbury and White 2019). The influence of the human-wild boar coexistence on the HWBC sensitization can be explained by contextualizing the citizen-wild boar interactions into the dual-process theory. Grooves and Thomson (1970) hypothesized that 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. The citizens from the CD, with their attitudes influenced by emotions and lay-knowledge were sensitized against potential hazards and economic losses posed by wild boar. The most habituated citizens to the presence of wild boar (Clusters 1 and 2) were also those ranging in PD, especially those citizens showing higher degree of everyday coexistence with wild boar (Cluster 2).

On one extreme, some citizens in clusters 1 and 2 fed wild boar as an active behavior. These had the lowest scores of HWBC sensitization, something linked to their perception of safe or non-problematic coexistence with wild boar (Adams 2016). On the other end, the citizens in cluster 5 had the highest score of HWBC sensitization (lowest habituation score) and exhibited the lowest proportion of cases of wild boar feeding.

Altogether with the PIS, citizen lay-knowledge (wild boar fouling the city and wild boar risk consideration for public health and security) was determinant in all the clusters: clusters 1 and 3 showed no concern about them, whereas clusters 4 and 5 expressed the highest concern about those wild boar-related perceptions (Jacobson et al. 2014). Citizen attitudes towards wild boar in clusters 1 and 2 can be explained through its lack of traumatic incidents as vehicle collisions (Rosell and Llimona 2012, Conejero et al. 2019a). Although the citizens in cluster 5 scored lower PIS than citizens

in cluster 2, they had the highest HWBC concern, probably because they experienced more traumatic experiences involving wild boar, namely traffic accidents (Madden et al. 2014, Nyhus 2016).

Regarding citizen HWBC perception drivers, the most relevant agonistic experience boosting aversive attitudes towards wild boar in Barcelona were traffic accidents, which affected the 1.5% of the surveyed citizens (ESM2, Rodríguez-Morales et al. 2013, Zuberogoitia et al. 2014). Attacks to people (0.7%) and perception of wild boar as a threat for themselves (3.9%) were minor, with most of the surveyed citizens (95.2%) stating that they did not experience any incident involving wild boar (ESM2), something which resonate with reports from other contexts (Manipady et al. 2006, Nyhus 2016, Lewis et al. 2020). It is important to consider the negative human-wild boar experiences to properly understand drastic shifts of social perception due to sensitization processes in wild boar-coexistent citizens (Çevik 2014). However, human-wild boar interactions involving pets were significantly perceived as a threat, probably being one of the highest sensitization process boosters towards wild boar presence, which may be due to the potential occurrence of wild boar attacks to pets or people (Soulsbury and White 2015). Namely in Barcelona, wild boar forages for anthropogenic food resources, raiding public parks, urban cat colonies and human waste (González-Crespo et al. 2018, Castillo-Contreras et al. 2018 and 2021). Potential wild boar-pet interactions are most likely to occur during twilight day-frame, when pet owners walk their dogs on wild boar foraging areas such as urban parks (Parker and Nilon 2012). Accordingly, an appropriate management of pets, including urban feral cat colonies, can help to reduce the risk of conflict (Licoppe et al. 2013, Soulsbury and White 2015).

3.2.e.2. Construction of citizen attitudes towards wild boar

Our results indicated that attitudes towards wild boar and the perception of measures to mitigate HWBC differed among the population clusters (Figure 11, tables 8.1 and 8.2). Personal emotions and social attitudes towards conflictive wildlife have been already described for other large mammals (Bath 1998, Slagle and Bruskotter 2019, Batavia et al. 2021), which in turn determines all responses to interactions and drive citizen behavior facing HWBC in urban areas as well. In concordance with previous studies (Whittaker et al. 2006, Kansky and Knight 2014), experiences with wild boar together with previous emotions and lay-knowledge are configuring citizen attitudes, influencing human behaviors towards wild boar presence in urban areas and driving the acceptance of management measures. In addition to Jacobson et al. (2014), Soulsbury and White (2015), and Nyhus (2016), we make clear that when coexistence occurs without associated negative experiences, the HWBC sensitization is low and encountering urban wild boar is seen as an emotional, pleasant and positive value (Clusters 1 and 2), even if it can potentially cause damage or pose a threat to both humans and wild boar. Therefore, as indicated in previous research (Rosell and Llimona 2012, Adams 2016, Conejero et al. 2019a), our results confirm that citizens influenced by positive emotions (Clusters 1 and 2) were more likely to disprove lethal measures based on targeted capture and removal. On the contrary, traumatic experiences related to wild boar led to an incremented sensitization towards HWBC derived risks on human health and safety (Cluster 5), resulting in negative attitudes constructed by citizens towards the wild boar (Conejero et al. 2019a). Highly sensitized citizens in cluster 5 had a higher rural background than citizens in the other clusters,

lower school education, and their attitudes towards wild boar were influenced by negative emotions, traumatic experiences, and unfavorable perceptions. Consequently, these citizens were also more prone than citizens of other clusters to reduce or remove (through lethal management measures) the wild boar population as ideal solutions to mitigate HWBC. Citizens in clusters 3 and 4 showed moderate attitudes when compared to clusters 1,2 and 5, declaring a low degree of coexistence or interaction with wild boar, and therefore their attitudes were largely based on emotions and lay-knowledge and not on direct experience, leading to an absence of polarized attitudes towards HWBC. However, citizen characteristics, attitudes and acceptance of wild boar management measures differed between clusters 3 and 4. Cluster 3 was mostly composed of low-educated elder citizens with little or no contact with natural environments, who showed a higher perception of HWBC than cluster 4 citizens. In addition, citizens in cluster 3 were largely supporting the use of lethal management measures to manage urban wild boar population, in consonance with previous studies that associate citizen attitudes to specific personal characteristics (Blanco and Cortés 2002, Sakurai et al. 2013). The lack of coexistence and interactions with the wild boar may lead to a diminished understanding of wildlife dynamics and behavior among urban citizens, boosting fear and increasing the social sensitization to HWBC, which results in the acceptance of lethal methods of control (McCleery et al. 2014). Conversely and accordingly with previous research on tolerance for wildlife (Frank 2016, Slagle and Bruskotter 2019), cluster 4 was composed by younger citizens who defined themselves as being animal lovers as well as more passive and tolerant towards HWBC.

Our findings support that a more frequent and quotidian contact with the urban wild boar promotes HWBC tolerance, as shown by PD citizens as well as by the citizens in both clusters 1 and 2, which provided that no negative experiences involving the wild boar were associated to human-wild boar encounters. In return, a lower degree of human interaction with wildlife boosts the rejection of wild boar presence in the city, as shown by CD citizens and citizens in clusters 3 and 5 (Zhang et al. 2014, Nettles et al. 2021). However, negative experiences, mainly traffic accidents, determine the most negative perception of HWBC and the highest acceptance of lethal control measures. Understanding how citizens respond to wild boar presence on the social and material environment is an essential part of dealing with potential HWBC in urban areas (Soulsbury and White 2015, Adams 2016).

Besides the negative experiences, human emotions towards wild boar in urban areas were also determinant on HWBC sensitization. Emotions such as sympathy, closeness to nature and pleasant aesthetic value differed among clusters, with citizens in cluster 1 having the most positive emotions, followed by clusters 4 and 2, and citizens in cluster 5 showing the most negative ones. According with previous studies (Jackobson et al. 2014, Soulsbury and White 2015, Nettles et al. 2021), the alignment between emotions and experience in citizen clustering suggests that encounters with urban wildlife can led to a wide spectrum of feelings, ranging from fear and caution to enjoyment or pleasure.

Citizen attitudes may be determined by the perception of wild boar potential to compromise (or not) personal wellbeing or safety (Clusters 1, positively, and 5, negatively). These attitudes stem from a combination of personal experiences resulting in citizen habituation (Cluster 2) or sensitization (Cluster 5), emotions (Clusters 1 and 3) and are influenced by personal lay-knowledge and previous experiences (Clusters 3 and 5. Moreover, citizens that coexist with wild boar may be motivated to directly

engage in human-wild boar interactions. Attitudes from urban inhabitants can thus vary from ignoring potential risks and searching for active contact with wild boar (clusters 1 and 2), to engaging in indirect contacts (cluster 3), passive contacts (cluster 4), or showing an increased perception of wildlife-related risks and avoiding any kind of contact with the wild boar (cluster 5). As has been mentioned by other authors (Sun 2013, Zhang et al. 2014, Soulsbury and White 2015, Nyhus 2016), this relationship between the low sensitization of HWBC, the disregard of associated risks, and the enhancement of positive emotions therefore drives citizen tolerance towards the presence of wild boar in Barcelona. The five citizen clusters identified are distributed along a HWBC tolerance gradient which reflect a sharp discrepancy among citizen's clusters. According to that, the urban wild boar has both defendants and detractors, citizens who show positive as well as negative trigger emotions.

3.2.e.3. Citizen characterization and HWBC

Wild boar-related emotions such as sympathy, pleasant aesthetic value, and closeness to nature correlated positively with each other and negatively with the perceptions of wild boar fouling the city and causing health and safety risks (Figure 9). As a measure of the relationship between emotions, perceptions and experiences, these correlations were distributed differently among the five citizen clusters identified. Therefore and according with previous research on human-wildlife conflict (Bath 1998, Nyhus 2016, Adams 2016), the patterns of sensitization towards HWBC can be difficult to identify because of the complexity inherent to human attitudes, emotions and personal experiences. In Barcelona, the citizens habituated to the presence of wild boar -not sensitized towards HWBC (Clusters 1 and 2)- were surveyed in HG and SSG. The presence of wild boar in the PD is influenced by a wide variety of environmental and urban factors, including seasonal variations, forest cover characteristics, proximity to the CNP, landscape fragmentation, presence of natural corridors, and availability of trophic resources of human origin (Bieber and Ruf 2005, Castillo-Contreras et al. 2018). Due to those multifactorial drivers, when people coexist with wildlife, the related costs can be variably addressed and are therefore difficult to understand and estimate (Dickman 2009, Nyhus 2016). However, our results may contribute to a better understanding of how human dimension factors are causing higher economic and material costs in public management of wild boar populations, especially in HG and SSG.

Positive emotionally based attitudes towards wild boar presence in urban areas were more frequent in young citizens, students or unemployed, who had high education level, lived in the PD, had contact with wild boar and showed higher degree of animal affinity. These people were largely rejecting the use of lethal management measures and supported the maintenance of the current urban wild boar population. Although the economic cost of wild boar management measures was higher in PD, these suburban dwellers were not concerned by HWBC, risks or nuisances caused by wild boar and were the most prone to feed the wild boar, mainly men. Conversely, citizens with a rural background, lower education level, similar animal affinity, higher acceptance of hunting, who had low contact with wild boar and stronger concern about HBWC than positive emotions towards wild boar, were the ones with the most negative perception of wild boar, and the highest acceptance of lethal measures. The gradient of positive and negative attitudes and the acceptance of lethal management measures among citizens, influenced by individual and social characteristics such as age, school

level, gender, and rural or urban background, has been previously reported in other human-wildlife conflicts (Blanco and Cortés 2002, Sakurai et al. 2013). According with other authors (Lindsey 2016, Adams 2016, Frank and Glickman 2019), the personal interactions, socio-economic aspects and cultural background are essential factors to understand HWBC and its sensitization effect in relation to actual impacts of wild boar into specific social contexts and environments.

3.2.e.4. Peripheral and Core District characterization

As previously appointed Zhang et al. (2014) and Nyhus (2016), the spatial gradient and distribution of citizen-wild boar coexistence is determinant for the HWBC perception. Accordingly, our results support that HWBC sensitization in urban areas is not homogeneous in Barcelona (Figure 11, tables 5.1 and 5.2). Citizens from the CD do not coexist in everyday spaces with wild boar, and therefore exhibit a stronger influence of emotions and lay-knowledge on their attitudes towards HWBC (Bath 1998, Nettles et al. 2021). In comparison, PD citizens are in general less sensitized against potential hazards and economic losses caused by wild boar than the CD citizens. As was mentioned by Kansky and Knight (2014) and (Conejero et al. 2019a), in Barcelona, the acceptance of targeted captures and euthanasia as a measure of control can be explained either by the lack of coexistence with wild boar (in the CD), or by experienced coexistence which is marked by previous traumatic experiences (PIS), being the most significant incidents in the PD. Although the citizens surveyed in the PD reported higher wild boar encounters, they were also more habituated and tolerant towards wild boar presence in urban areas and therefore having a minimized perception of HWBC, hazards and public health implications, and being more prone to show positive attitudes towards the wild boar. The perception of wild boar by CD citizens, driven by emotions and personal perceptions is probably more dependent on current public opinion, social media reports and emotional approaches than that of PD citizens (Kaltenborn et al. 2006, Liordos et al. 2017), for whom their own experience of coexistence plays a crucial role.

Beyond human habituation to wild boar, differences in individual and social features determining the emotions and attitudes of citizens towards wild boar in absence of direct experience of encounter were also found between the PD and the CD. The socio-economic indexes indicated a higher lifestyle quality in PD than in CD, and lower unemployment rate, AROPE and human density. Moreover, the surveyed PD citizens were younger, with a higher proportion of women and students, and a higher level of school education. These were also more prone to have vegetarian food habits.

3.2.e.5. Differences among Peripheral Districts

Similar to the differences between CD and PD, differences in perceptions, emotions and experiences, with consequent differences in attitudes towards wild boar and HWBC sensitization and acceptance of lethal measures, could be identified among the five PD in relation to socio-economic factors. While the indicators of wild boar presence and HWBC were higher in three of the PD (namely SSG, HG and NB) compared to the other two (LC and G), these two districts presented higher citizen sensitization towards HWBC. The absence of positive emotions (raised from non-conflictive experiences), in combination with lay-knowledge concerns with sanitary and safety risks posed by wild boar, increased the acceptability of lethal management measures among local citizens in the more sensitized PD, as previous research described in other contexts (Bath 1998, Bruskotter et al. 2009, Adams 2016, Slagle and Bruskotter 2019).

However, wild boar presence and the cost of HBWC were not the only or even the most relevant factors determining differences in attitudes and perception of HWBC among the five PD. Although the wild boar presence, HWBC and associated costs in

SSG, HG and NB were similar, HWBC sensitization was positively correlated with education level and negatively correlated with AROPE and human population density at the district scale. This means that the district with higher education leveland lower AROPE (SSG) had a more negative perception of urban wild boar and a stronger HWBC sensitization than HG, which in turn was half-way for all these indicators between SSG and NB. The higher AROPE in NB could explain why citizen-wild boar interactions and wild boar-related incidents did not generate additional costs on HWBC mitigation efforts, due to the higher social concern with other unsolved social and economic struggles, since these citizens prioritize solving basic needs at the expense of addressing less urgent problems (Nilon 2014, Nyhus 2016). Similarly, in the two PD with minor wild boar presence and associated HWBC and costs (LC and G) a higher HWBC sensitization and acceptance of lethal measures could be found in LC, with lower education level, AROPE and population density than G. Our experimental design allowed fine-tuning the geographic distribution of HWBC sensitization and management measures acceptance at a finer scale within Barcelona, supporting the existence of patterns of poverty and social inequality that link current HWBC with local socio-economic and cultural variables (Nilon 2014, Kaltenborn 2006).

3.2.e.6. Implications for management

Anthropogenic food resources are a key urban attractant for wild boar in Mediterranean cities, including food from stray cat colonies (Loss et al. 2013, Castillo-Contreras et al. 2018 and 2021), producing negative ecological and physiological impacts, exposing wild boar to potential harms from human waste (Reshamwala et al. 2018) and leading to negative consequences for both animal and human wellbeing (Cox and Gaston 2018). Moreover, feeding wild boar in early social stages (while being piglets) by citizens in clusters 1 and 2 boosts future urban wild boar foraging behavior, generating more conflictive wild boar (Rosell and Llimona 2012, Nyhus 2016, Cox and Gaston 2018). Apart from applying management measures to reduce the growth of wild boar population in the CNP, to prevent the wild boar entry into the urban area, and to decrease the lure of the city (e.g., food resources) for wild boar, (Stillfried et al. 2017a and b, Castillo-Contreras et al. 2018, González-Crespo et al. 2018, Castillo-Contreras et al. 2021), addressing the human dimension is essential to address HWBC (Nilon 2016, Slagle and Bruskotter 2019). For the first time in history, the urban human population has overcome the rural population (Nyhus 2016), leading to increased distancing with nature and a decrease of lay-knowledge on wildlife dynamics, behavior, and ecology. Natural environments can enhance physical and mental population health (Zhang et al. 2014, Adams 2016). More research is needed to understand the outcomes of social and ecological processes that impel humans and wildlife to coexist in specific spaces (Soulsbury and White 2015, Cox and Gaston 2018).

Awareness campaigns that succeed in implementing in society the need to reduce such anthropogenic food resources and explain the detrimental consequences and risks posed by the urban environment for the wild boar. To achieve such success, messages must be tailored to the specific requirements, emotional motivations, and consequent attitudes and behaviors of each of the clusters identified. The current emotionally based wild boar feeding behavior of citizens in clusters 1 and 2 is unlikely to change through awareness slogans based on rational cost-benefit motivations alone (Sun 2013, Madden et al. 2014, Jacobson et al. 2014, Emre Can and Macdonald 2018). Conflict mitigation may be more difficult among population clusters with limited

education levels (clusters 3 and 5) or specific historical or cultural attributes predisposing to conflict (Nyhus 2016, Adams 2016), as is the case for clusters 1, 2 and 5. Then, arguments regarding animal welfare and ecosystem balance must be integrated into awareness campaign messages and management measures, therefore appealing to the appropriate values for each reluctant cluster (Jacobson et al. 2014). If succeeding, the management and sensitization efforts focused on these problematic clusters could contribute to mitigate HWBC. On the long term, to deal with not extremely positioned population (cluster 4) and to prevent intolerance to management measures due to lack of knowledge of wildlife dynamics and ecology (cluster 3), youth education could improve wildlife knowledge during childhood, and therefore increase environmental awareness and well-informed attitudes towards wild boar (George et al. 2016, Zhang et al. 2018).

Non-acceptance of lethal wild boar management measures is prevalent among both the wild boar-coexistent citizens (clusters 1 and 2 -Table 8.1-) and the Barcelona citizens as a whole (43.9%, ESM2). At the same time, both lethal and nonlethal approaches are available to reduce HWBC, each with advantages and disadvantages (Massei et al. 2011, Barasona et al. 2013, Nyhus 2016, Liordos et al. 2017, Torres-Blas et al. 2020). According with previous research on human-wildlife conflicts (Sakurai et al. 2013, Zhang et al. 2014, Cox and Gaston 2018, Conejero et al. 2019a), our findings suggest the need to communicate more effectively with residents about HWBC, so that citizens can adopt a coexistence attitude and a specific behavior by resorting to well-nuanced knowledge of each situation of human-wildlife interfaces

Our results contribute to the growing recognition that efforts aimed at understanding human perception, and consequently their attitudes and behavior, can be more important than simply reducing the damage caused by wild boar by implementing technically sound but socially decontextualized measures. Social and cultural research on the factors promoting citizen tolerance of potentially hazardous human-wildlife relations in urban areas could help to properly manage HWBC (Zhang et al. 2014, Nilon 2016, Slagle and Bruskotter 2019). Nowadays, social media can be a tool to orient public opinion through the framing human-wildlife conflict in all its social and ecological complexity (Nyhus 2016) and public services may assist in providing a well-nuanced picture of each scenario of coexistence.

3.2.e.7. Application to other human-wildlife conflicts

The complete understanding of HWBC in urban areas is complex and includes wildlife behavior and ecology, human behavior, changes in seasonality and resource availability (Nyhus 2016, Stillfried et al. 2017c, Castillo-Contreras 2018, González-Crespo 2018, Conejero et al. 2016 and 2019a, Castillo-Contreras et al. 2021). Classifying the main drivers of the human dimension of HWBC into emotions, lay-knowledge and past experiences, provides a potentially useful quantitative and qualitative assessment of citizen attitudes. With this analysis, we can disclose not only the animal habituation, but also the reciprocal process of a habituation of humans to wildlife. This methodology can be a useful tool for management strategies of other human-wildlife conflicts, by addressing the specific cultural, social and psychological aspects that determine the human dimension of these processes (Bath 1998, Kansky and Knight 2014, Nettles et al. 2021). A local sociological analysis of citizen emotions, attitudes and lay-knowledge undertaking management actions, including public

acceptance of required measures, should increase management specificity and success (Whittaker et al. 2006, Jackobson et al. 2014, Sakurai et al. 2014).

Beyond reciprocal habituation and sensitization, socio-economic variables may also contribute to the understanding of human-wildlife conflicts perception and acceptance of management measures and should also be considered in both the design of awareness campaigns and in the application of 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 human-wildlife conflicts management (Kaltenborn et al. 2006, Nilon 2016, Nyhus 2016). 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 human-wildlife conflicts in urban areas. This could orient citizen attitudes towards a more comprehensive frame of their social and environmental agency and responsibility.

The combination of anthropological, social and psychological knowledge may assist wildlife managers to better understand how social, cultural, economic, psychological and ecological factors interact with each other, driving citizen perception of wildlife conflict in urban areas. Our multi-sided methodology can help to undertake the most feasible and socio-ecologically adapted management measures for each location and time. Data gathering on these dimensions and its corresponding analysis may be helpful to wildlife managers in order to identify and address specific targets to mitigate potential conflict, damages and the increase of human and wild boar shared vulnerability. Further research on human dimension factors influencing human-wildlife conflict and reciprocal habituation, focusing on environmental awareness and a balanced human-wildlife coexistence, is urgently required in order to face the currently growing uncertainties related to large mammal presence in urban areas.

3.2.f. Conclusions

Citizen attitudes towards HWBC in Barcelona are driven by personal emotions, experiences and lay-knowledge of wild boar. With the description of the ongoing tensions between conflict and processes of reciprocal habituation between humans and wild boar, our findings revealed that the pleasant aesthetic value, sympathy and the feeling of closeness to nature are positively correlated among them and negatively correlated with perceptions of wild boar as fouling city and posing health and safety risks to humans. Spatial gradient and distribution of citizen-wild boar interactions and respective habituation or sensitization influence human tolerance towards HWBC, promoting polarized attitudes toward wild boar presence in urban areas. Hence, the variability intrinsic to the human dimension is determinant in HWBC management. In order to optimize the success of wildlife management measures in Barcelona, we suggest concentrating efforts on the relatively small proportion of citizens boosting HWBC by feeding wild boar. Awareness campaigns based on empirical data of wild boar growth and wild boar-related damages can be useful to reach citizens without significant emotional attachment to wild boar, but fail with citizens who feel positive emotions towards wild boar. In this regard, arguments concerning animal welfare and ecosystem imbalances (which could damage the local population of this species in the medium and long term) need to be included in public communications about wild boar presence in urban areas.

3.2.h. Supplementary material

Table 9. Short summary of clustering results describing the main features of the citizens belonging to each cluster.

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

STUDY 2

ESM2. Summary of survey results, group of variables, name of the variable, short description of the variable, categories, abbreviations (Abb.), number of respondents (n) and answer proportion over total counts are included.

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
Citizen range						
	Survey district	District survey				
	District where the citizen was surveyed		Ciutat Vella	CV	110	5,62
			Eixample	E	288	14,72
			Sants-Montjuïc	SM	236	12,07
			Les Corts	LC	99	5,06
			Sarrià-Sant Gervasi	SSG	182	9,30
			Gràcia	G	139	7,11
			Horta-Guinardó	HG	214	10,94
			Nou Barris	NB	222	11,35
			Sant Andreu	SA	152	7,77
			Sant Martí	StM	314	16,05
	Residence district	District Residence				
	Citizen district of residence		Ciutat Vella	CV	89	4,55
			Eixample	E	205	10,48
			Sants-Montjuïc	SM	259	13,24
			Les Corts	LC	74	3,78
			Sarrià-Sant Gervasi	SSG	141	7,21
			Gràcia	G	119	6,08
			Horta-Guinardó	HG	201	10,28
			Nou Barris	NB	217	11,09
			Sant Andreu	SA	149	7,62
			Sant Martí	StM	271	13,85

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			Fora de la ciutat	FC	223	11,40
			NR-No answer	NA	8	0,41
	Working district	Working District				
	Citizen working district		Ciutat Vella	CV	140	7,16
			Eixample	E	263	13,45
			Sants-Montjuïc	SM	225	11,50
			Les Corts	LC	98	5,01
			Sarrià-Sant Gervasi	SSG	147	7,52
			Gràcia	G	107	5,47
			Horta-Guinardó	HG	164	8,38
			Nou Barris	NB	178	9,10
			Sant Andreu	SA	125	6,39
			Sant Martí	StM	274	14,01
			Fora de la ciutat	FC	109	5,57
			NR-No answer	NA	126	6,44
Citizen characteristics						
	Gender	Sex				
			Male	M	887	45,35
			Female	F	1068	54,60
			Other	A	1	0,05
			NR-No answer	NA	0	0,00
	Student	Student				
			YES	1	350	17,89
			NO	0	1592	81,39
			NR-No answer	NA	14	0,72

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
	Growth environment	Growth environment				
			Town	P	517	26,43
			City	C	1426	72,90
			NR-No answer	NA	13	0,66
	Working area	Working Area				
			Student	1	227	11,61
			Retired	2	715	36,55
			Unnemployed	3	95	4,86
			Homemaker	4	58	2,97
			Industry	5	34	1,74
			Trade	6	115	5,88
			Agriculture and farming	7	5	0,26
			Construction	8	28	1,43
			Public administrator	9	83	4,24
			Services	10	518	26,48
			NR-No answer	NA	78	3,99
	Age	Age				
			<16 years	1	25	1,28
			16-25 years	2	293	14,98
			26-45 years	3	556	28,43
			64-65 years	4	417	21,32
			> 65 years	5	661	33,79
			NR-No answer	NA	4	0,20
	Academic background	Formation				
			None	1	76	3,89

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			Primary school	2	477	24,39
			Secondary school	3	501	25,61
			High school	4	778	39,78
			NR-No answer	NA	124	6,34
Citizen behaviour						
	Eating habits	Eating habits				
	Independently of the motivation, according Lap T Le & Joan Sabaté (2014)		Non-vegetarian (Animal products almost every day)	1	772	39,47
			Non-vegetarian (Animal products sometimes during the week)	2	446	22,80
			Non-vegetarian (Animal products minimized)	3	634	32,41
			Lacto-ovo-vegetarian (Eat eggs, milk, or both but no other animal products)	4	68	3,48
			Vegan (No animal products)	5	12	0,61
			NR-No answer	NA	24	1,23
	Do you like animals?	Do you like animals				
	Linkert scale from 1 (I hate animals) to 10 (I love animals inconditionally)		I hate animals	1	30	1,53
				2	17	0,87

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
				3	9	0,46
				4	24	1,23
				5	350	17,89
				6	112	5,73
				7	231	11,81
				8	358	18,30
				9	230	11,76
			I love animals inconditionally	10	583	29,81
			NR-No answer	NA	12	0,61
	I felt threatened by WB presence	Threat perception				
	Yes/No		YES	1	75	3,83
			NO	0	1874	95,81
			NR-No answer	NA	7	0,36
Citizen perception of Human-Wild Boar Conflict (HWBC), lethal management measures and possible solutions						
	Do you think the presence of wild boar in urban areas is a problem?	Problem level				
	Linkert scale from 1 (the WB causes no problem) to 5 (WB is a plague)		WB not a problem at all	1	112	5,73
			WB causes minor problems	2	179	9,15

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			If they were controlled. they would not cause problems	3	889	45,45
			They represent a threat in urban areas, they should live in the forest	4	697	35,63
			WB is a plague, and we should exterminate them all	5	43	2,20
			NR-No answer	NA	36	1,84
	Do you approve hunting or other lethal methods to control WB abundance?	Hunting perception				
	Linkert scale from 1 (No, I do not approve lethal methods) to 4 (Yes, I have no problem with lethal methods)		No, never	1	858	43,87
			I approve ethical sacrifice, not hunting	2	493	25,20
			Yes, with legal and well-regulated hunting activity	3	359	18,35
			Yes, always	4	162	8,28
			NR-No answer	NA	84	4,29
	How the city should deal against wild boar presence?	Solution				

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			Eliminate the WB	E	217	11,09
			Reduce WB population	R	902	46,11
			Maintain WB population	M	736	37,63
			Grow WB population	A	1	0,05
			Do not control WB population	NC	96	4,91
			NR-No answer	NA	4	0,20
Citizen emotions towards the WB						
	The wild boar make the city more aesthetic	Aesthetics				
	linkert scale 1 (the WB make a beautiful city) to 5 (the WB make a nasty city)		Totally agree	1	158	8,08
			Agree	2	154	7,87
			Agree/disagree	3	437	22,34
			Disagree	4	584	29,86
			Totally disagree	5	574	29,35
			NR-No answer	NA	49	2,51
	The WB inspires me sympathy	Sympathy				
	linkert scale 1 (the WB inspires me lots of sympathy) to 5 (the WB is unfriendly)		Totally agree	1	304	15,54
			Agree	2	323	16,51

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			Agree/disagree	3	631	32,26
			Disagree	4	395	20,19
			Totally disagree	5	271	13,85
			NR-No answer	NA	32	1,64
	The WB makes me feel closer to nature	Close to Nature				
	linkert scale 1 (the WB makes me feel closer to nature) to 5 (the WB doesn't make me feel closer to nature)		Totally agree	1	229	11,71
			Agree	2	230	11,76
			Agree/disagree	3	374	19,12
			Disagree	4	478	24,44
			Totally disagree	5	593	30,32
			NR-No answer	NA	52	2,66
Citizen lay-knowledge towards the WB						
	The WB represent a threat for public health and security	Risk health security				
	linkert scale 1 (the WB is a threat for public security and health) to 5 (the WB is not a threat for public security and health		Totally agree	1	752	38,45
			Agree	2	541	27,66

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			Agree/disagree	3	288	14,72
			Disagree	4	257	13,14
			Totally disagree	5	82	4,19
			NR-No answer	NA	36	1,84
	The WB damages the city	Fouling city				
	linkert scale 1 (the WB is fouling and damaging the city) to 5 (the WB is not fouling or damaging the city)		Totally agree	1	729	37,27
			Agree	2	506	25,87
			Agree/disagree	3	402	20,55
			Disagree	4	223	11,40
			Totally disagree	5	55	2,81
			NR-No answer	NA	41	2,10
Citizen experiences with the WB (Coexistence)						
	How often do you see the WB?	Frequency				
	linkert scale from 1 (I never sighted a WB) to 6 (I sight the WB every day)		Never	1	940	48,06
			Once in my live	2	489	25,00
			Once a year	3	282	14,42

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			Once a month	4	125	6,39
			Once a week	5	69	3,53
			Every day	6	40	2,04
			NR-No answer	NA	11	0,56
	Did you ever fed the WB?	FeedingWB 18				
	linkert scale from 0 (I never fed the WB) to 3 (I feed the WB daily or almost daily)		I never fed the WB	0	1908	97,55
			I fed the WB sometimes	1	38	1,94
			I feed the WB with relative frequency	2	3	0,15
			I feed the WB daily or almost daily	3	1	0,05
			NR-No answer	NA	6	0,31
	I felt an aggression from a WB	Attack				
			YES	1	6	0,31
			NO	0	1944	99,39
			NR-No answer	NA	6	0,31
	I tried to hunt the WB	Trying to hunt				
			YES	1	7	0,36
			NO	0	1943	99,34
			NR-No answer	NA	6	0,31
	Total Perception of Incident Score					
	PIS			0	1862	95,19

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
			1	44	2,25
			2	42	2,15
			3	5	0,26
			4	1	0,05
			5	2	0,10
	Did you ever had personal incidences with the wild boar?	Incidents				
	(YES = +1 PSinc18)		YES	1		
			NO	0	62	3,17
			NR-No answer	NA	1888	96,52
	They enter into your home or garden	Home garden				
	(YES = +1 PSinc18)		YES	1	19	0,97
			NO	0	1931	98,72
			NR-No answer	NA	6	0,31
	Aggressiveness towards your pet?	Agressiveness Pets				
	(YES = +1 PSinc18)		YES	1	11	0,56
			NO	0	1939	99,13
			NR-No answer	NA	6	0,31
	Aggressiveness towards yourself?	Agressiveness People				
	(YES = +1 PSinc18)		YES	1	13	0,66
			NO	0	1937	99,03
			NR-No answer	NA	6	0,31
	Have you ever had a traffic	Traffic incident				

STUDY 2

Group of variables	Variable and description	Name of the variable	Categories	Abb.	n=1956	Percentage %
	incident with the WB?					
	(YES = +1 PSinc18)		YES	1	29	1,48
			NO	0	1921	98,21
			NR-No answer	NA	6	0,31
	Have you ever had other kind of incidence involving the WB?	Other incidents				
	(YES = +1 PSinc18)		YES	1	23	1,18
			NO	0	1926	98,47
			NR-No answer	NA	7	0,36
	Have you ever seen the WB feeding in urban areas?	Eating in city				
			YES	1	516	26,38
			NO	0	1430	73,11
			NR-No answer	NA	10	0,51

3.3. Study 3. Synurbization impairs wild boar welfare

Figure 12. Food waste in urban areas is an anthropogenic and highly caloric nutritional source for the wild boar. This fact is boosting wild boar habituation to urban landscapes, hence contributing to HWBC, inducing changes in wild boar behavior and being potentially detrimental for wild boar health and welfare. Artist: Laura Gil (2018).

STUDY 3

3.3.a. Abstract

The urban wild boar phenomenon is a more recent consequence of the generalized increase of wild boar (*Sus scrofa*) populations occurring worldwide since decades ago. However, its management in the urban scene faces specific challenges derived from a sociological component. Namely, the management in the short term of conflicts derived from wild boar presence in urban environments strongly relies on lethal control, which is up to now the only cost-effective strategy to safeguard public safety. However, a sounding part of the urban population considers that public safety is not important or threatened enough as for to accept lethal control and advocates cohabitation with wild boar in the urban environment. We argue that wild boar welfare may be a better argument to show this society sector and achieve a consensus on the need to take wild boar out of urban settings and hypothesize that the urban environment is detrimental for wild boar health and welfare. Between 2015 and 2019, 845 wild boars were either hunt-harvested in forestry areas (presumably non-urban) or captured and euthanized in suburban areas (presumably urban) for management purposes in the Metropolitan Area of Barcelona. Necropsy findings and lesions were described and those non-attributable to capture method classified using a Severity Score ranging 1 (less severe) to 3 (more severe). Our results confirm that wild boars ranging in urban environments are more likely to suffer severe traumatic injuries, attributable to vehicle collisions, dog attacks and even poaching, resulting in a shorter life expectancy. Hence, the urban environment is not a suitable ecological niche nor habitat for wild boar, resulting in a higher probability of decreasing fitness, health and welfare. In addition, although lethal control of wild boar is not desirable, it is nowadays necessary in urban environments, which further shortens life expectancy of urban wild boar. Hence, measures/initiatives aimed at promoting cohabitation with wild boar in urban settings are neither acceptable nor desirable, neither from the perspective of wild boar.

3.3.b. Introduction

Worldwide, wild boar (*Sus scrofa*) populations have been increasing for the last decades (Massei et al. 2015), and so has its presence in urban settings more recently (Cahill et al. 2012). Wildlife species adapted to humanized environments (or synantropic) expand their range of distribution and/or become more abundant as a result of anthropogenic activities. When this process takes place in urban environments, it is called synurbanization, which is a growing phenomenon around the world (Luniak 2004, Francis and Chadwick 2012).

The high behavioral plasticity of wild boar allows its adjustment to urbanization (Stillfried et al. 2017a), which has been described in several large cities worldwide (Cahill et al. 2012, Sakurai et al. 2014, Jordt et al. 2016, Toger et al. 2018). Wild boar population management is necessary to manage conflicts such as damage to agriculture, vehicle collisions, or diseases shared with livestock and zoonoses. This management strongly relies on lethal control through hunting (Massei et al. 2015, González-Crespo et al. 2018), which is feasible in rural and forest settings but not so much in suburban landscapes. Not only because of the difficulty to juggling hunting with other space usages in densely populated areas (e.g., to avoid the risk of firearms

for people other than hunters such as hikers or bikers), but also because of rejection attitudes by animal welfare activists and allied supporters (Warburton and Norton 2009). This society sector gains weight in urbanite contexts and complicates management by influencing policymakers to the point of having municipalities self-declared anti-hunting where this activity is banned. However, it cannot be neglected that wild boar is one of the biggest wildlife species that have proven to thrive in urban environments (Cahill et al. 2012), which together with its behavioral plasticity confers this species a great harmful potential. It is not only about vehicle collisions, but more dangerous motorcycle and moped collisions with the wild boar occur at higher frequency in urban and suburban settings (Zuberogoitia et al. 2014). Attacks on people and pet (not hunting) dogs are underreported in the scientific literature, but they are reported in the media (Manipady et al. 2006, Ingendaay et al. 2008, Kose et al. 2011, Mayer et al. 2013).

Keeping this in mind, when wild boar presence in the urban scene occurs, lethal control continues to be necessary to manage the threat in the short term, despite other methods may be used instead of hunting (Torres-Blas et al. 2020). In this scenario, there is a need and a social demand to act, whereas another sounding part of the urbanite population is not concerned with public safety, rejects lethal control, and defends cohabitation with the wild boar in the urban environment (Conejero et al. 2019a). Despite the rebuttal of these positioning is easy, this part of the population fosters the habituation and presence of wild boar in the urban scene, either by feeding them directly or by indirectly facilitating the access of wild boar to anthropogenic food sources (Castillo-Contreras et al. 2018). As a result, conflicts derived from wild boar may increase in the urban scene and lethal control is even more necessary, resulting in a paradoxical detrimental effect for wild boar that has been partly promoted by wild boar "defenders" and a misunderstood friendship relation (Warburton and Norton 2009). Hence, it is not only wild boar potentially harmful to the urban environment (specially for people and pets), but also the urban environment may be detrimental to wild boar (Birnie-Gauvin et al. 2017), which would be a stronger argument to gain support amongst those advocating for cohabitation. Achieving a consensus on the inconvenience of wild boar presence in the urban scene, not only for human interests but also for wild boar itself, would lay a suitable basis to settle a mid-long term ethical and evidence-based approach to minimize both wild boar presence in the urban scene and, consequently, the need for lethal control (Warburton and Norton 2009).

It is considered that urban populations of synurbic species differ in ecological, ethological, morphological, physiological, and parasitological characteristics from their natural counterparts (Luniak 2004, Francis and Chadwick 2012). In fact, urban wildlife must cope with conditions that differ from those of their wild conspecifics in non-urban areas (Grimm et al. 2008). Consequently, a recent review on the relationships between urbanization and wildlife health concludes that, overall, urbanization is harmful to wildlife health. Specifically, urban wildlife tends to be exposed to more toxic substances (Alabau et al. 2020) and are at greater risk of direct transmission of parasites as compared with non-urban wildlife (Murray et al. 2019). Most studies on this matter -urban ecology- focus on sublethal consequences of urban life, such as pollution, stressors, or nutrition, but acute lethal effects must also be considered. To name some mortality causes in the urban environment, wildlife involved in vehicle collisions are also victims (Underhill and Angold 2000), and when lethal control is used to manage human-wildlife conflicts, it adds to the causes of mortality. Finally, despite health and welfare are closely related, urban wildlife welfare

senso stricto is rarely considered. Regarding urban wild boar, there is scarce information available on the detrimental effects of urbanization beyond roadkills (Tenés et al. 2007, Toger et al. 2018). In Berlin, the urban scene has been proposed to act as an ecological sink for the peripheral rural wild boar population (Underhill and Angold 2000). Despite the fact no significant differences were observed in the type of food resources used between the urban and rural wild boar in Berlin (Stillfried et al. 2017b), anthropogenic food sources have been observed to be keystone drivers of wild boar venture into the cities (Castillo-Contreras et al. 2018). Adequate dietary intake is essential to the optimal growth and reproductive success of vertebrates. Thus, the intake of unbalanced food would be expected to have an impact on wild boar fitness, including growth, reproductive capacity and overall survival (Birnie-Gauvin et al. 2017).

In the Metropolitan Area of Barcelona (MAB), the urban wild boar phenomenon has been present since, at least, 2004. Since then, wild boars accustomed or indifferent to the presence of people and with little or no flight reaction have been regularly removed to address complaints from residents or authorities (Cahill et al. 2012). Between 2013 and 2018, telephone calls to the emergency number prompted by urban wild boars averaged 700 per year (Ajuntament de Barcelona 2020b). In 2013, a new action plan was set up including several actions aimed at improving management of the urban wild boar phenomenon in the city of Barcelona in the short-, mid- and long-term. In brief, social (human), behavioral (wild boar) and health (both) issues have been addressed. Since then, several cumulated observations lead us to hypothesize that urban lifestyle is detrimental for the wild boar foraging the suburban areas in the MAB. Body condition has been documented as a proxy for the benefits of living in a certain environment and wild boars foraging in urban areas have been described to display higher body condition (Castillo-Contreras et al. 2021). However, despite the assumption that individuals act on a trade-off basis by rationally weighing the pros and cons of urban foraging, we suspect that wild boars may not be adequately assessing the risks of urban foraging, especially those with a higher level of urban habituation as a consequence of aberrant behavioral changes resulting from early life-stage learning. To test these hypotheses, we set out to reveal differences in the pattern of lesions observed and other necropsy findings between urban and forest wild boars belonging to the same source population.

3.3.c. Materials and methods

3.3.c.1. Study area

The MAB is a densely populated area with 16,149 human inhabitants/km2 (Idescat 2019) located in northeast Spain. It has Mediterranean climate, with mild winters, hot dry summers, mean annual temperatures are 3 to 15°C in winter and 20 to 30°C in summer, and mean annual precipitation is 600-650 mm (Meteocat 2018 and 2019). Specifically, this work was conducted in three areas of the MAB with an increasing degree of human presence: namely, the Collserona massif, the Campus of the Autonomous University of Barcelona (UAB campus) and the city of Barcelona, respectively (Figure 13).

The Collserola massif belongs to the Catalan coastal mountain range, has an area of approximately 10,000 ha and its highest point is 510 m above sea level. It includes two

hunting areas where wild boar hunting has been allowed since 1995 (Gencat 2010) and recent estimations indicate that the wild boar population increased almost ten times (from 165 to 1500) in the central area of the massif (8000 ha) from 2000 to 2015 (González-Crespo et al. 2018). A mixture of forests, scrublands, grasslands, croplands and human infrastructures such as roads, recreational spaces and residential areas compose the landscape of Collserola. The vegetation is typically Mediterranean, with abundant and diverse scrub species (Gencat 2010). Collserola is used by MAB inhabitants for leisure activities such as running, cycling, hiking, walking or picnicking and receives approximately three million visitors per year (Gencat 2010). The UAB campus is located north to Collserola, covers approximately 260 ha, and is regularly used by more than 45,000 people, including the students and staff (UAB 2021a). It is surrounded by urbanized, forested and agricultural areas, but also contains forest and agricultural patches covering approximately 60% of its surface (UAB 2021b). Moreover, there are several gardens, some of them with ornamental plants and irrigation (UAB 2021c). The wild boar is present in the UAB campus and between 15 and 30 individuals are removed every year as part of the wild boar management plan aimed at preventing damages in gardens, experimental crops and other negative interactions with people as vehicle collisions or attacks (Lavín et al. 2016). The city of Barcelona is located southeast of Collserola, with a population of 1,600,000 inhabitants in 10,100 ha of land area (Idescat 2021). Unlike the Collserola massif, Barcelona is mostly urbanized, although it has 1,077 ha of public green areas (Ajuntament de Barcelona 2020a). In addition, the northern districts of Barcelona are adjacent to Collserola and frequently visited by wild boar, so they concentrate the highest proportion of wild boar-related incidents (calls to the local emergency number) in the entire urban area (Ajuntament de Barcelona 2020b). We thus assume that human activities are low in Collserolla, medium in the UAB campus and high in Barcelona city.
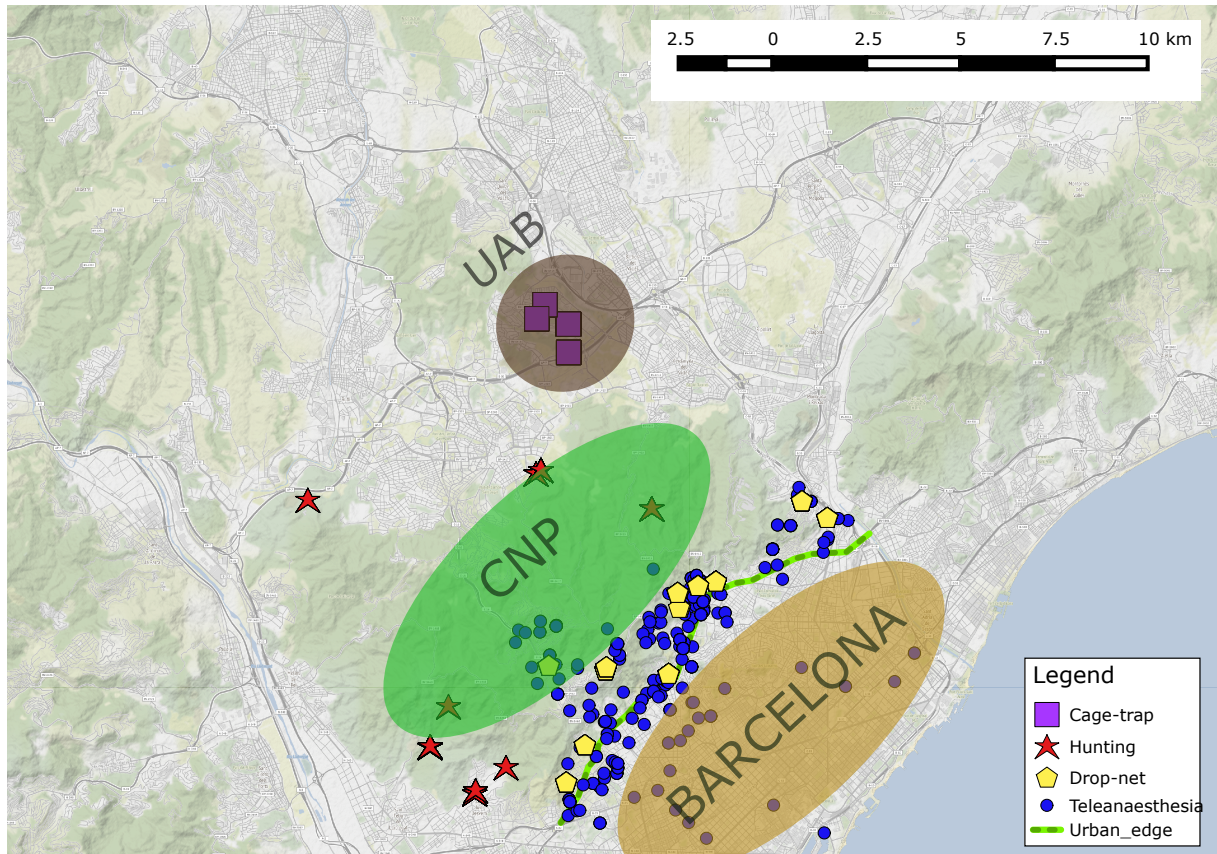
Figure 13 Study area, trapping methods and WB capture locations along the natural-to-urban gradient of Barcelona, Spain.

3.3.c.2. Animal sampling

A total of 845 wild boars were examined postmortem: four-hundred and ninety-two -492- were either directly darted (n=319), drop-net trapped first and then anesthetized (n=170) or found death (n=3) in suburban areas of the the municipality of Barcelona; in the UAB campus, however, cage-traps were used prior to anaestesia (n=99); the remaining wild boars (n=254) were hunt-harvested in the Collserola massif during the ordinary hunting season (October through February). Anaesthetized individuals received a combination of 3 mg/Kg of xylazine and 6 mg/Kg of tiletamine-zolazepam intramuscularly (Casas-Díaz et al. 2015) and next were euthanized with T-61® (6 ml/50Kg) by intracardiac puncture. Both the euthanized and the found death wild boars were stored in a cold area and necropsied at the UAB Veterinary school facilities within 24 hours post-mortem. On the other hand, local hunters allowed and facilitated for the field necropsies, sampling and examination of the hunt-harvested wild boars. All individuals were captured or hunted within the ordinary management plan of the species in their respective areas, and no wild boar was captured or hunted specifically for the purpose of this study. UTM coordinates, date, sex, age of death -determined by tooth eruption- (Matschke 1967), biometrical measurements and weight were systematically recorded for all individuals. Body condition was assessed using biometrical measurements (body weight, total length and chest girth) as indicators to predict brisket fat thickness (Risco et al. 2018).

3.3.c.3. Gross pathological findings and severity score

All lesions were categorized according to their pathogeny, and those unrelated to the capture method classified using a severity score (SS) ranging 1 to 3 (adapted from Smith et al. 2018). Namely, healthy wild boars (without lesions) were assigned a SS=1; wild boars displaying minor to moderate lesions (unlikely to cause death and probably healing without treatment) were assigned a SS=2 (Figures 14.A and B); and wild boars found death and/or presenting severe to lethal lesions (unlikely to heal without significant repercusions on health and welfare and probably causing death) were assigned a SS=3 (Figures 14.C, 14.D, 14.E and 14.F).

3.3.c.3. Statistical analysis

The raw data was processed in an "excel" file and exported to a modeling software. We performed an exploratory analysis to find out which continuous and categorical variables best describe the overall "distance to core city" and better explain the severity score value. We applied a Principal Component Analysis (PCA, Macci et al. 2012) using a correlation matrix (n=845) including age, severity score, fat prediction on sternum and distance to core city as explanatory variables determining wild boar trade-off when approaching to urban environment. Sex, age classification, presence and cause of traumatic injuries (abrasion, contusion, laceration, luxation and fracture -Figure 14-) were included as qualitative supplementary variables on the PCA. After that, the PCA dataset was grouped into nesting clusters performing a Hierarchical Clustering on Principal Components (HCPC). Because the dataset was based on multidimensional scales, dissimilarity was calculated using Euclidean distances, computing distances

among individuals and balancing the influence of each data measurements by applying Ward's agglomeration criterion on HCPC (Husson et al. 2010a and b).

Statistical analyses were performed using R software (R Core Team 2017). Packages "readxl" (Wickham and Bryan 2019), "dplyr" (Wickham et al. 2021), ggplot2 (Wickham 2016) and "GGally" (Schloerke 2018) were used to perform the exploratory análisis and modeling. FactoMinerR (Lê and Husson 2008) was used to find which variables describe the best overall "distance to the core city" through "Condes" function. Finally, PCA and HCPC analysis were performed using the "PCA" and "HCPC" function of the package FactoMinerR (Lê et al. 2008); and "fviz" function of the Factoextra package (Kassambara and Mundt 2020) was used to visualize the output correlation of explanatory variables in the PCA.

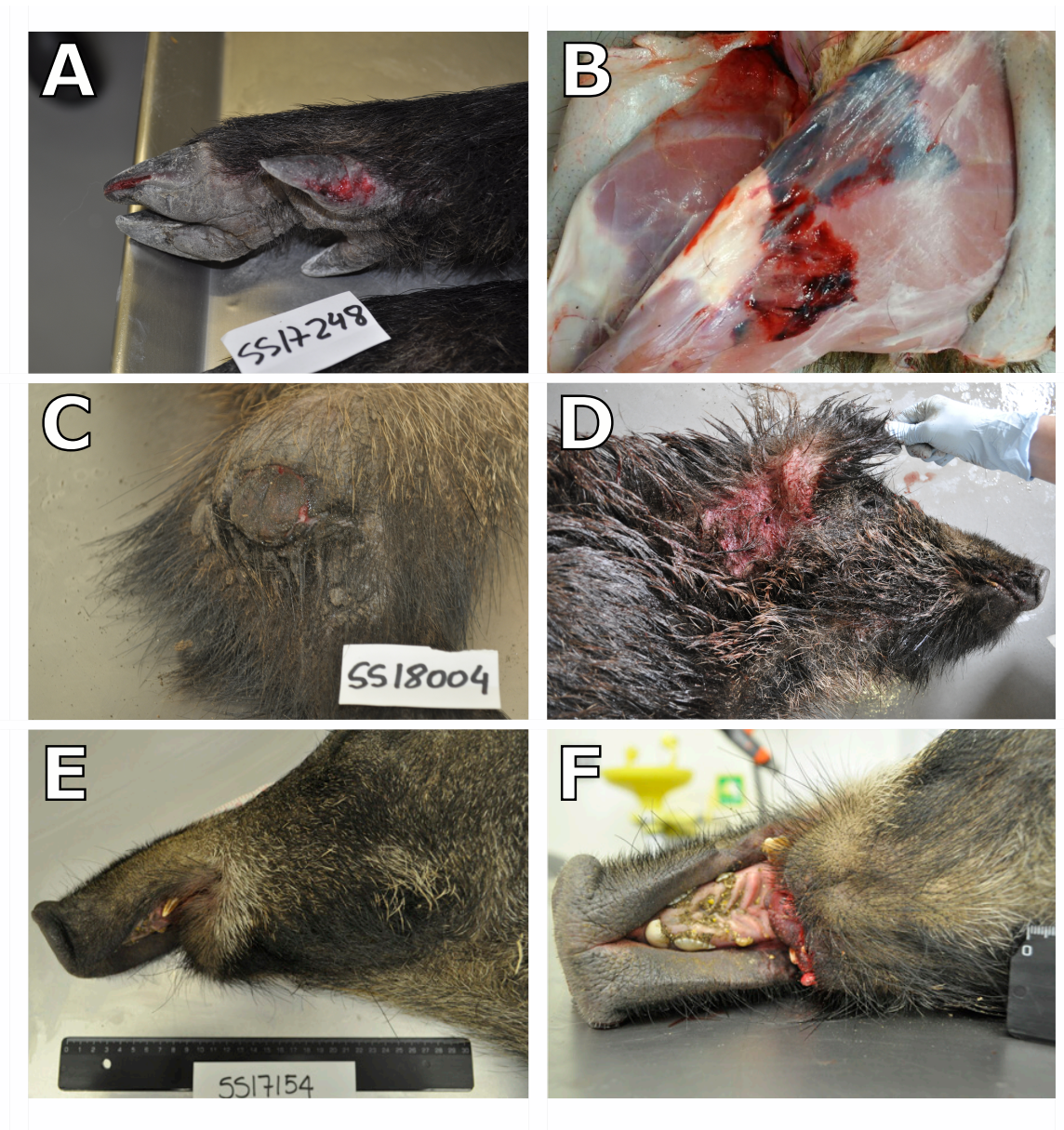Figure 14. Different examples of traumatic injuries attributable to anthropogenic factors. **A:** Minor abrasion in hoof (SS = 2). **B:** Lateral aspect of a hindlimb contusion (SS = 2). **C:** Medial aspect of tarsal joint with tibial open fracture (SS = 3). **D:** Deep lacerations with internal and external hemorrhages caused by dog bites. **E** and **F:** Lateral and ventral aspect of distal jaw amputation (SS = 3).

3.3.c. Results

The results of the exploratory analysis showing the distribution of wild boars (number and percentage) according to their severity score value and the mean distance to the core city are shown in Table 10.

Table 10: Distribution of the 845 wild boars (number and percentage) examined postmortem according to their assigned severity score value (SS). Mean distance (MD) to the core city for each category of SS is shown. SS Category = Categorical group of SS; Definition = inclusion criteria for the lesions found in wild boar necropsies into each category of SS; Sample size = Number of wild boars classifyied into each SS category, SS Percentage = Proportion of individuals into each category of SS, Mean Distance (MD) to the core city ± Standard Deviation (SD).

SS Category	Definition	Sample size (n=845)	SS Percentage	MD to core city (± SD)
1	No lesions	462	54,47	5397,75 (± 3006,52)
2	Minor to moderate traumatic lesions (laceration, abrasion)	314	37,20	4959,44 (± 2699,94)
3	Polytraumatisms with serious to lethal lesions (fractures, luxations and lacerations)	69	8,20	4952,09 (± 2444.37)

3.3.c.1. PCA results

The PCA analysis produced four principal components (Dim). The first component explains the 40.81% of the variance, is composed by the prediction of brisket fat and mean age. The second component explains the 26.76% of the variance and is composed by the the distance to the core city and severity score. For further PCA results check table 11 and Figure 15.

Table 11. Active variables describing Dim1 and Dim2. Correlation coefficients (Corr.) and p.value are given.

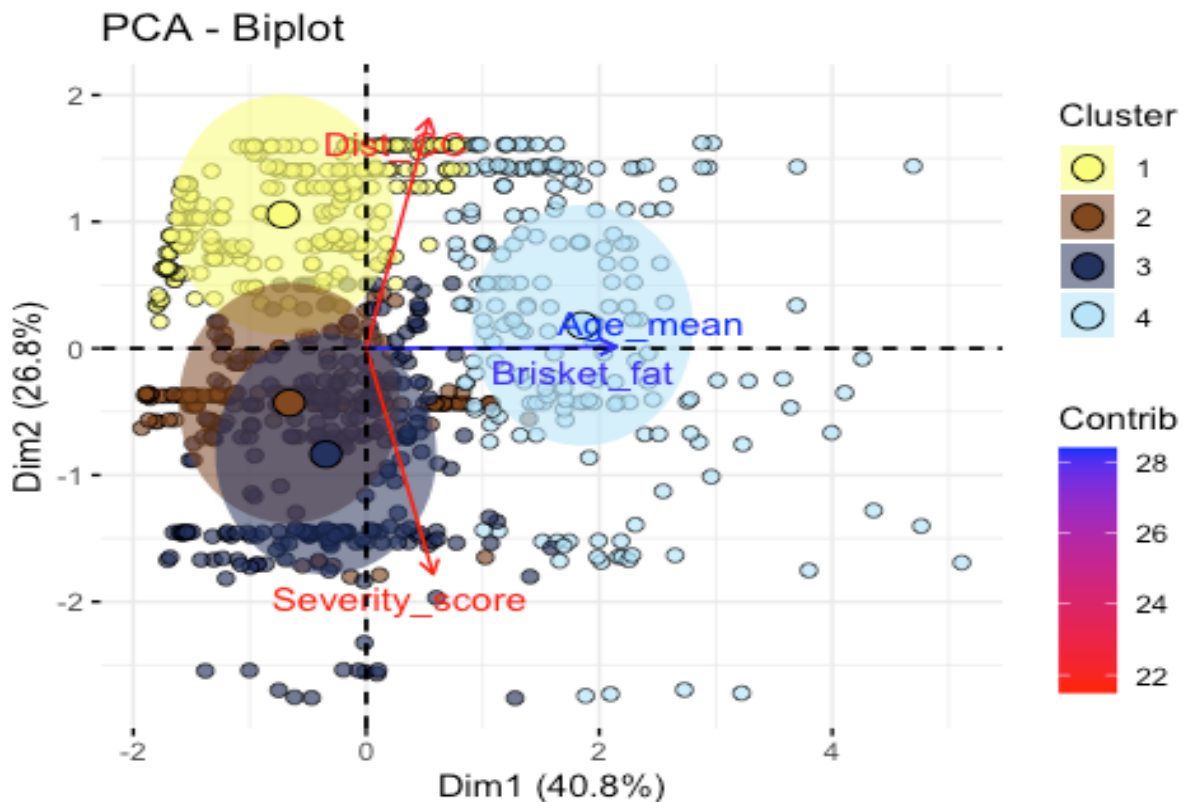| Principal Component	variable	Corr.	p.value
Dim1	Mean age	0,88	$3,16*10^{-269}$
	Brisket fat	0,87	$3,49*10^{-265}$
	Severity score	0,23	$5,49*10^{-12}$
Dim2	Distance to the core city	0,74	$6,09*10^{-146}$
	Severity score	-0,73	$6,89*10^{-139}$

Figure 15. Hierarchical Clustering on Principal Components (HCPC). HCPC identified four clusters using euclidean distances on PCA results. Cluster 1 was captured or hunted at higher distance from the core city (Dist_CC), Cluster 2 was highly represented by yearling individuals dispersing into the urban area, Cluster 3 was composed maninly by juveniles captured at closer distance from the core city and showed the highest Severity Score (SS). Cluster 4 was composed by adult breeding females ranging along the natural-to-urban gradient. The x axis is Dim1 and the y axis is Dim2. The color scale indicates the contribution (Contrib) of the active variable on the Dim, higher contributions are displayed in blue.

3.3.c.2. Four different ways of wild boar life according to sex, age and distance to the core city

Hierarchical clustering of principal components provided 4 clusters (Figure 15, table 12). Cluster 1 was mainly composed by younguer WB (mean age=10.03), mainly piglets (p = 2.95×10^{-19}), showing the lowest severity score (p = 3.40×10^{-52}) and captured at higher distance from the core city (p = 2.73×10^{-34}). Cluster 2 was represented by yearling individuals (mean age=15.62, p = 4.42×10^{-3}), scoring low severity score (p = 5.25×10^{-23}), captured closer to the core city (p = 5.15×10^{-69}) without noticing the evidence of traumatic injuries in necropsy (SS=1). Cluster 3 showed the highest severity score (p = 9.24×10^{-93}) and included yearling (p = 6.08×10^{-8}) and juvenile (p = 4.00×10^{-9}) individuals (mean age=11,27, p = 3.26×10^{-16}) that were captured closer to the core city (p = 0.001) than cluster 2. Cluster 3 suffered traumatic injuries (i.e. fractures, contusions, abrasions and lacerations) attributable to vehicle colisions (p = 2.26×10^{-6}) and/or dog attacks (p = 0.015). In contrast, cluster 4 showed traumatic

lesions that do not compromise their survival (mean SS = 1.63, p = 0.017). This cluster comprised the oldest boars (p = 4.15 * 10^{-95}), mainly adult (p = 1.96*10^{-82}), breeding females (p = 1.04^{-17}) and captured along all the natural-to-urban gradient (p = 9.41 * 10^{-10}).

Table 12: Results of Hierarchical Clustering on Principal Components. Cluster variability levels in Mean age, Mean Distance (MD) to core city ± Standard Deviation (SD), mean score for Severity Score (SS) ± SD and mean Brisket fat thickness ± SD.

Cluster	Mean age in months (± SD)	MD to core city -metres- (± SD)	SS (± SD)	Brisket fat -cm- (± SD)
1	10.03 (±10.06)	7110.33 (± 1508.06)	1.00 (± 0.00)	7.12 (± 4.00)
2	15.62 (± 13.66)	1357.03 (± 838.04)	1.05 (± 0.22)	9.90 (± 4.12)
3	11.28 (± 7.51)	4737.66 (± 2543.65)	2.19 (± 0.39)	8.15 (± 3.50)
4	50.37 (± 27.57)	6304.38 (± 2530.81)	1.63 (±0.64)	16.59 (± 3.70)

3.3.d. Discussion

Wild boar habituation to urban environments is happening in urbanized areas of Barcelona since 2012 (Cahill et al. 2012). In Mediterranean habitats, and due to their preference for natural trophic resources (Stillfried et al. 2017c), the period with less presence of wild boars in urban areas (Nov-Feb) coincides with the higher food availability in CNP (i.e. acorn falls). Conversely, many wild boars visit urban settingsin summer, during the seasonal food shortage period, and when energetic demands of breeding females are higher, haunting patches with trophic resources such as urban green areas or dry pet food provided in stray cat colonies (Castillo-Contreras et al. 2018). Nevertheless, we must consider that changes in hunting pressure, as well as alterations on food and shelter availability, may also imply changes in social dynamics on wild boar populations (Ryan and Partan 2014, Massei et al. 2015). The frequency of wild boar traffic accidents (Tenés et al. 2007), certain aberrant behaviors (Cahill et al. 2012; unpublished data on own observations) and the repetitive observation of severe lesions in urban wild boars due to anthropogenic reasons motivated this study.

A synurbic wild boar population could reach high density concentrations in urban areas, without habitat suitability correlation but with a strong correlation with its behavior (Parker and Nilon 2012). In Barcelona, breeding females (Cluster 4) seem to improve their body condition and fitness when reaching trophic resources (e.g., human waste) in suburban environments (Castillo-Contreras et al. 2018), countering anthropogenic disturbances and increasing their litter size (Rosell and Llimona 2012). Therefore, if a wild boar population is obtaining more fitness in urban areas, a fundamental trade-off would occur between feeding optimization and offspring survival, where the urban wild boar can easily find highly energetic resources coping with anthropogenic disturbances, which are absent in forested landscapes (Birnie-Gauvin et al. 2017, Stillfried et al. 2017a and 2017b).

According to our results (Figure 15, table 12), wild boars with lower severity score were represented by younger WB hunted at high distance from the core city (Cluster 1) and adult (breeding) females (Cluster 4). Clusters 1, 2 and 3 differ in their distance to the core city and are probably representing the weaned offspring of cluster 4 captured along the natural-to-urban gradient. Considering that anthropic fearless traits are usually negatively selected and only if they increase the fitness of the population could bypass natural selection (Fulgione et al. 2016). Young and habituated wild boar (Cluster 3) may wrongly perceive the fragmented habitat of the urban environment as a suitable ecological niche to occupy. It implies exposure to roads, increasing potential due to vehicle collision or dog attacks Hence, this boldness exploratory behaviour and dispersion into the urban scene apparently increases their vulneravility in front of vehicle collisions or dog attacks, resulting in a higher severity score, wellbeing loss and even death (Toger et al. 2018, Nyhus 2016).

The current management measures in Barcelona include public awareness campaigns (with special attention to feral cat colonies managers), protection of urban waste containers -reduction of food supply- and removal of conflictive or potentially conflictive individuals through capture and euthanasia (Ajuntament de Barcelona 2020b). Our results suggest that urban areas act as ecological traps for dispersing juvenile and yearling wild boars (D'amico et al. 2015, Stillfried et al. 2017a). Wild boar is supposed to act on a trade-off based on weighting the pros and cons of urban foraging behavior (Stillfried et al. 2017a and 2017c). However, the urban habituated wild boars

are apparently failing to adequately assess risks and cost of urban foraging, probably due to the habituation process towards anthropogenic stimuli experienced during early life stages. Similar to other studies, our results suggest that the increased level of boldness/habituation of cluster 3, which has been observed amongst successive generations of wild boar dwelling in the suburban environment (Cahill et al. 2012, González-Crespo et al. 2018, Castillo-Contreras et al. 2018, Conejero et al. 2019a and b), is contributing to an early death of wild boar due to anthropogenic causes (Bremner-Harrison et al. 2004). Our results provide new evidence on urban-related detrimental welfare consequences for the wild boar, justifying lethal management measures in order to prevent wild boar from unnecessary suffering in the short-term, as well as measures aimed at reducing attractiveness of the urban environment for wild boar, mainly the reduction of anthropogenic food sources.

3.3.e. Conclusion

Wild boars using the urban environments are more prone to suffer severe to critical traumatic lesions than wild boars ranging in forest environments. Foraging in urban environments can easily supply the energetic requirements of breeding females in urban areas but, once the offspring are born, the whole group must deal with anthropogenic risks. Urban environment does not compensate for the fitness of wild boar due to the occurrence of critical and lethal traumatic lesions that impair the recruitment of offspring into the breeding population. Our findings are knowledge-based ethical arguments that should be disseminated in citizen awareness campaigns and useful to achieve a consensus on the need to take the wild boar out of the urban environment, hence gaining social acceptance of management measures aimed at taking the wild boar. Altogether should assist wildlife managers and institutions in the prevention of supplementary feeding of wildlife in urban areas.

3.4. Study 4. Assessing mammal trapping standards in wild boar drop-net capture

Figure 16. Juvenile wild boar sounder expressing habituated behavior towards human presence in a suburban area (La Floresta, Sant Cugat, Barcelona). On breeding or dispersal sounders, the wild boar shows its gregarious behavior. Due to that, in comparison with individual trapping methods, colective trapping methods capable to capture entire sounders avoid targeted group breakdown, which may be considered more humane. Moreover, the complete removal of habituated sounders improves success and duration of HWBC mitigation measures.

STUDY 4

3.4.a. Abstract

Applying contemporary trapping standards when managing wildlife should no longer be an option, but a duty. Increasing wild boar populations originate a growing number of conflicts and hunting is the only cost-effective management option in most cases. However, new scenarios where hunting is unfeasible emerge and trapping necessities cope with lacking regulatory frameworks and technical guidelines. In this research, we evaluated drop nets, a capture method not considered by the international trapping standards, to capture Eurasian wild boar (*Sus scrofa*), a wildlife species not included in the list of mammal species under the scope of the Agreement on International Humane Trapping Standards (AIHTS).

Less than 20% of the captured wild boars presented moderate or severe injuries attributable to the capture method, hence fulfilling the acceptance thresholds of the outdated AIHTS. Based on the new standards thresholds of acceptance, the humaneness of drop-nets in our study ranged 66% to 78%, under the 85% required. The capture success and selectivity were 100%, as ensured by operator-driven triggering, which should be considered the main strengths of this method, together with the minimization of animal suffering owing the short duration of the stressful situation. Additionally, in spite of the socially adverse environment, with people contrary to wild boar removal, no disturbances against the capture system or operations occurred.

This is the first assessment of a drop-net capture method according to internationally accepted mammal trapping standards, with unconclusive results. However, there is a need for adapted procedures and thresholds of acceptance aimed at not-mechanical traps in general, and specifically at drop-nets. Compared to other live-capture methods, drop-nets minimize the duration of the stressful situation -at the expense of a strong adrenergic acute response-, maximize the probabilities of capturing entire sounders of prosocial species, which may be also considered as more humane, and has the ability to coordinate higher values of capture success, absolute selectivity and adaptability to difficult environments.

Keywords: Human-wildlife conflict, wild boar, drop-net, mammal trapping standards, humaneness

3.4.b. Introduction

Globally, there is a growing consensus on the need to make progresses towards ethical wildlife control, starting by considering altering the human practices that cause human–wildlife conflict and by developing a culture of coexistence (Dubois et al. 2017, Frank and Glikman 2019). Eurasian wild boar (*Sus scrofa* L. 1758) populations are expanding and increasing worldwide, and so does human-wild boar co-existence and conflicts. The wild boar has the broadest geographic range of all ungulates and conflicts arise due to both direct and indirect interspecific interactions resulting in ecological, economic and health impacts; namely, wild boars cause crop damages, road traffic accidents, increased risk for shared livestock diseases and zoonoses, altered food webs and damage to some plant and animal species (Meng et al. 2009, Massei et al. 2011, Carpio et al. 2021). Furthermore, and due to its high behavioural plasticity, the wild boar has successfully adjusted itself to a wide range of landscapes in the last decades, including urban areas (Stillfried et al. 2017a, Castillo-Contreras et al. 2018). As a consequence, wild boar population lethal control remains the only cost-effective measure to manage human-wild boar conflicts in most cases (Keuling et al. 2016, Vajas et al. 2020). However, hunting is unfeasible and/or illegal in certain scenarios due to safety and/or social constraints (Licoppe et al. 2013) and then other management measures must be considered (Torres-Blas et al. 2020). The urban scene faces specific challenges in managing this species because of increasing sensitivity and social demands for animal welfare considerations (Adams 2016, Lewis et al. 2019, Conejero et al. 2019a). Fertility control (Massei et al. 2008) has been proclaimed as a more ethical alternative management measure in spite of lacking supportive evidence for its effectiveness at the population level (Náhlik et al. n.d., Massei et al. 2011, Croft et al. 2020). In this respect, and according to modelling, more than 50% of the fertile females within a specific population should be sterilized to obtain meaningful reductions in wild boar numbers (González-Crespo et al. 2018), which is far from current technical capacities when working with abundant free-living wild boar populations (Carpio et al. 2021). At this point, live trapping and removal remains the only cost-effective and feasible option in certain scenes.

Many techniques, methods and/or devices/systems have been developed for killing and/or restraining wildlife for fur harvest, wildlife and/or related-conflicts management or with research purposes (Schemnitz et al. 2009). Killing traps have probably been the most used devices for both food/fur harvesting and conflict management with little, if any, consideration to animal suffering in the beginnings. Later, the increasing interest in safeguarding animal welfare led to the Agreement on International Human Trapping Standards (AIHTS), which is a binding agreement that has a direct impact on fur trading between the signatory countries (European Comunity and United States of America 1998, European Comunity et al. 1998). Almost simultaneously, the International Organization for Standardization (ISO) published its own mammal trapping standards, with no legal value or enforcement capability, but voluntary (European Comunity and United States of America 1998, International Organization for Standardization 1999). Both the AIHTS and the ISO standards established the need for fulfilling welfare standards according to certification protocols of every intended trap previous to its authorization for mass production, commercialization and use. These certification protocols are mostly based (but not exclusively) on either time to irreversible unconsciousness, insensibility or death

(TIU), in the case of killing traps, or in numerical scores that quantify the extent of injury incurred by a trapped animal in the case of restraining traps (Proulx et al. 2020, Proulx 2022). Mammal capture usually becomes more difficult as animal size increases, hence killing traps are mostly used to catch species ranging in size from rodents to lynx or wolf, at the most (Iossa et al. 2007), probably because of increasing difficulties to meet with welfare and performance (efficiency and selectivity) standards when used with bigger species. Although this is probably one of the raison d'être of restraining -non-lethal- traps, most certified ones according to international standards are also aimed at small to middle-sized furbearing, pest or predatory species, probably to prevent killing or damage to protected and/or endangered non-target species (Muñoz-Igualada et al. 2008, Fur Institute of Canada 2018). On the other hand, and for further concern, both the AIHTS and the ISO standards have been repeatedly criticized with a growing list of concerns including ineffectiveness in ensuring animal welfare due to insufficient and outdated standards and test procedures, incomplete list of mammal species included and/or lacking or insufficient thresholds of acceptance (Iossa et al. 2007, Virgós et al. 2016, Proulx et al. 2020, Proulx 2022). In line with this, wild boar or wild artiodactyls in general seem to be out of the scope of this regulatory framework. Very recently, new mammal trapping standards addressing the mentioned concerns have been proposed (Proulx 2022). Both outdated (AIHTS and ISO) and recent standards are focused on mechanical traps -both killing and restraining- ("devices that have mechanical energy if they are in motion and/or if they are at some position relative to a zero-potential energy position" which are activated by the (hopefully) target species to be captured).

Methods developed for trapping wild artiodactyls consist mainly in restraining/live trapping systems that have been used primarily for research, population monitoring and/or translocation purposes. These include mainly different kinds of cage and corral traps, as well as net-based systems (drop-, drive- or gun-nets), also used with less attention to animal welfare in the past and increasing standards later promoted by institutional Animal Care and Use Committees, domestic regulations and/or research studies (Barasona et al. 2013, Shury 2015). These methods have been mostly evaluated in terms of capture efficiency and level of case morbidity and mortality associated to the capture methods. When considered, animal welfare evaluations have been made in-vivo by means of hematological, serum biochemical and/or physiological parameters used as indicators of individual acute stress response or by attending to post-release mortality whenever possible (Webb et al. 2008, López-Olvera et al. 2009, Mentaberre et al. 2012, Barasona et al. 2013, Breed et al. 2019, Torres-Blas et al. 2020). More recently, the global rising trends in wild ungulate populations, especially those of wild boar in Europe (Carpio et al. 2021), are doing population control through methods other than hunting necessary. As a result, restraining methods (e.g. drop-nets) are being used as a previous step to either gunshot sacrifice or pharmacological euthanasia (Torres-Blas et al. 2020, Gaskamp et al. 2021). Despite animal welfare concerns are important regardless of the reason for capture, in this new context where abundant ungulate species come into the category of pest or nuisance species, the risk for double or even multiple standards exists (Baker et al. 2017). This is even more feasible in the absence of international standards considering these species distinctive features, such as size, anatomy, behavior or use as game species, so that attention to welfare standards may differ according to operator background and expertise, as well as to requirements established for capture in every specific context. In this regard, their

legal consideration as game or invasive species may further contribute to this problem due to less strict regulations compared to species with a higher level of protection.

Barcelona city is one of the big metropolises around the world suffering conflicts derived of wild boar presence in the urban structure since years ago, some of which entailing serious hazards and/or real consequences for public safety and requiring prompt measures. The Barcelona city council (BCC – Ajuntament de Barcelona) is involved in a multiple approach to this problem since 2013, including actions in the short, middle and long term (López-Olvera et al. 2017, Conejero et al. 2019b). Short-term actions mostly rely on live capture and removal of conflictive or potentially conflictive individuals (Torres-Blas et al. 2020). ESTRATEKO S.L. (https://www.ESTRATEKO.com/en/) is a small enterprise founded to provide solutions in wildlife-derived conflicts management that has developed its own drop-net based system. It was the first company to be hired by the BCC to perform captures of wild boar sounders with the potential to cause conflictive situations within the urban scene. The requirements determined by the BCC include veterinarian supervision of these captures in order to minimize animal suffering and increase humaneness by applying pharmacological euthanasia instead of gunshot sacrifice (which also prevents spilled blood in capture sites, which are public green spaces where people pass-by at daytime). Properly executed, drop-net capture minimizes the duration of the stressful situation, at the expense of a strong adrenergic acute stress response (Torres-Blas et al. 2020). According to preliminary visual inspections of both capture events and the captured wild boars, the ESTRATEKO drop-net system was considered as apparently respectful with animal welfare. Although drop-nets are not considered mechanical traps, due to the interest of ESTRATEKO S.L. in objectifying this assessment, and given the absence of specific standards, and regulations, the aim of this study was to evaluate the ESTRATEKO drop-net system for wild boar capture according to available mammal trapping standards. In addition, we discuss other operational and ethical considerations.

3.4.c. Methods

3.4.c.1. Estrateko® remote-controlled drop-net system and operation

The ESTRATEKO drop-net system is a homemade standard drop-net device with technological improvements. Namely, the drop-net frame consists of 4 metal poles (2.5-3 m high, 10 cm in diameter), with the bottom of the poles buried 30-50 cm into the ground once placed on-site and supported by rope tension lines fastened to the top of each pole and staked to the ground (Figures 17 and 18). The net used measures 10 x 10-m and is made of 0.5-cm diameter nylon rope displaying a 10-cm mesh made ad-hoc by a local manufacturer. The operational adaptations consist of the inclusion of an electromagnet-based system as fastening device and remote-controlled trigger mechanism, and a Wi-Fi real time video-cameras device for distance monitoring of animals' presence under the drop net by means of a tablet and suitable software. A 12V car battery is used for electromagnet electric supply under field conditions. Arrangement of poles allowed different and adaptable shapes and measures of the drop-net trap to the specific selected capture sites, sometimes reduced in size or with physical obstacles such as big trees.

Real-time distance monitoring is always performed on-site, in a previously selected waiting location out of sight from the trap location but less than 250-300 meters away, in order both to reduce wariness around trap sites due to the operators' proximity and to rapidly assist the captured animals after remotely triggering drop by means of the tablet software.

Figure 17. The Estrateko® drop-net trap deployed in a peri-urban location of Barcelona city at dusk, ready to run. Corn kernels are used as bait to attract wild boars to the central area under the net.

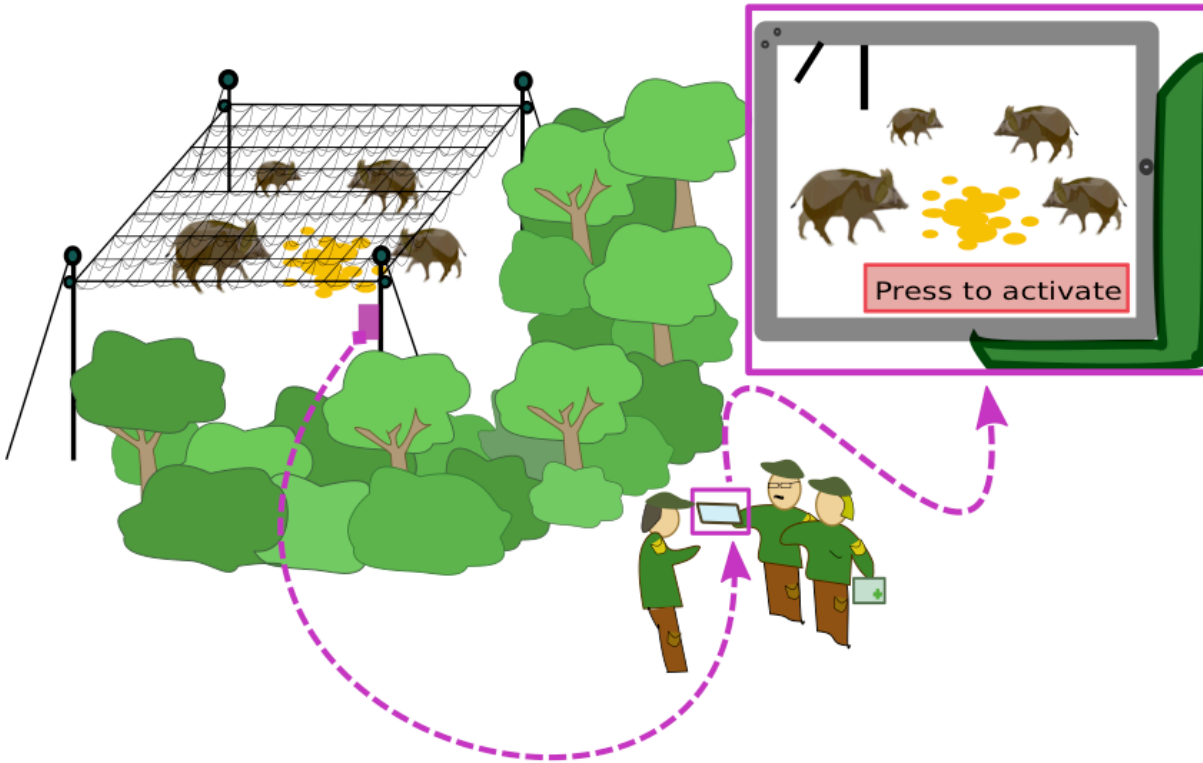Figure 18. Schematic representation of the Estrateko® drop-net system during a capture event. The trap is remote-controlled through Wi-Fi real time video-camera devices. Real-time distance monitoring is performed on-site, in a previously selected waiting location out of sight from the trap location, to rapidly assist the captured animals after remotely triggering drop by means of the tablet software.

3.4.c.2. Study area and capture protocol

From September to November 2017, the ESTRATEKO drop-net system was used in six operations in a periurban context and within the framework of the contract 16/0243-00-PR/01 with the BCC aimed at urban wild boar derived conflicts management. Three capture areas were determined at districts' request and based on hotspots for human-wild boar conflicts in the boundaries between the urban area of Barcelona and the natural area of Collserola (Figure 19). Specific trap sites were selected on the basis of physical characteristics (suitable for drop-nets assembly), wild boar traces and discretion (low frequented sites or with the possibility to temporary limit people access), baited with corn to promote wild boar loyalty for one to two weeks and monitored through infrared-triggered cameras to confirm continued daily visits by the targeted wild boars. Drop-net trap was not set during this period but only the specific days when captures were scheduled. The capture days, drop-net assembly was done before sunset, real-time distance monitoring performed as abovementioned and complete dismantling was done just after capture, the same night and before dawn.

During the capture operation, two remote cameras recorded the space beneath the suspended net and sent the live video through Internet to portable digital tablets, which allowed operators triggering the drop-net when the targeted wild boars were under the mesh, including entire sounders or family groups. Once activated, the net dropped over the targeted group or individuals, which ended up entangled and physically restrained in few seconds. Immediately, the group of operators including at least one veterinary moved to the trap site and injected the trapped wild boars in the thigh area with a mixture of tiletamine (3 mg/kg) and zolazepam (3 mg/kg) (ZOLETIL100, Virbac Animal Health, Spain) with xylazine (3 mg/kg) (XILAGESIC 20%, Calier Laboratories, Spain) prefilled in syringes according to the estimated weight of each individual. Next, wild boars were allowed to stay undisturbed and reach anesthetic unconsciousness, re-dosed when necessary, disentangled, blood sampled and finally sacrificed through intra-cardiac injection of T-61 (Merck Sharp & Dohme Animal Health, Spain). Once finished the capture operations, at late night, the animals were transported and stored in a cold camera at 4ºC within the following two hours and necropsied the following day, less than 24 hours after capture.
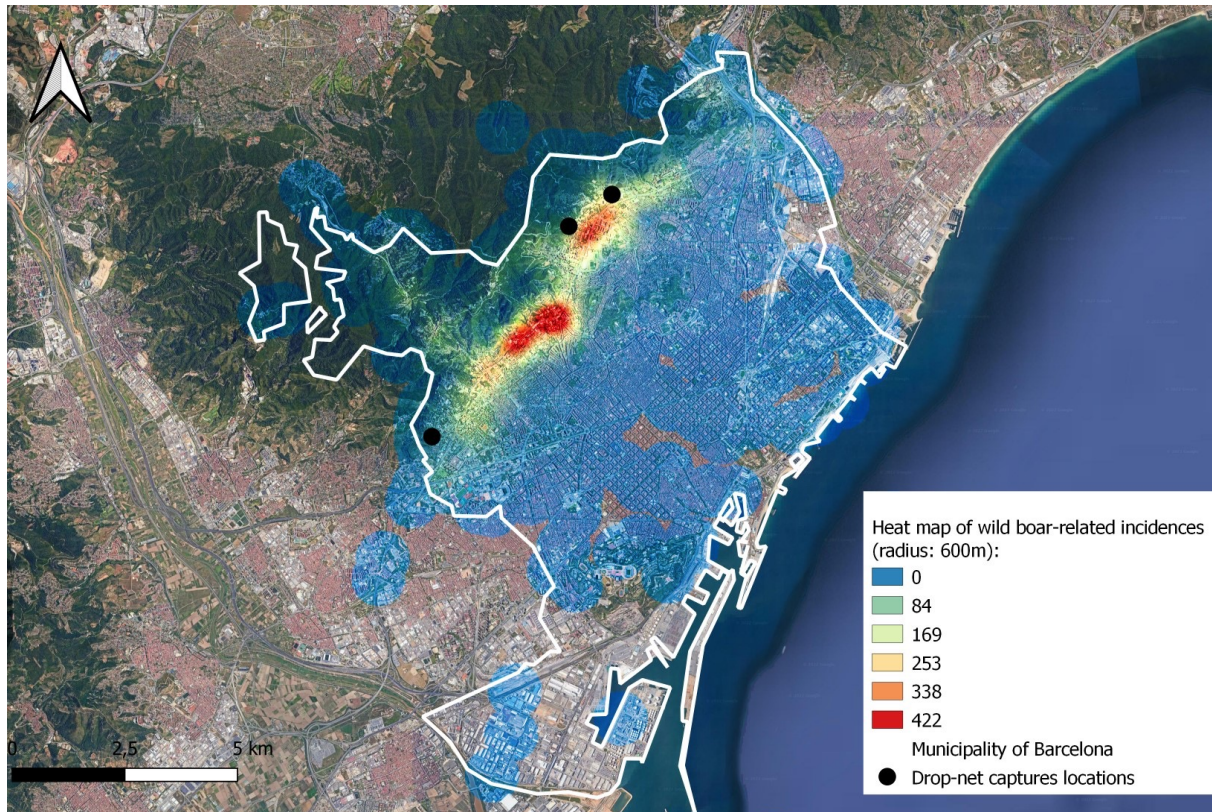
Figure 19. Heat map generated with QGIS version 3.22.7 Bialowieza (https://qgis.org/en/site) of the wild boar-related incidences recorded by the Barcelona city police department from 2010 to 2019, and approximate location of specific trap sites in the boundaries between the urban area of Barcelona and the natural area of Collserola.

3.4.c.3. Assessment of mammal trapping standards

Drop-nets are operator-triggered restraining traps that have not the consideration of mechanical traps (Proulx 2022), hence apparently out of the scope of either currently in force mammal trapping standards (AIHTS) or the new proposed ones. However, in the absence of specific and/or alternative procedures, to assess humaneness of the ESTRATEKO drop-net system for capturing wild boars, we adopted a hybrid procedure including the pathological evaluation and trauma scoring of field - instead of compound/captive- captured wild boars, as proposed by ISO 10990-5, as well as the injury indicators and the performance threshold proposed by the AIHTS, according to national and regional regulations -also focused mainly on fur predatory species- (Conferencia Sectorial del Medio Ambiente 2011, Generalitat de Catalunya 2014). Namely, we necropsied 20 (the minimum number considered by the AIHTS to obtain meaningful results) out of 32 captured wild boars. An experienced wildlife pathologist examined carcasses for the presence of injuries and/or indicators for negative effects resulting from the drop-net capture method and to evaluate animal welfare (Table 13). Next, for a more proper assessment, we discuss the results according to the recently released standards and guidelines for improvement (Proulx 2022).

Table 13: Indicators of poor welfare to be assessed during humane trapping standards validation of capture methods, according to the Agreement of International Humane Trapping Standards (first column) and scores assigned to these lesions either by the International Organization for Standardization (second column) or by the new proposal for international mammals trapping standards -according Proulx 2022- (third column).

Behavioral indicators	ISO 10990-5 Annex C	New mammal trapping standards proposal (Proulx 2022)
Self-inflicted bite causing severe injuries (e.g. mutilation)	na	50
Excessive immobility and apathy	na	na
Injuries		
Fracture	30-100	50-100
Carpus, tarsus or closely related joints luxation	30	30
Tendon or ligament ruptures	25(each)-100	25(each)-100
Severe periosteum graze	30	15
Severe external or internal hemorrhage	10-100	30-100
Significant skeletal muscle degeneration	55	50
Limb (upper or lower) ischemia	55	50
Definitive tooth fracture with pulp cavity exposition	30	30
Ocular damage including corneal laceration	100	100
Spinal cord affectation	100	100
Myocardium degeneration	100	100
Amputation	25-100	30-100
Death	100	100

3.4.c.4. Necropsy protocol and histopathological study

For this aim, the postmortem study included the systematic necropsy of every individual, as well as a specific histopathological study. Complete external and internal evaluation was performed on all individuals in order to characterize and determine the severity of the traumatic injuries that could be related to the drop-net capture. Following external examination and before opening internal body cavities, the wild boars were completely skinned to better assess the presence of contusion injuries.

The histopathological study was mainly addressed to assess if restraining time in the net before anesthesia was long enough as to provoke capture (exertion) myopathy, which may be due to excessive stress and suffering by the captured individual. The targeted tissues for microscopical examination after fixation and staining with hematoxylin and eosin included: myocardium, skeletal muscles (longissimus dorsi, semitendinosus and/or semimembranosus) and kidney.

3.4.c.5. Operational factors

A record was made of every capture event including the following data: location, date, assembly and starting time, times at which the drop-net was triggered, number and individual characteristics of the wild boars captured in every net fall, finishing time and concerning additional observations (e.g.: incidences due to unexpected opposing witnesses or another kind of disturbances detrimental to the capture event success, or operators' safety accidents).

3.4.c.5. Ethical statement.

No ethical permit for animal experiments applies or must be permitted as no animals were harmed or killed specifically for the purposes of this study. Wild boar capture operations were done for population management purposes, not for research, and according to national and local legislation. All described methods were conducted during or after legal trapping activities, according to national, regional and local laws. All international and/or institutional guidelines for animal handling were followed. Thus, all experiments were carried out in compliance with ARRIVE guidelines.

3.4.d. Results

Thirty-two wild boars were captured during the six capture operations, 12 males and 20 females ranging two months to six years old and 10 to 90 kilograms. To perform the postmortem study, a partially random selection of individuals was done after every capture event to obtain representation of the six capture operations (hence, different circumstances including separate dates, locations and environmental conditions) as well as of both sexes and different age classes, until completing 20 wild boars (6 males and 14 females; same age and weight range). None of the twelve excluded wild boars displayed external signs of trauma. A male piglet suffered severe gingival laceration due to the placement and friction of the mesh nylon rope between the upper lip and the gingival space while entangling together with an adult female (its mother), which probably increased the forces between the piglet and the mesh. According to the pathological criteria established in Annex C of ISO 10990-5, this injury displayed

ligament rupture, periosteum abrasion and mild to moderate external hemorrhage. In addition, two adult females caught in the same capture event displayed acute myodegenerative lesions consistent with capture myopathy. Individually, the lesions observed could be classified as mild but, under a rigorous interpretation, the simultaneous affectation of, at least, two major muscles (*longissimus dorsi* and *semitendinosus*) could be compatible with the indicator "major skeletal muscle degeneration" established by the ISO-10990-5 and classified as moderate. Hence, altogether, and depending on the interpretation, moderate to severe injuries associated with the drop-net capture were observed in one to three (5-15%) wild boars (Table 14; Figure 20).

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Table 14. Date, place and results from the six capture operations with the Estrateko® remote-controlled drop-net system. Bold letters refer to the dates, age classes, sex and number of individuals with significant trap-related injuries. WB: Wild boar; PM: post-mortem.

A = Velòdrom d'Horta; Coordinates (UTM31N – ETRS89): 429088 E 4587916 N
B = Escola Baloo; Coordinates (UTM31N – ETRS89): 428127 E 4587226 N
C = Av. Pearson; Coordinates (UTM31N – ETRS89): 425048 E 4582627 N

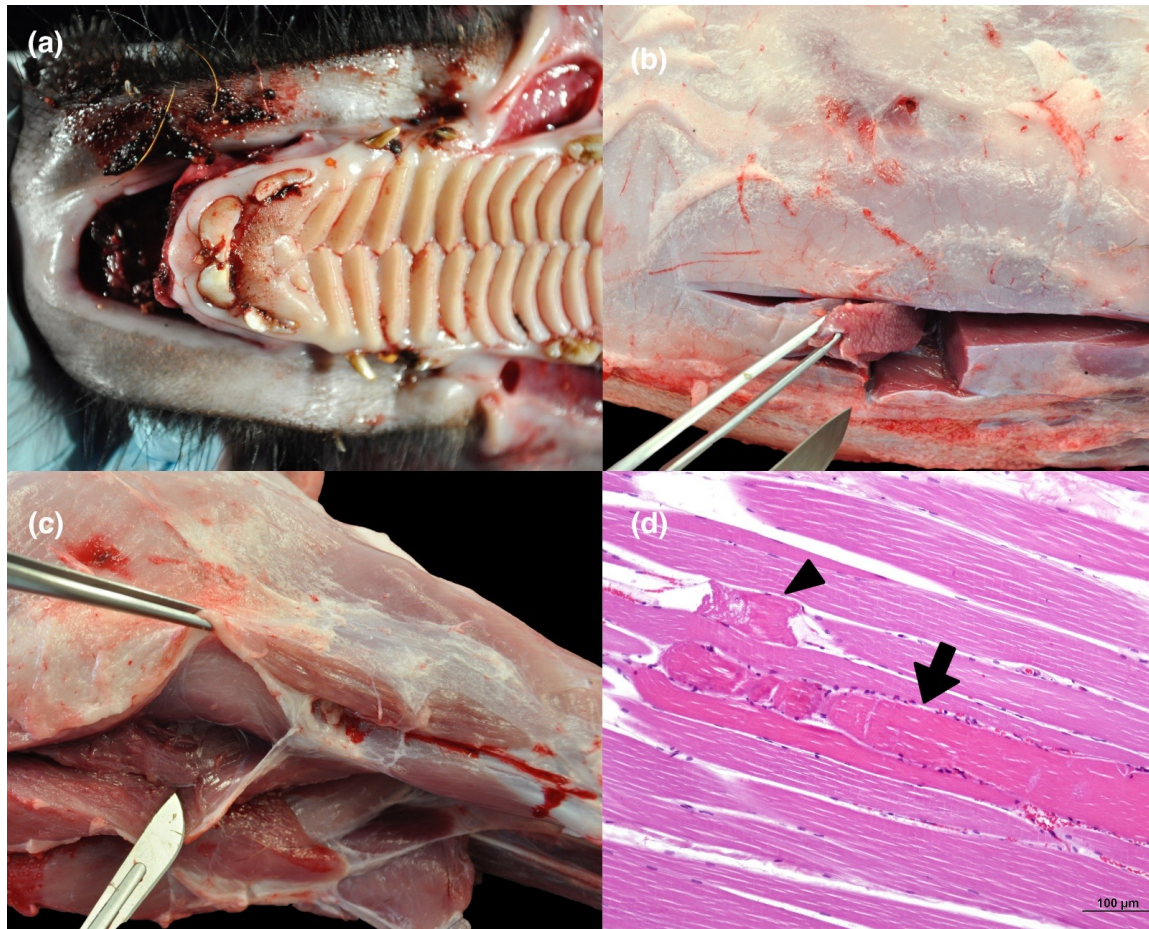| Date (2017)	Area	Captured WB	WB selected for PM study	♂ Piglets	♀ Piglets	♂ Juveniles	♀ Juveniles	♂ Yearlings	♀ Yearlings	♂ Adults	♀ Adults
				Captured / Selected for PM study (with significant injuries due to the capture system)							
12/09	A	8	4	4 / 1	2 / 1	-	-	1 / 1	-	-	1 / 1
18/09	A	5	5	2 / 2 (1)	2 / 2	-	-	-	-	-	1 / 1
27/09	A	2	2	-	-	-	-	-	2 / 2	-	-
2/10	B	9	5	3 / 1	3 / 1	-	-	-	-	-	3 / 3 (2)
16/10	C	4	2	-	-	1 / 0	1 / 0	-	-	1 / 1	1 / 1
28/11	C	4	2	-	-	1 / 0	2 / 1	-	-	-	1 / 1

Figure 20. (a) Severe, deep gingival laceration with external haemorrhage exposing the maxillary bone. (b). Sampling of *longissimus dorsi*. (c) Sampling of *semitendinous* and *semimembranous muscles*. (d). Acute skeletal muscle degeneration. A central myofiber is swollen and hypereosinophilic (arrow) and a fragmented segment of another myofiber is also present (arrowhead).

A fourth individual (adult female) displaying chronic gingivitis suffered moderate gingival laceration presumably due to the mesh rope friction; in this case, the previous condition was considered as a predisposing factor and was overall classified out of the ISO pathological criteria. Finally, ten individuals (including the adult female with gingivitis) displayed minor abrasions (n=7) or contusions (n=3) with either superficial and/or intramuscular bruise and including an individual showing a minor bruise in the snout and another one with minor injuries in the inner side of the oral mucosa due to self-biting presumably while entangled. Minor and focal acute myodegeneration on muscular fibers associated to subcutaneous and intramuscular contusive traumatisms were observed in the histopathological study of the same individuals. Despite most of these lesions may be related to the drop-net capture system, they were all classified as mild and not to fulfil the AIHTS established severity pathological criteria. Three individuals showed previous and already healed moderate to severe traumatisms, including a partial jaw amputation, a tail amputation and a bone callus on two ribs, that were not associated to the capture method. Finally, intramyofibrillary cystic structures compatible with Sarcocystis spp. were observed on myocardium and/or skeletal muscle of seven individuals. See Table 15 for the detailed information of all the examined wild boars, including sex, age, condition, weight and pathological findings.

The capture success of the ESTRATEKO drop-net system was 100%; i.e. wild boars appeared and placed beneath the net in every planned capture event, so that the system was triggered and the outcome resulted in multiple captures (all the wild boars observed through the cameras were captured). The selectivity was also 100%, as ensured by operator-driven triggering. And average performance was 5.3 wild boars per capture operation (Minimum: 2; Maximum: 9 -Table 14-). Operator safety was warranted as no one resulted injured during the capture operations. Finally, it deserves mention that the capture system was not vandalized, nor disturbances aroused during the capture operations. In no case, the trap was assembled more than seven hours (Minimum: 3 hours and 30 minutes; Maximum: 6 hours and 45 min) between 19 hours p.m. and 3:15 hours a.m. of the following day.

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Table 15: Identification, mean age, weight and pathological findings on evaluated individuals. WSL = "Without significant lesions". *According to new mammal trapping standards proposal (Proulx 2022); **According to ISO-10990-5 Annex C.

Id.	Mean age (months)	Condition weight (kg)	Trap-related pathological and histopathological findings (Injury score -points*-; Trauma scale**)	Pathological and histopathological findings not trap-related
SS17153	4,5	Very good, 11	WSL	WSL
SS17154	30	Good, 44	WSL	Anomaly in lower jaw (previous traumatism)
SS17155	4	Good, 15,5	WSL	WSL
SS17156	4	Good, 16	Low grade, superficial abrasion in forelimb with subcutaneous and intramuscular bruise (10; Mild)	Tail amputation (previous traumatism)
SS17162	60-72	Good, 47,5	WSL	Intramyofibrillary cystic structures on myocardium and skeletal muscle consistent with Sarcocystis sp. Minor perivascular lymphoplasmacytic infiltrates in the renal pelvis
SS17163	4	Good, 13,5	WSL	Minor interstitial and lymphoplasmacytic infiltrate on kidney
SS17164	4	Good, 16,5	WSL	WSL
SS17165	4	Good, 15,5	WSL	WSL
SS17166	5,5	Good, 15	Severe, deep gingival laceration (100; Severe) with external hemorrhage exposing the maxillary bone (30; Moderate) Low grade, superficial abrasion of oral mucosa (5; Mild)	WSL
SS17170	17,5	Good, 42	Self-inflicted bites on oral mucosa (5-10; Mild)	Intramyofibrillary cystic structures on myocardium and skeletal muscle consistent with Sarcocystis sp. Minor interstitial lymphoplasmacytic infiltrates on renal medulla.

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Id.	Mean age (months)	Condition weight (kg)	Trap-related pathological and histopathological findings (Injury score -points*-; Trauma scale**)	Pathological and histopathological findings not trap-related
SS17171	17,5	Good, 33	Low grade, superficial longitudinal abrasion on forelimb with focal acute hemorrhagic degeneration on brachialis muscle. Erythrocytes between swollen and fragmented hypereosinophilic muscular myofibers (10; Mild)	WSL
SS17172	54	Very good, 75,5	Low grade, superficial longitudinal abrasion on forelimb with associated subcutaneous and intramuscular hemorrhage (10; Mild) Mild myodegeneration on longissimus dorsi and semitendinosus muscles with swollen and fragmented eosinophilic fibers -8%- (30; Moderate)	WSL
SS17173	4,5	Good, 11	Low grade, superficial and intramuscular bruise on forelimb with minor focal degeneration on contused muscle (10; Mild)	WSL
SS17174	54	Good, 59,5	Low grade, superficial abrasion with erythema on forelimb (10-Mild) Swollen eosinophilic and fragmented fibers -3%- on	Bone callus on thoracic cavity (ribs 6 and 7) due to a previous traumatism. Intramyofibrillary cystic structures on myocardium and skeletal muscle consistent with Sarcocystis sp.

Id.	Mean age (months)	Condition weight (kg)	Trap-related pathological and histopathological findings (Injury score -points*-; Trauma scale**)	Pathological and histopathological findings not trap-related
			longissimus dorsi and semitendinosus (30; Moderate)	
SS17175	54	Very good, 57	Low grade contusion, superficial and intramuscular bruise in right thorax and dorsal flank with moderate focal bruise (10; Mild)	Intramyofibrillary cystic structures on skeletal muscle consistent with Sarcocystis sp.
SS17176	3	Good, 12,5	WSL	WSL
SS17192	54	Very good, 90	WSL	Intramyofibrillary cystic structures on myocardium and skeletal muscle consistent with Sarcocystis sp.
SS17193	66	Very good, 83	Low grade, superficial and longitudinal bruise on nasal bone (10-Mild)	High number of intramyofibrillary cystic structures on myocardium and skeletal muscle consistent with Sarcocystis sp.
SS17242	54	Very good, 59,5	Moderate grade, laceration on mandibular gingiva due to previous chronic swollen gingivitis with incisive spacing (10-30; Mild)	Multifocal coalescent pyogranulomatous glossitis, tonsilitis, lymphadenitis (submandibular and retropharingic lymphnodes), abscess (1,5 cm) caudal to mammary gland (right M3), cranioventral suppurative chronic pneumonia (10%). Intramyofibrillary cystic structures on myocardium consistent with Sarcocystis sp.
SS17245	7,5	Good, 18,5	Low grade, superficial abrasion on forelimb (10; Mild)	WSL

3.4.e. Discussion

Worldwide, the harsh reality is that many wildlife traps continue to be widely used without any or poor evaluations of trapping standards (Fahlman et al. 2020) probably due to lacking political will, regulations and supervision or control mechanisms. Even so, the need for updating the current AIHTS in order to improve animal welfare standards and test procedures has been long stated (Iossa et al. 2007, Virgós et al. 2016) and recently boosted (Proulx et al. 2020, Proulx 2022). Some of the alleged concerns for this claim are incomplete lists of mammal species and trap types included on it. In this research, we evaluated a capture method not considered in the AIHTS to capture a wildlife species not included in the list of mammal species under the scope of the AIHTS, with apparently satisfactory results. To the best of our knowledge, this is the first assessment of welfare performance of a drop-net capture method according to international mammal trapping standards. However, as far as drop-nets are not mechanical traps, they would fall out of the scope of any standards, either the outdated AIHTS or the newly released ones (Proulx 2022). Nevertheless, given the absence of specific and/or alternative standards, procedures and thresholds of acceptance, we decided to adopt the existing ones. Altogether, amongst the 20 wild boars captured and analyzed, at most three displayed significant trapping-associated alterations. This value is under the 20% maximum allowed by the AIHTS, hence the ESTRATEKO drop-net system fulfilled the requirements of this norm for restraining traps. However, the new mammal trapping standards expand on the indicators of distress by including behavioral and physiological parameters, assign scores to the injuries observed in the pathological evaluation -similarly to ISO 10990-5- and establishes stricter thresholds of acceptance. Behavior evaluation is feasible and deserves interest when live-traps do not completely restrict mobility and the captured individuals may remain for hours inside the trap or held by it. This is not the case for drop-nets, which immobilize individuals almost completely and immediate assistance is required in order to alleviate their strong acute stress response, either by gunshot or by chemical methods, depending on the intended purpose. Regarding physiological evaluation, a previous study already made clear a predominantly adrenergic stress response of wild boars captured with the ESTRATEKO drop-net system that contrasted with cortisol-induced changes observed in cage and corral trap captured wild boars (Torres-Blas et al. 2020). Since stressful stimuli and both intensity and duration of the stress response provoked differ amongst capture methods, direct comparison and interpretation of physiological parameters may be difficult to assess unless extreme and pathological values are observed or thresholds of acceptance are determined/provided. Evaluating the results of our pathological evaluation based on the new standards thresholds of acceptance ("acceptable restraining trap systems are expected, at a 95% confidence level, to hold ≥85% of target animals for a specific time period without serious injuries [≤50 points], signs of distress or exertion [≤50% of the capture time], and significant physiological stress changes"-Proulx 2022-), only the male piglet suffering severe gingival laceration clearly scored over 50 points. The points/score to be assigned to the two individuals displaying skeletal muscle degeneration deserves further discussion. While the ISO 10990-5 differentiate minor from major skeletal muscle degeneration, scoring 30 (Moderate) and 55 (Moderately severe), respectively, the new standards proposal considers a single category of skeletal degeneration scoring 50 points. Since both

individuals presented other mild affectations, their cumulative injury score with the new standards would be over 50, resulting altogether also in three unsatisfactory captures and 17 successful ones out of 20, which corresponds to a 66% humaneness efficacy (95% CI; estimated through the normal approximation to the binomial distribution -Proulx et al. 2020 and 2022-), under the 85% threshold. Even doing a lax interpretation and considering only the piglet with severe gingival laceration, we would not exceed the established threshold (78%). On the other hand, the short duration of restraint during drop-net capture, as well as for other nets-based capture systems, should be considered a plus (Sharp and Saunders 2011) and adapted trapping standards, thresholds and evaluation procedures could be desirable.

It is worth notice that when evaluating welfare standards and performance of a capture system, it is not only the device that is under examination, but also the way it is used (Iossa et al. 2007, Ziegler et al. 2018), which altogether could be referred as the capture method or set. This is specially so in the case of drop-nets given that the trapped animals must be attended immediately and cannot remain unattended for hours, as it may happen with other methods to live-capture wild animals that are normally allowed to work overnight and revised next morning (Fahlman et al. 2020). In this regard, we suggest that a combined test procedure of both killing and restraining traps could be advisable when using restraining traps for population control and as a previous step to sacrifice or euthanasia. Namely, the parameter "TIU" should be taken into consideration, probably with adapted thresholds to the specific live trapping method. This reasoning has been elaborated later than the experimental phase of the present study, hence we did not precisely record times from drop-net triggering to anesthesia-induced unconsciousness of the captured wild boars. However, we can assure that in no case more than 15-20 minutes passed between these two moments. If these data were available and we could fine-tune this assessment, we may could find a relation between the TIU values and the two wild boars displaying myodegenerative lesions compatible with capture myopathy. Going beyond, we previously stated that the wild boars captured in the present study were sacrificed by means of pharmacological euthanasia after previously induced anesthesia in order to increase humaneness of process and avoid blood spill in the periurban scene. If we omit aesthetic concerns, gunshot or captive bolt followed by exsanguination would probably have resulted in shorter TIU values in the drop-net captured wild boars, which are subjected to a highly stressful situation previous to anesthesia. Furthermore, physical immobilization provoked by drop-nets makes possible this operation in suitable conditions and safely for the operators. The two adult females observed with capture myopathy were captured in the event with a higher number of captured wild boars, which probably resulted in extended time to anesthesia. Capture myopathy is a time-dependent syndrome that normally correlates with the duration of an overwhelming (that overcome the physiological mechanisms to cope with) stressful event (Marco et al. 2006, Breed et al. 2019). The significance of capture myopathy probably differs depending on the fate of the animals, being specially concerning if the captured animals are to be released (e.g. after marking and/or sampling); not so much if sacrificed. Hence, the operating protocol should consider increasing the number of skilled operators and/or limiting the number of wild boars to be captured before triggering the system to minimize the time of handling and prevent capture myopathy in the case of live-trapping and release (Torres-Blas et al. 2020), whereas capture of entire sounders must be prioritized when capturing for population control. On the other hand, exceptional injuries such as that of the male piglet suffering severe gingival

laceration while entangling together with a much bigger and heavier individual, despite infrequent may be avoided using a thicker and softer mesh or reducing mesh hole size. Considering the relative position of individuals beneath the net before triggering the system could serve also to prevent crowding under the net and during the entangling phase and to reduce post-triggering handling time.

Drop-nets were first conceived to capture game birds and later adapted and widely used to capture ungulates, mainly ruminant herbivores. According to the literature, drop-nets are considered suitable for mass capture of ungulates smaller than an antelope (Antilocapra americana) and recommended to capture deer (roe -Capreolus capreolus-, red -Cervus elaphus- and white-tailed -Odocoileus virginianus- deer), European mouflon (Ovis aries) and mountain goats (Oreamnos americanus) in non human-dominated scenarios (Rideout 1974, European Comunity and United States of America 1998, Lavelle et al. 2019). However, to our knowledge, its use in free ranging swine has been quite limited, restricted to feral/wild pigs in North America (Gaskamp et al. 2021) and only once reported in European wild boar (Torres-Blas et al. 2020). Other capture methods targeting wild boar such as corral or cage-traps have been proposed as one of the safest, most efficient and humane means of capturing wild pigs, also allowing for the safe release of non-target captures (Lewis et al. 2019). However, these methods have also been reported to provoke severe injuries, and even related mortality, in a significant number of individuals (Barasona et al. 2013, Fahlman et al. 2020). This discrepancy is probably due to differences in the design of the specific devices evaluated and in the way they are used. In fact, measures to reduce injuries and fight-or-flight responses when using these methods have been described, resulting also in quicker delivery of chemical immobilization drugs via darting and, hence, shorter time values until unconsciousness (Lavelle et al. 2019). Furthermore, trap-related physical injuries may not fully reflect other capture-induced stressors such as fear, pain and poor environmental conditions (Fahlman et al. 2020). Even more, the stressful situation provoked by capture has also been described to cause distress in individuals other than the ones captured in prosocial species such as wild boar (Masilkova et al. 2021). Probabilities for this situation to occur are higher when using methods with less ability to capture entire sounders of prosocial species than drop-nets.

In addition to welfare considerations, a capture method must warrant capture success or trap performance (i.e.: the rate at which a device or system catches the intended species) (López-Olvera et al. 2009). Capture success may be estimated according to efficacy, or percentage of successful capture events, and efficiency, or number of captured individuals per unit of capture effort, which were maximum in our study, with 100% of successful capture events and 100% of multiple captures (i.e., more than a single wild boar captured). However, to be fair, a previous assessment of the ESTRATEKO drop-net system including a bigger number of capture events resulted in 85% of successful capture events (i.e., wild boars did not appear in 15% of the planned capture events, hence the drop-net system could not be triggered) and when the wild boars made an appearance, multiple captures occurred in 94.1% of triggering events. These differences can be due to urban wild boar spatial ecology and seasonality (Podgórski et al. 2013, Castillo-Contreras et al. 2018), as well as to suitable trap sites selection and monitoring during pre-baiting/capture periods (López-Olvera et al. 2009). Efficiency can be determined as the number of wild boars captured per successful capture event, or mean performance, which was higher in the aforementioned study (8.12 vs 5.3) (Torres-Blas et al. 2020) and even higher during wild pig captures in the USA (10.7) (Gaskamp et al. 2021) Compared to cage or corral

traps, and amongst live-capture methods aimed at wild boar, drop-nets have consistently been observed to display the highest performance (Torres-Blas et al. 2020, Gaskamp et al. 2021) Selectivity towards the targeted animals and operator safeness are also amongst the most common parameters used for capture method evaluation. Selectivity can be ensured through operator-mediated triggering or activation, which is the case of drop-nets, with the ability to prevent any stressful situation to any non-target species or individual. Other live-trapping methods may allow for the safe release of non-target captures, provided trapper professionalism, but in no case prevent the stressful episode supposed by restraint, which can result even in mortality of species or individuals particularly susceptible to capture myopathy (Iossa et al. 2007, Proulx et al. 2020).

Finally, it deserves interest the adaptability of every capture method to different scenarios, which is a poorly evaluated but key aspect. This is probably due to the fact that, until recently, wildlife capture has been mostly performed in remote areas or landscapes with low levels of urbanization, which reduces public awareness and/or social concerns due to more utilitarian human values towards animals. In contrast, in more urbanized landscapes, human values tend to be more protectionist, where people are less supportive of killing animals and more supportive of protecting wildlife (Manfredo et al. 2003, Cahill et al. 2012, Lewis et al. 2019). These circumstances can give room to social disturbances by animal sympathizers contrary to management measures based on wildlife capture and removal (population control). These disturbances may include opposing actions during captures performance, if found out, but more probably and difficult to prevent, deliberate vandalism of non-guarded traps, stealing of trap-related devices, such as camera-traps, or even freeing of the captured animals, which suppose a risk for the involved people. Cage and corral traps require longer deployment time of capture gear on field, which raises public awareness and increases the risk of vandalism when used in urban and peri-urban environments. This is the case for wild boar in the Metropolitan Area of Barcelona -MAB- (Conejero et al. 2019b), where most of these incidents have occurred when using cage and corral traps and ahead determined trap sites selection when using these methods (to avoid sites accessible to the general public) and limited capture success (Torres-Blas et al. 2020). The operating protocol applied by ESTRATEKO S.L., including set up at dusk and dismantling at the end of the capture event, always during the night and before dawn, avoided any incident and resulted in increased and higher adaptability of the drop-net trap. This allowed the most suitable trap sites selection according to urban wild boar activity hotspots and maximized capture success. This adaptability may also apply to other non-urban scenarios that impose short times of trap system deployment.

3.4.e. Conclusions

To summarize, (1) the application of the test procedures aimed at evaluating trapping standards suppose an opportunity to improve wildlife traps, capture protocols and welfare, being necessary their adaptation and that of acceptance thresholds to capture methods and species not considered previously; (2) to the best of our knowledge, this is the first assessment of welfare performance of a drop-net capture method according to international mammal trapping standards, resulting in the certification of the ESTRATEKO drop-net system for wild boar capture according to the AIHTS requirements. Although certification is not so clear when revisited

according to newly proposed state-of-the-art standards, the need for adjusted test procedures and acceptance thresholds for restraining non-mechanical traps, namely for drop-nets, is clear. (3) Nonetheless, we suggest that a combined test procedure of both killing and restraining traps could be more suitable when using restraining traps by considering the parameter "time to unconsciousness" (either irreversible or not, if sacrifice is not the final objective of live-trapping) and establishing adapted thresholds. In any case, (4) to fully warrant animal welfare performance of drop-nets, the conditions to minimize time of handling or time to unconsciousness must be provided, preferably by ensuring a suitable number of skilled handlers. (5) Compared to other live-capture methods aimed at wild boar, drop-nets provoke a strong adrenergic acute stress response. However, the immediate assistance by handlers shortens the duration of the stressful situation. In addition, drop-nets maximize the probabilities of capturing entire sounders of prosocial species, which may be considered as more humane, as well as more efficient for population control purposes. (6) When properly used, drop-nets have the potential to easily coordinate minimum animal physical and mental distress with the highest values of capture success and maximum selectivity and adaptability to difficult environments and/or conditions. (7) Finally, other advantages of using drop-nets include easy technical management, operator safeness, low costs on maintenance over years and reduced trap visibility and distrust by targeted animals.

4. GENERAL DISCUSSION

This PhD thesis provides insights into the main drivers of social perception of the urban wild boar, determining the major influence of negative experiences (Study 1), socio-economical context, previous knowledge and human emotions (Study 2) on wild boar perception. Also, the detrimental effect of synurbization on wild boar health and welfare has been evidenced (Study 3). Finally, drop-net capture has been assessed according to humane/mammal trapping standards for the first time (Study 4).

4.1. Human dimension factors influencing wild boar social perception in the urban environment.

Urbanization is widening the gap between humans and nature (Zhang et al. 2014). In urban areas, people often lack historical and cultural contexts for wildlife, either because they lack direct experiences in themselves or in their social community (Soulsbury and White 2019). With urban areas increasing globally, the interactions between humans and urban wildlife will steadily increase. Because not all human-wildlife interactions are enjoyable, the unadressed current conflict is expected to rise in the coming years (Lindsey 2016, Soulsbury and White 2019).

Accordingly, study 1 confirmed that negative past experiences are more important than socio-demographic variables such as gender, education and public health concern in driving citizen perception and explaining resident attitudes towards HWBC (Kansky and Knight 2014). In line with this, other authors previously reported that social and local concern about threats and risks posed by wildlife, particularly those related to human safety and health, can induce strong negative perceptions among local citizens, and therefore more strongly determine attitudes than positive perceptions (Sakurai et al. 2013, Browne-Nuñez et al. 2014, Kansky and Knight 2014). Our results confirm the importance of previous experiences in wild boar-related risk, especially when negative interactions imply a sensitization process, which fosters the conflict and induces fear or frustration (e.g.: traffic accident with a wild boar; Zhang et al. 2014, Lute and Gore 2019). On the other hand, risk perceptions are value-laden judgments about the personal likelihood of harm, which include affective and cognitive dimensions. Therefore, risk perceptions are not only experiential, but also emotional (Lute and Gore 2019).

In urban areas, modern lifestyles lead to develop lower perceptions of risk posed by wildlife (Dietsch et al. 2019), which increases the risk of unexpected aggression to humans (Cosculella 2015, Ibáñez 2021) or acquisition of zoonotic resistant pathogens carried by urban wild boars (Navarro-Gonzalez et al. 2018). Therefore, risk perceptions can influence conflict more than technical assessments and hence are critical to address when trying to move from conflict to the coherent coexistence (Lute and Gore 2019). In urban areas, people are also less likely to learn about wildlife as a result of direct experiences and instead learn more through self-selected indirect sources, resulting in depictions of animals that are limited to those preferred by the information consumer (Dietsch et al. 2019). Indeed, coexistence is less problematic with species for which humans have positive emotional dispositions, and more difficult with species for which humans have negative emotional dispositions (Jacobs and Vaske 2019).

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In the suburban area of Barcelona, where encounters with urban wild boar are common, citizens without negative experiences are more prone to express a positive perception of wild boar presence and to display behaviors that reinforce the phenomenon, such as feeding wild boars. This fact contributes not only to boosting wild boar habituation process to the urban landscape (Nyhus 2016) but is also fostering at the same time the process of human habituation towards an increasing wild boar presence in urban areas. Hence, wild boar feeding is contributing to reinforce the reciprocal human-wild boar habituation process occurring in Barcelona (Morrison et al. 2006, Cahill et al. 2012). This is expected to happen in wild boar-coexistent citizens until a traumatic incident lead to sensitization (Çevik 2014, Cosculella 2015, Castillo-Contreras 2021). Considering that social tolerance towards wild boar is limited by the perception of threat poseed to humans (Bombieri et al. 2018), the occurrence of negative human-wild boar interactions (Ibáñez 2021, Castillo-Contreras et al. 2021) fosters citizen fear and perceived harmfulness posed by wild boar (Bencin et al. 2016).

However, in Barcelona, the influence of direct interactions loses importance in citizens' attitudes towards the HWBC along the natural-to-urban gradient when perception samples are taken closer to the core city. The tendency to humanize animals induces the view that wild animals are like humans and therefore deserve similar consideration/rights (FAADA 2016, Dietsch et al. 2019, Walter and Jenkins 2020). Results from studies 2 and 3 make clear that citizens who humanize wild boar are boosting negative health and welfare drawbacks for both the wild boar and humans.

Into this context, analyzing citizen risk perception is important to properly understand and assess the current HWBC (Lute and Gore 2019). To inform about the benefits needed in order to counter the costs of living with problematic urban wildlife, it would be useful to know the relative importance of costs versus benefits in determining attitudes towards wildlife species (Kansky and Knight, 2014). Study 2 shows that anthropomorphization processes are enhanced in situations where humans have a greater need for social affiliation, as is happening recently in urbanized societies and in every human-dominated landscape, where there is a loss of community (Dietsch et al. 2019).

Altogether, studies 1 and 2 make clear that citizen perception of HWBC depends on a combination of personal emotions, lay-knowledge and the magnitude of habituation and sensitization processes from previous experiences of human-wild boar interactions. Both emotional arguments and costs and benefits ratios should be considered in designing urban wild boar management measures, especially when countering citizen behaviors that reinforce wild boar presence in urban areas. Interestingly, we also show that some perceived conflicts depend more on previous lay-knowledge, personal wild boar-related emotions and human values than on actual impacts (Frank and Glickmann 2019). Due to that, HWBC in one specific situation may not be perceived as such in another similar one due to several factors including culture, location, frequency, severity, intensity and time among other factors (Nyhus 2016, Frank and Glickmann 2019).

In many situations, the framework of human-wildlife conflict hides a human-human component; namely, a friction between different stakeholders over different interests and values, including how to protect and conserve wildlife (Kotulski and König 2008, Frank and Glickman 2019). Human values guide their personal actions (e.g., feed wildlife vs hunt wildlife), give them an identity in interpersonal dealings (e.g., member of a collective of animal lovers, member of a hunting crew) and provide a motivational basis for group membership. At an organizational level, the way the people in the group

act influences individuals, as the group articulates and demonstrates the appropriate behaviors and attitudes to be adopted by its members (Dietsch et al. 2019). Because values permeate from individual thinking to cultural and political institutions, an exploration of the nature of values towards wildlife and how they are influencing human attitudes is critically needed (Whittaker et al. 2006, Dietsch et al. 2019). Therefore, in order to promote long-term coherent coexistence with wildlife in increasingly human-dominated landscapes, the main working plan must consider a multilevel approach that includes local and current societal values regarding wildlife (Bencin et al. 2016, Dietsch et al. 2019).

In order to optimize the success of HWBC management measures in Barcelona, awareness campaigns should include the cooperation of anthropological, social and psychological knowledge, concentrating efforts on the relatively small proportion of citizens boosting HWBC by feeding wild boar. The inclusion of science-based knowledge of wild boar natural habits and useful information about preventing HWBC may enhance human safety, prevent social polarization and facilitate the coherent coexistence through knowledge rather than fear (Bombieri et al. 2018, Linnell and Kaltenborn 2019). Furthermore, since socio-economic variables also determine HWBC perception, to maximize efforts, social inequality in urbanized landscapes need to be considered prior to the design and application of specific management measures (Nyhus 2016, Adams 2016).

Citizen education and awareness campaigns that seek to reduce behaviors, such as voluntary feeding, that promote wild boar presence, must consider the diversity of citizen attitudes towards the urban wild boar. Shifting perceptions through education has its own limitations, but success is possible, and more likely if multiple tactics are used in tandem (Bencin et al. 2016, Kansky and Knight 2014). Mass media has an important impact on social tolerance and risk perception towards wild boar, reducing the high number of graphic elements in media reports concerning wild boar attacks on humans may help avoid creating unnecessary fears (Bombieri et al. 2018). Within this context, there is an opportunity for media information and education programs to strongly drive attitudes, which in turn can amplify or reduce people's perception of risk (Soulsbury and White 2019).

Our findings regarding tensions between conflict and reciprocal habituation can help to better understand current and local citizen contribution and tolerance towards wild boar presence in Barcelona. Moreover, the methodology used to analyze current social perception of conflictive urban wildlife is a useful tool to properly address the expected citizen acceptance management measures prior to its implementation. The evaluation of current public attitudes towards human-wildlife conflicts can be a useful tool to adapt wildlife management measures to upcoming complex social and cultural contexts. Our findings about the reciprocal habituation phenomenon may assist urban wildlife managers to better understand the key factors influencing citizen perception towards wild boar presence in urban areas, and hence undertake the most feasible management measures according to urban characteristics, citizen attitudes and achieving the desired acceptance among inhabitants. More research is needed into the emerging conceptual framework focused on human-wildlife interaction as a booster of human behavior in order to understand the potential linkages between humans, wildlife and the broader landscape (Morzillo et al. 2014).

Figure 21. Contact with nature during childhood can improve environmental consciousness, which is necessary to reach the coherent coexistence with wildlife in urban and suburban areas. The photo was taken during a school workshop (La Floresta, Sant Cugat, Barcelona). The activity was carried out as part of a citizen awareness campaign to prevent incidences with the urban wild boar under the title: "Campanya informativa per millorar el coneixement del senglar i reduir les incidències". The proposal was voted by locals on 2017, executed along 2018 and funded through the Sant Cugat Council Participative Budget.

4.2. The influence of synurbization process on wild boar health and welfare

The Study 3 confirms that urban wild boars are more exposed to severe traumatisms than their forest counterparts. Therefore, wild boar fitness in urban areas may not be so benefited as it could be assumed, providing new insights on actual socio-ecosystem dynamics from the natural-to-urban gradient (Bremner-Harrisson et al. 2004, Morzillo et al. 2014, Carpio et al. 2020). Due to its greater reproductive effort, the wild boar is expected to be more dependent on current resources than other ungulates with similar size and anthropogenic food resources may enhance wild boar survival through harsh periods (Cahill and Llimona 2004, Servanty et al. 2009, Castillo-Contreras et al. 2021). Urban ecosystems can easily provide accessible and abundant food resources for the wild boar among other plastic species, as well as a more temperate and stable urban microclimate and fewer natural predators than natural environments (Bonenfant et al. 2009, Townsend et al. 2019). A number of studies reveal that human activities impact the evolutionary changes observed in wildlife populations, leading to marked influences on life-history traits, such as body mass and reproductive factors (Servanty et al. 2011, Hagemann et al. 2022). Urban wild boar presents changes in phenotypic traits influenced by urbanization, having larger body size and mass and better body condition than non-urban wild boars (Castillo-Contreras et al. 2021). Age and size at maturity are key life-history traits that shape demographic tactics observed in vertebrate populations through their influence on survival, reproduction and growth, as well as on offspring survival (Servanty et a. 2009, D'amico et al. 2015). In this context, the optimization of foraging in urban environments can easily supply the energetic requirements of breeding sows in urban areas, but once the offspring is born the whole group has to deal with anthropogenic disturbances.

Juvenile females made a major contribution to the yearly reproductive output (González-Crespo et al. 2018), and comparisons among wild boar facing contrasted hunting pressures indicate that a high demographic contribution of juveniles is a likely consequence of a higher mortality rate rather than a species-specific life-history pattern that characterizes wild boar (Servanty et al. 2009).

In Barcelona, our findings indicate that the the current reciprocal habituation between humans and wild boar (Study 2) fosters wild boar to exploit the urban environment, which has welfare and health drawbacks for both species (humans and wild boar) in response to the higher food supply. Namely, urban environment does not compensate wild boar fitness trade-off due to the occurrence of critical and lethal traumatic lesions that impair offspring welfare and recruitment into the breeding population. These observations lead us to presume that wild boar synurbization process may contribute to a shorter life expectancy, which is attributable to vehicle collision, dog attacks and even poaching. Thereby, despite the availability of highly caloric anthropogenic food sources (Castillo-Contreras et al. 2021), the urban environment cannot be a suitable ecological niche nor habitat for wild boar, resulting in a higher probability of expression of aberrant behaviors, decreasing fitness, health and welfare. According to this, urban settlements seem to serve as attractive sinks explored by wild boar dispersers (Stillfried et al. 2017a).

In fact, study 3 provide knowledge-based ethical arguments, useful if applied in citizen educational and awareness campaigns towards wild boar presence in urban area. Hence, measures/initiatives or human behaviors aimed at promoting

cohabitation with wild boar in urban settings (Study 2) are neither acceptable nor desirable, nor from the wild boar perspective (Study 3).

Figure 22. Urban habituated wild boars use to forage on urban food waste. This phenomenon shows a trade-off where the wild boar can harness highly caloric nutritional source supplies in exchange of exposing itself to anthropogenic disturbances such as vehicle collisions or dog attacks.

4.3. Management measures for wild boar conflict

Although wildlife populations lethal control, *per se,* is neither socially accepted nor desirable (Study 2), it remains the only efficient method to counter WB conflicts in urban areas. In addition, Study 3 provides ethically based arguments to support removal of wild boar when falling into the ecological sink of the urban landscape in order to prevent loss of health and welfare. As a consequence, WB lethal control is to date necessary in urban environments, mainly because it is the only cost-effective strategy to prevent conflicts and safeguard public safety in the short term (attacks to humans, vehicle collisions or diseases transmission) (Keuling et al. 2016, Vajas et al. 2020), as well as to manage wild boars with serious health and welfare problems in a humane way. Globally, there is a growing consensus on the need to make progresses towards ethical wildlife control; in line with this, applying contemporary trapping standards when managing wildlife should no longer be an option, but a duty. To the best of our knowledge, Study 4 is the first assessment of welfare performance of a drop-net capture method (Estrateko®) according to internationally accepted mammal trapping standards, with unconclusive, but apparently satisfactory results. This makes clear the need for adapted procedures and thresholds of acceptance aimed at not-mechanical traps in general, and specifically at drop-nets. On the other hand, the Estrateko® drop-net system maximize the probabilities of capturing entire sounders of prosocial species, which may be also considered as more humane, and can coordinate higher values of capture success, absolute selectivity and adaptability to deal with social detraction in difficult environments.

To summarize, to successfully mitigate and prevent the HWBC in the long term, a multifocal approach including the following complementary measures are needed: (1) strict avoidance of supplementary feeding, shelter and water sources (Bieber and Ruf 2005, González-Crespo et al. 2018); (2) reducing urban attractiveness for the wild boar; and (3) conducting citizen education and awareness campaigns to prevent human-wild boar reciprocal habituation, with a increased effort aimed at the most conflictive human clusters (Study 2). Regarding the specificities of citizen clusters, while rational slogans are expected to influence the broadest part of citizens in Barcelona (Clusters 3, 4, and 5), the emotion-based wild boar feeding behavior of citizens of clusters 1 and 2 is unlikely to change through awareness slogans based solely on rational cost-benefit motivations (Sun 2013, Madden et al. 2014, Jacobson et al. 2014, Emre Can and Macdonald 2018). Accordingly, the detrimental repercussions of urban foraging for WB health and welfare (Study 3) provides a knowledge based ethical argument able to influence emotion-based perceptions, useful if exposed on citizen awareness campaigns. Therefore, we suggest the need to communicate more effectively with residents about HWBC, so that citizens can adopt a coexisting attitude and a specific behavior by resorting to well-nuanced knowledge of each situation of human-wildlife interfaces (Sakurai et al. 2013, Zhang et al. 2014, Cox and Gaston 2018, Study 1). These recomendations may assist urban wildlife managers to better understand how social, cultural, economic, psychological, and ecological factors interact with each other and drive citizen perception of wildlife conflict in urban areas. Our multi-sided methodology can help to undertake the most feasible and socio-ecologically adapted management measures for each location and time. With these data and analysis, wildlife managers can identify and address specific targets to mitigate potential conflict, damages and increased shared vulnerability between humans and wild boar.

GENERAL DISCUSSION

To address the increasing uncertainties related to the presence of large mammals in urban areas, more research is urgently needed on the human dimension of human-wildlife conflicts and reciprocal habituation, with a focus on environmental awareness and achieving balanced human-wildlife coexistence. Wildlife agencies and non-governmental organizations have an important role in promoting education on coherent coexistence with urban wildlife, its benefits as and risks (Karanth et al. 2008, Sakurai et al. 2013, Zhang et al. 2014). The fate of urban ecosystems and wildlife depends on our ability to provide appropriate prevention by implementing effective communication methods with diverse audiences in the urban scene (Loss et al. 2013, Jacobson et. al 2014, Lute and Gore 2019).

5. CONCLUSIONS

1. Citizen attitudes towards HWBC in Barcelona are driven by personal emotions, experiences and lay-knowledge of wild boar.

2. The distribution of citizen-wild boar interactions and respective habituation and sensitization processes influence human tolerance towards HWBC, promoting polarized attitudes towards the presence of wild boar in urban areas.

3. Educational messages should be tailored to the specific citizen requirements, emotional motivations, attitudes and consequent behaviors. The inclusion of science-based knowledge on wild boar ecology and how to avoid conflict may enhance human safety, prevent social polarization and facilitate coexistence.

4. Wild boars in urban environments are more exposed to suffer severe traumatic lesions than wild boars ranging in forest environments.

5. Anthropogenic disturbances in urban areas impair the recruitment of wild boar offspring into the breeding population.

6. Measures/initiatives aimed at promoting cohabitation with wild boar in urban settings are neither acceptable nor desirable, either from the wild boar or human perspective.

7. The Estrateko's® remote controlled drop-net system is a selective method that complies with the AIHTS and ISO welfare standards. However, adapted assessment procedures and thresholds of acceptance are still lacking to properly assess newly proposed mammals trapping standards.

8. Managed by skilled wildlife technicians, Estrateko's® remote controlled drop-net is a low cost, operator-safe and effective system for capturing large numbers of wild boars in sub urban environments, minimizing the duration of the stressful event and animal suffering.

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