Human-wildlife conflicts in Polish cities: an analysis of official reports and public perceptions

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ABSTRACT

Due to rapid urbanisation, interactions with humans and wildlife are an increasing phenomenon in cities, leading to both beneficial and adverse (called human-wildlife conflicts: HWC) encounters. Therefore, a comprehensive understanding of these interactions is crucial for successful urban wildlife management. This study aimed at understanding urban HWC across multiple species in two Polish cities (Krakow and Gdansk) over two years (2022 and 2023), drawing insights from official municipal reports and public perceptions. Official reports from Krakow and Gdansk over two years provided quantitative data on property damage, animal-vehicle collisions, allowing identification of wildlife conflict hot spots. Additionally, questionnaire responses from 100 respondents in both cities highlighted perceptions of urban wildlife among residents. The conflict reports revealed species-specific interactions within the urban landscape. Wild boar (*Sus scrofa*) conflict reports were the most frequent, followed by roe deer (*Capreolus capreolus*) and red fox (*Vulpes vulpes*). Property intrusion was the most common conflict category in both cities. Conflicts varied seasonally, with spring recording the highest incidents. Spatial analysis revealed concentrated wild boar conflicts in specific regions of both cities. Furthermore, residents' attitudes toward urban wildlife differed between cities. Wild boar, stone marten (*Martes foina*), red fox, and roe deer were consistently reported as both frequently observed and sources of conflict in both cities. Thus, the study highlights the importance of context-specific and the need for tailored approaches for conflict management strategies. Our findings will contribute to global efforts promoting urban wildlife conservation, including emphasising on city-specific conflict management instead of a one-size-fits-all approach.

Keywords: attitude; nuisance wildlife; Poland; questionnaire survey; wild boar

1. Introduction

Urban areas are experiencing ongoing expansion, with 56% of the current human population residing in cities, with a prediction to rise to 68.4% by 2050 (United Nations et al., 2019). Europe is also not far behind in dynamic expansion, and urbanisation is expected to increase to 87% by 2050 (United Nations et al., 2019). In the upcoming decades, urban development will reach unprecedented levels (McPhearson et al., 2016), with the global population in urban areas rising by 1 million people every ten days (Acuto et al., 2018). Thus, the world we are living in is significantly changed by human activities, and this change is most evident in the cities worldwide (Magle et al., 2019). This gradual land transformation is leading to the creation of urban areas with each passing day, with a continuous loss of biodiversity.

These transformations of natural habitats into residential, commercial, and industrial areas frequently result in the displacement of wildlife, compelling wildlife to seek food and shelter within anthropogenic landscapes. Thus, human-wildlife interactions (HWI) are an inevitable component of urban ecosystems, particularly in the context of ongoing global urbanisation (Soulsbury & White, 2015). These HWI are complex and show considerable variation in terms of their intensity and characteristics (Nyhus, 2016), ranging from positive benefits such as improving physical and mental health, flourishing positive emotions and inspirational experiences (Methorst et al., 2020) to harmful conflicts such as damaging crops, threatening, killing or injuring people and domestic animals (Mekonen, 2020). Such conflicts are commonly referred to as human-wildlife conflicts (hereafter HWC). Moreover, the rapid acceleration of urbanisation in the last decade led to an increased interaction of humans and wildlife, thereby amplifying the likelihood of encounters that may culminate in frequent HWC (Soulsbury & White, 2015) in the urban landscape. These HWC encompass not only ecological challenges but also socio-cultural dilemmas (Chaves et al., 2024), showing significant variability across different spatial and temporal scales (Schell et al., 2020). The complex interplay of HWC within urban environments creates a necessity to understand the consequences stemming from these HWI. This is so because a comprehension of these interactions and, more importantly, conflicts, is essential for the formulation of effective mitigation and management strategies to resolve HWC (Basak, Hossain, et al., 2022). Therefore, successful mitigation strategies call for interdisciplinary methodologies that integrate ecological insights, urban planning frameworks, and community involvement to promote coexistence and mitigate adverse impacts for both human populations and wildlife (Basak et al., 2020).

1.1 Reports of human-wildlife conflict and hot spot analysis

Official municipality reports are valuable for understanding HWC because they provide direct, localised data on the interactions between people and wildlife (Buchholtz et al., 2023). These records often include details on property damage, animal-vehicle collisions (AVC), and other incidents, offering a quantitative basis for assessing the nature of conflicts in specific areas (Basak et al., 2020). Furthermore, consistent data collection over time allows for the evaluation of long-term trends and the effectiveness of implemented interventions (Redpath et al., 2013). These records offer a systematic basis for assessing the magnitude and patterns of HWC over time and across different urban locations. By analysing such data, urban planners, wildlife managers, and policymakers can identify conflict hot spots, evaluate the effectiveness of existing mitigation measures, and develop targeted strategies to address specific challenges (Basak, O'Mahony, et al., 2022; Ritzel & Gallo, 2020). Such wildlife conflict hot spots refer to specific locations where wildlife conflicts occur more frequently than anticipated (Bíl et al., 2019). The combination of various physical factors, including habitat type, terrain, and landscape, plays a significant role in determining the distribution of these hot spots (Chen et al., 2016). Consequently, mapping the presence or activities of urban wildlife, more importantly, those identified as conflictual species by urban inhabitants, is essential for identifying hot spot locations, thereby enhancing efforts to identify areas with a high likelihood of HWC (Ramp et al., 2005). To achieve this, a spatial strategy focused on identifying high-priority conflict hotspots should be widely utilised (Ruda et al., 2018).

1.2 Perceptions and attitudes towards urban wildlife

Furthermore, to understand the nature of any conflict with wildlife in an urban environment, we must include human users, which requires the integration of ecology with social science (Milner-Gulland, 2012). However, disciplinary boundaries often hinder conservation science (Struebig et al., 2018) due to a lack of integration of scientific disciplines. Consequently, conservation interventions involving ecological social systems are still limited (Redpath et al., 2013; Rissman & Gillon, 2017), yet essential when addressing an effective biodiversity management strategy. This holds particularly true when addressing HWC (Pooley et al., 2017; Struebig et al., 2018). The number of people living in human-modified areas can provide an untapped and valuable opportunity to engage the public in the process of ecological research (Dickinson et al., 2012). Therefore, public participation, which is the applied aspect of human dimensions of wildlife management, has the potential to assist managers in obtaining insights into the perspectives (such as beliefs and levels of support or opposition for the species and its management) (Bath, 1998). Thus, residents' perception and attitude data regarding urban wildlife are also important in understanding the conflict, as they highlight the nuances and complexities of public opinion toward wildlife within urbanised settings, and provide essential insights into human tolerance, risk perception, and support for various management strategies. Investigating attitudes and perceptions of residents towards wildlife is indispensable for crafting effective conservation strategies, fostering community participation, and addressing the complex challenges inherent in human-wildlife coexistence within urban environments (Nicole, 2019). Thus, neglecting human perception data in conservation efforts may lead to misalignment with community needs and values, potentially undermining long-term effectiveness and sustainability (Nicole, 2019).

By 2025, an impressive 60.50% of Poland's population will reside in cities, surpassing the global average of 53.80%, and this figure is projected to rise to 70.4% by 2050 (*UN*, 2025). Yet, existing urban studies have numerous limitations that restrict our understanding of urban wildlife ecology. Nevertheless, the focus on a single species or a single city stands out as the most constraining factor of current urban wildlife research (Magle et al., 2019). Therefore, this research aimed at understanding urban HWC across multiple species in two Polish cities (Krakow and Gdansk) over two years (2022 and 2023). This aim was achieved by the following three specific objectives:

1. Firstly, to identify and depict (temporally and spatially) official reports concerning conflicts with urban wildlife while delineating regions identified as wildlife conflict hot spots.
2. Secondly, to understand residents' attitudes towards urban wildlife, particularly focusing on species that cause conflicts.
3. Finally, conduct a comparative analysis between official conflict reports and public opinions to evaluate the extent to which the official documentation accurately represents the people's perception of conflicts within urban environments.

Thus, understanding the HWC in Polish cities is necessary to manage urban green spaces, create effective mitigation plans to minimise HWC, thereby creating coexistence between humans and wildlife. Ultimately, the result of this study will enable us to understand and improve the conservation of urban wildlife in Poland and other urban areas around the world.

2. Material and Methods

2.1 Study area

The study was carried out in two cities in Poland (Fig. 1). The first study area was the city of Krakow (N 50°02′59″ and 19°56′40″ E), the second-largest city in Poland with an area of 327 km^2 and a human population of 803,282 (Karwinska et al., 2024). The city has a population density of 2457 people per 1 km^2 in the most populated regions (Karwinska et al., 2024). The city is located in the southern part of the country and is an important transportation hub for major national and international roads. The River Vistula bisects the city, thereby serving as a natural migration corridor for many wildlife species. The city is home to many wildlife species, such as wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*) and medium-sized carnivores such as red fox (*Vulpes vulpes*) and stone marten (*Martes foina*) (Basak et al., 2020). The sightings of wildlife have constantly risen since the 2000s (Wierzbowska et al., 2017). The city's built-up and urbanised areas constitute over 45% of the city, with 44% of the city used for agricultural purposes, including crops, orchards, meadows and pastures. In terms of land use and land cover, the city exhibits one of the most rapid land development dynamics (Cegielska et al., 2018).

The second study area was the city of Gdansk (N 54°21′07″ and E 18°38′46″), the sixth largest city in Poland with an area of 262 km^2 and a human population of 470,621 (https://www.brg.gda.pl/). It has a population density of 2001-2568 people per 1 km^2 in the most populated regions (https://bdl.stat.gov.pl/, 2023). The city is located in the northern part of the country and is a principal seaport of Poland. The population density and distribution generate various problems, such as habitat fragmentation and strong anthropopressure on fauna that have limited migration possibilities (Borman et al., 2016). The main species in this city are roe deer, wild boar and red fox (Jakubas et al., 2018). In terms of land use and land cover, in recent years, Gdansk has observed a noticeable reduction in agricultural and fallow land and an increase in built-up area. For example, the built-up area increased from 23.38% in 2005 to 33.06% by 2022. Similarly, fallow land decreased from 18.03% in 2005 to 10.91% by 2022 (Gulshad et al., 2024). This substantial change in the land cover of both cities over the last decade has led to frequent sightings of wildlife, thereby facilitating the choices of the study areas. The estimated number of individuals for the species in the two cities is given in Table 1.

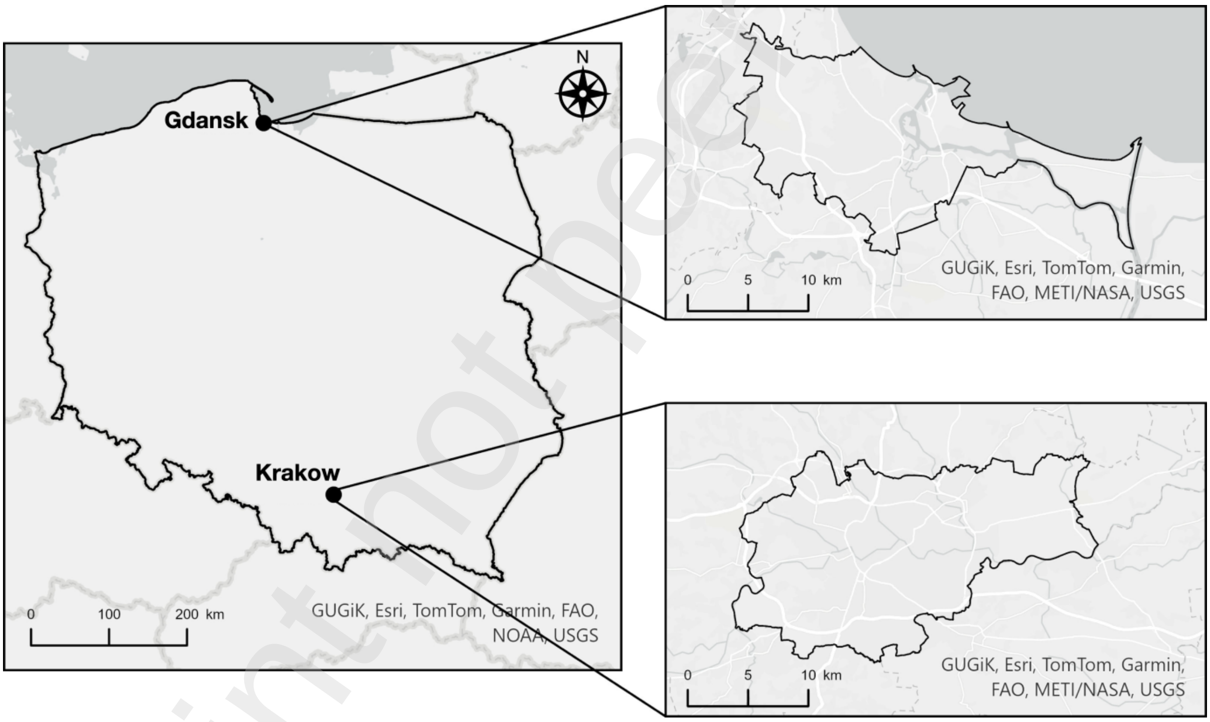

Figure 1. The location map of the cities of Krakow and Gdansk in Poland.

Table 1: Distribution of common species in Krakow and Gdansk

City	Category	Species				
		red fox	marten	red deer	roe deer	wild boar
Krakow	Estimated number	179	104	76	536	135
	Shot or lost in previous year	110	8	27	141	668
	Planned harvest	225	50	30	174	328
Gdansk	Estimated number	80	25	-	180	25
	Shot or lost in previous year	137	4	-	47	71
	Planned harvest	140	15	-	48	45

Source: Forest Data Bank, Poland (https://www.bdl.lasy.gov.pl/portal/en)

2.2 Data Collection

2.2.1 Data from official municipality records

In Krakow, the Department of Environment, Climate, and Air, Division of Nature, Agriculture, Forestry and Animals is responsible for maintaining conflict data with wildlife. The reports are collected by the 24-hour emergency services for protected and game animal species in the Municipality of Krakow and passed on to the contractor (CentrumHodowlane.pl). The contractor reviews these reports for content accuracy. Later, the contractor submits monthly reports on interventions to the municipality of Krakow, specifically to the Department of Environment, Climate, and Air.

In Gdansk, the Municipal Crisis Management Centre (MCZK) is responsible for handling reports related to the presence of large game animals and intervening when necessary. Residents can submit reports through multiple channels, including directly to the MCZK via a 24-hour phone number or email, as well as through other units that provide round-the-clock contact services. Examples of such units are the Gdansk Contact Centre, where reports can be made by phone, email, or through the dedicated 'Contact Gdansk' application, or the Gdansk

Municipal Police Department, which can be contacted via phone or email. Reports were also received from other public safety agencies, such as the Police or the Fire Department. Each report is forwarded to the MCZK duty officer, who registers it in the DART public safety management system and communicates it to the intervention team. Based on the nature of the report, the duty officer determines whether it necessitates immediate intervention (e.g., in the case of injured animals) or if it serves an informational purpose, aiding in the planning of actions in the reported area. Reports either specify a particular address or, as is common in most cases, indicate a general area where the wildlife was present. In such instances, the location of the event is assigned to the nearest specified address or described approximately, for example, by indicating a street and providing a verbal description of the area. In cases where clarification is warranted, the intervention team or other services may attempt to contact the reporting individuals to refine the location details, provided that the information is not sufficiently precise.

2.2.2 Data from questionnaire

From March to October 2024, a self-administered electronic questionnaire was made available for residents of Krakow and Gdansk to complete online through Google Forms. The questionnaire was designed to seek answers about HWC in the previous year (2023). The link to the questionnaire was disseminated extensively via email distributions, social media channels, and through the respective municipalities of both cities. The online questionnaire had three well-differentiated sections:

1. Socio-demographic information, encounters with wildlife and their reported behaviour

2. Perceptions of conflictual wildlife and their associated problems

3. Attitudes toward wildlife in the city

The first section of the questionnaire addressed the sociodemographic information of the respondents, such as age group and city of residence. Additionally, we also enquired whether they had observed wildlife in the city in the last year. The respondents were further asked to identify the three most frequently observed wildlife species in the last year within 100 m of distance and their behaviour. To aid in identifying specific wildlife behaviour, multiple choices were provided as options to choose from, such as "wildlife showed no fear", "wildlife was aggressive", or "wildlife was friendly". Multiple behaviour options for one wildlife species were accepted. For example, if one specific "wildlife showed no fear", it could also "ask for food". However, we did not ask about the number of wildlife (individuals) observed.

The second section of the questionnaire was intended to identify if respondents have had any problems with wildlife in the city in the last year. Answers to the next specific questions were only required from the respondent if they were relevant to this declaration. For example, if the respondents opined positively about having problems with wildlife in the city, they were asked to identify the species and choose from the problems mentioned in the questionnaire or mark as 'others.' Multiple choices were accepted, i.e., respondents could choose multiple problems with one specific wildlife. On the other hand, if the respondents chose "no" or "I don't know" for the same question, they were asked to proceed directly to the third section. A maximum of three problematic species could be identified by each respondent.

The third and final section of the questionnaire aimed to understand the attitudes of respondents toward wildlife. Firstly, the respondents were asked about their attitudes on observing wildlife in the city, and the options ranged from "very positive", "rather positive", "indifferent", "rather negative", and "very negative". Further, we asked respondents to choose a response for statements from the response scale ranging from −2 to +2 (see Appendix A). where −2 indicated 'definitely not', −1 indicated "probably not", 0 indicated "neutral", +1 indicated "probably yes" and +2 'definitely yes'. The statements included, for example, if "a wild animal should be killed" or if "wild animals appear as a result of shrinking their natural habitats". Multiple choices were not approved.

2.3 Data Processing

The data from the official reports were first grouped into seasons for further analysis. The seasons in Poland are categorised as spring (March-May), summer (June-August), autumn (September-November) and winter (December-February) (Basak et al., 2020). Next, the data was grouped into three conflict categories, namely: intrusion (property), damage (caused by wild animals in buildings, cars or other properties), and AVC for both years.

2.4 Data Analyses

2.4.1 Analysis of the official conflict report

Statistical differences between the conflict reports of the two cities were determined by Chi-square tests. The conflict reports from both Krakow and Gdansk were first stratified by months and further grouped into seasons (spring, summer, autumn and winter) of the respective year (2022 and 2023). The number of reports for individual species was visualised using a heatmap. Heat map enabled visualisation of the intensity (high or low) of conflict reports for each species in the two cities (Krakow and Gdansk) for 2 years (2022 and 2023) and for four seasons. Next, the number of conflict reports was normalised and $\log_2$ transformed to visualise the conflictual species in stacked bar plots. Mean values of conflicts ($\log_2$ transformed) for each city were used as a cut-off value (threshold) to determine significance. A Venn diagram was used to determine the number of species in each city that were higher than the cut-off mean, as well as the overlapping species in both cities. To compare variations across cities, types of conflict, year and season, the Wilcoxon Rank Sum test (Haynes, 2013) was used, and the distributions were visualised using box-plots. The p-value was adjusted using Benjamini-Hochberg FDR correction (Benjamini & Hochberg, 1995), followed by p-value ranking using the "rcompanion" (Mangiafico, 2025) package. Seasonal differences for the two cities were determined by Chi-square tests. All analyses were conducted in the R environment (R Core Team, 2020) using the "tidyverse" (Wickham et al., 2019), and "patchwork" (Pedersen, 2025) packages for data processing and visualisation.

2.4.2 Hot spot analyses

Hot spot analysis was performed using ArcGIS Pro 3.2.3 software. This analysis enabled the identification of areas with a high intensity of conflicts involving the common conflictual species. For each species, the analysis was conducted within a hexagonal grid, with each hexagon having an area of 10,000 m^2. The Optimised Hot Spot Analysis tool was employed to calculate areas of intensified use. This tool generated a map of statistically significant hot and cold spots using the Getis-Ord Gi statistics (Getis & Ord, 1992), taking into account event points features. The tool assesses the characteristics of the input feature class to produce optimal results.

2.4.3 Questionnaire dataset analyses

For the questionnaire dataset, a stacked bar plot was used to determine the response for observed and problematic species in both cities. Next, we analysed the relationship between observed wildlife and their behaviour (the two variables) using the Canonical Correlational Analysis (CCA) approach. The statistical significance of CCA analyses (i.e., the significance of overall models, axes and each explanatory variable) was tested using a permutation test (1000 permutations), at $\alpha = 0.05$. CCA, a multivariate statistical method, is effective in revealing the relationship between two sets of variables (Paliy & Shankar, 2016), categorised as explanatory and response variables (Braak, 1986). In our study, the explanatory variables were the behaviour of the wildlife, while the response variables represented the observed wildlife in two cities for two years. We used the Jaccard index calculated from the matrix to perform CCA and determined the variance explained in the dataset. This analysis was performed using the functions in "vegan" (Oksanen et al., 2019) package. A Venn diagram was then performed to determine the overlap of observed and problematic species for both cities. Significant differences between the two cities for problematic species were determined by Chi-square tests. Next, violin plots were used to determine the opinion of the respondents to the statements (values ranging from -2 to +2). Furthermore, to determine the difference in attitudes of the respondents between the two cities, we conducted a linear model for each statement. The p-value was adjusted using Benjamini-Hochberg FDR correction. The problems identified by the respondents from both Krakow and Gdansk, along with the respective conflictual species, were visualised in a Sankey diagram using the "networkD3" (Allaire et al., 2017) package.

3. Results

3.1 Reports concerning conflicts with urban wildlife

In the city of Krakow, a total of 4003 instances of conflicts have been documented over 24 months (2022 and 2023), with 1774 occurrences attributed to the year 2022 and 2229 occurrences corresponding to the year 2023, respectively. In the city of Gdansk, a total of 4049 instances of conflicts have been documented over the same period, with 1707 occurrences in the year 2022 and 2342 occurrences corresponding to the year 2023, respectively. There were no significant differences in reported conflicts between the two cities ($p = 0.05$).

The total number of documented conflicts involving wildlife (Fig. 2a) indicates that wild boar conflicts were the most consistent throughout the year and across seasons for both Krakow and Gdansk. Following closely behind this pattern were roe deer and red fox. Fig. 2b depicts the number of conflict reports, using a cut-off mean value to determine significance. (mean ($\log_2$)- Krakow: 5.98; Gdansk: 4.73). Based on this threshold, six wildlife species, namely wild boar, roe deer, red fox, bat (*Chiroptera* spp.), hedgehog (*Erinaceus* spp.), and red squirrel (*Sciurus vulgaris*), were found to be significantly conflictual (higher than the mean) in Krakow. In comparison, only four species (wild boar, roe deer, red fox and moose *Alces Alces*) were above the threshold in Gdansk (Fig. 2b). Thus, Krakow uniquely reported significant conflicts involving red squirrel, hedgehog and bat, while Gdansk exclusively noted conflicts with moose. Ultimately, the three wildlife species that were commonly involved in conflicts in both cities were wild boar, roe deer, and red fox (Fig. 2b).

Regarding the categories of conflict, in Krakow, out of the 4003 cases, there were 3606 cases of intrusion, 152 cases of damage and 245 cases of AVC. Similarly, in Gdansk, among the 4049 cases, there are 3347 instances of property intrusion, 478 incidents of damage, and 224 cases of AVC. Both cities demonstrated the highest occurrences of property intrusion by wildlife, and there was a significant difference overall between the categories of conflict for both Krakow ($p<0.01$) and Gdansk ($p<0.01$) (Fig. 2c). Furthermore, the analysis of the three conflictual species common to both Krakow and Gdansk revealed distinct patterns in the categories of conflicts with significant differences between the categories (Fig. 3). In Krakow, wild boar recorded the highest cases (n=2385) with the majority of the conflicts being intrusion to property (n=2318), followed by damage (n=54) and AVC (n=13). For roe deer (n=473), the primary conflict incidences were property intrusion (n=347) and AVC (n=126). Red fox (n=267) also had the highest conflict reports with property intrusion (n=244), followed by AVC (n=19) and a few instances of damage (n=4) (SI Table 1). In Gdansk, wild boar recorded the highest cases (n=3558) with the majority of the conflicts being intrusion to property (n=2878), followed by damage (n=582) and AVC (n=98). Roe deer (n=190) also witnessed the highest reports with intrusion (n=98) and AVC (n=92), with no record of damage. Red fox (n=165) had the highest conflict reports with intrusion (n=139) and AVC (n=26) (SI Table 2). Interestingly, there was an absence of any records of damage by roe deer in both cities.

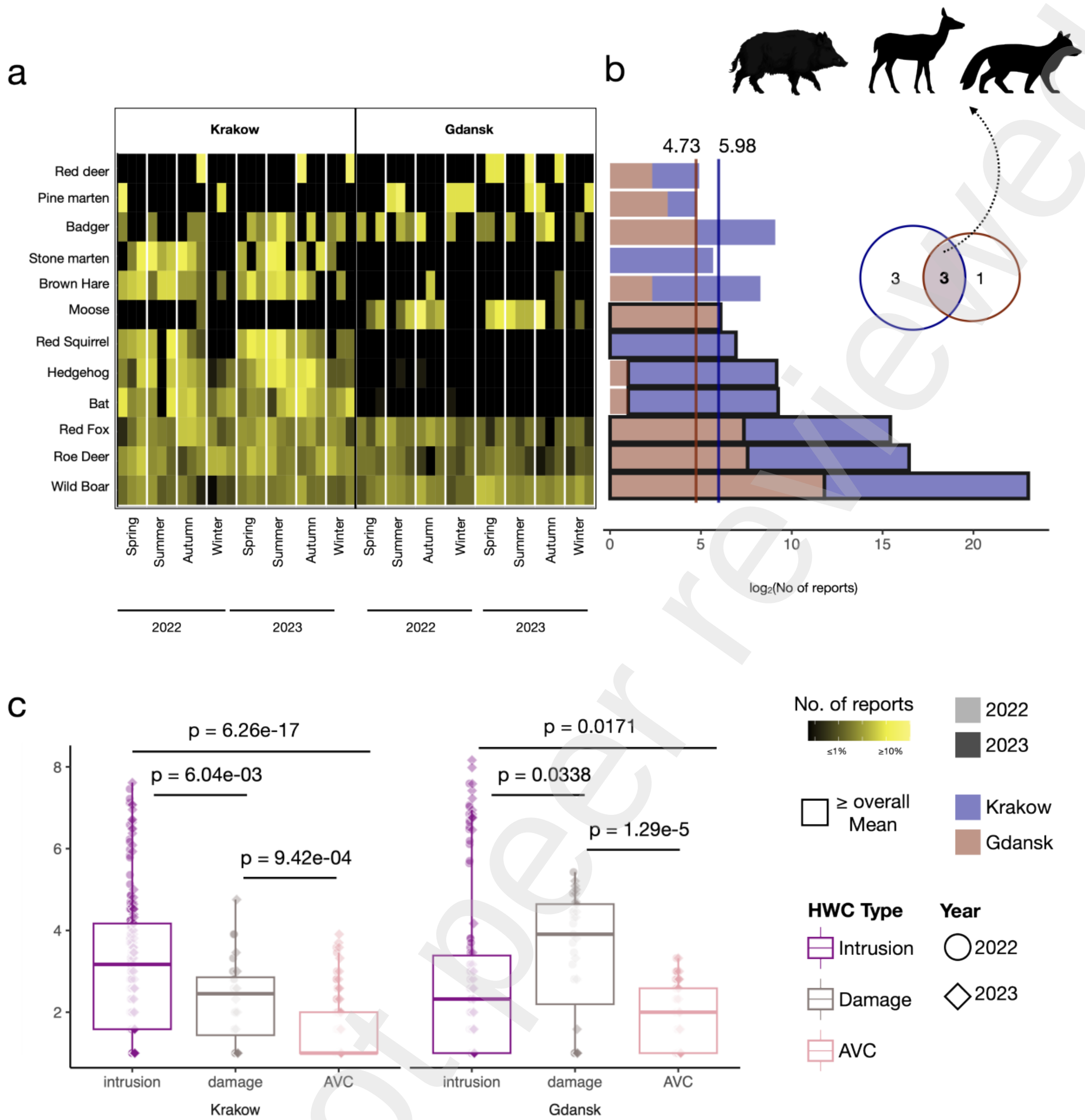

Figure 2. (a) The heatmap showing the percentage of conflict reports for the wildlife reported (y-axis) over season and months (x-axis) across two years for the two cities. The intensity of colour ranges from black (low values) to yellow (high values). (b) Stacked bar graph showing the number of conflict reports (log2) for each wildlife, with the vertical lines representing mean values for Krakow (in purple) and Gdansk (orange). The black box in the stacked bar graph indicates those wildlife which are higher than the threshold value for each city. The Venn diagram shows the number of wildlife species over the mean values in each city and the overlapping species. (c) Boxplots showing distribution of types of conflicts, representing the 25th, 50th (median) and 75th percentiles of the data; the whiskers represent the lowest (or highest) datum within 1.5 × interquartile range from the 25th (or 75th) percentile.

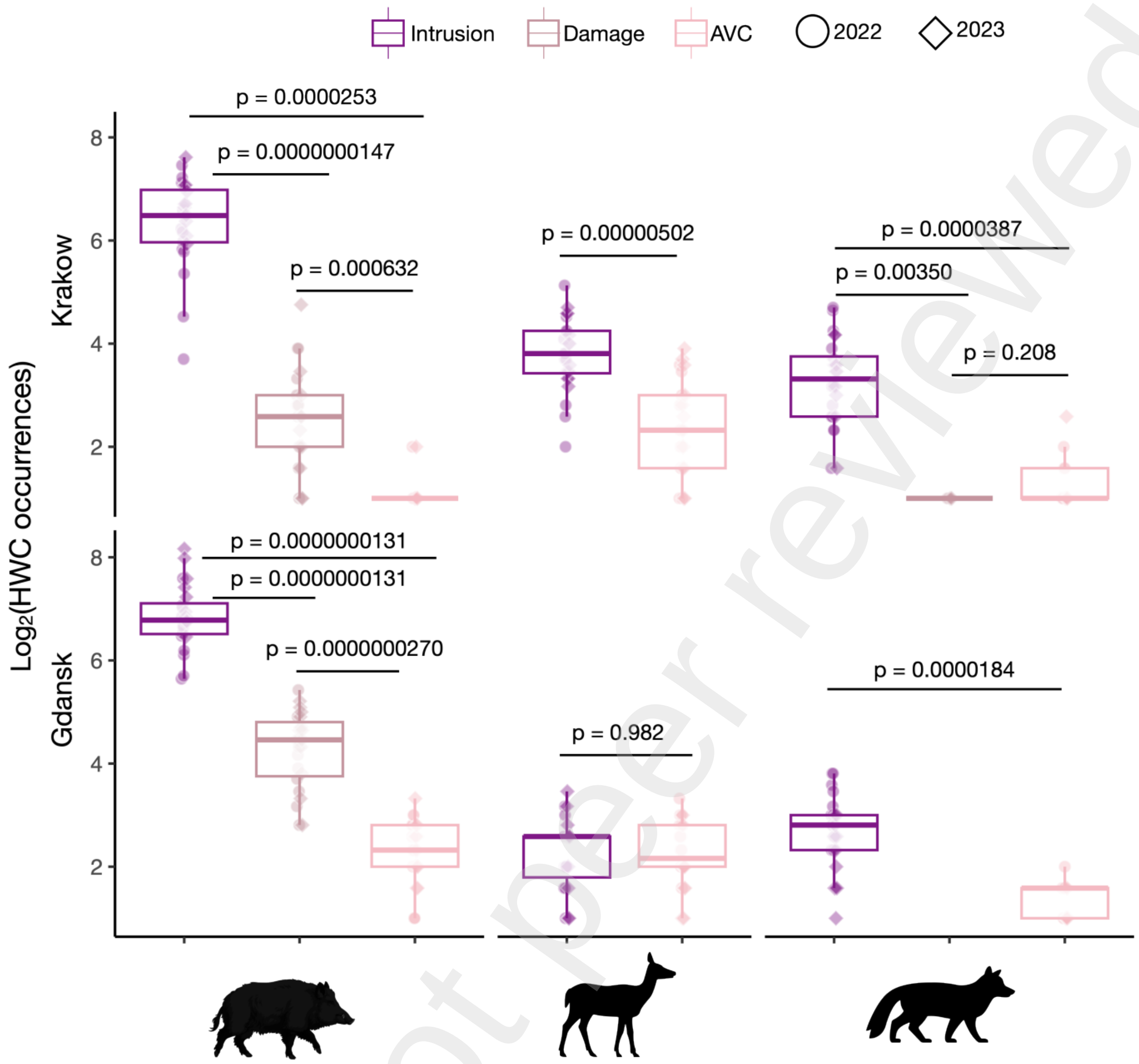

Figure 3. Boxplots showing distribution of types of conflicts of the three common overlapping species in both cities, representing the 25th, 50th (median) and 75th percentiles of the data; the whiskers represent the lowest (or highest) datum within 1.5 × interquartile range from the 25th (or 75th) percentile.

The seasonal breakdown of wildlife conflict reports in Krakow indicates the highest number of reports in spring (n=1187), followed by summer (n=1106), autumn (n=1053) and winter (n=657) (SI Table 1). Thus, there is a statistically significant variation across the seasons in Krakow ($\chi2$ (3, n=4003) = 93.91, $p < 0.01$). A comparable pattern was also observed in Gdansk, where the spring season (n=1263) again witnessed the peak number of reports, followed by autumn (n=1053) and summer (n=970), while the winter season had the lowest reports (n=763) (SI Table 2). The data further indicates a statistically significant difference in the number of seasonal reports in Gdansk ($\chi 2$ (3, n=4049) = 64.59, p <0.01).

A spatial analysis of the records of conflicts involving the three frequent species (wild boar, roe deer and red fox) for both Krakow and Gdansk was conducted. Conflict reports with wild boars revealed the locations of these conflict situations in both cities (Fig. 4). Although locations of reports with wild boar conflicts in Krakow were scattered across the city, these locations appeared to cluster more in the central and south-western regions (Fig. 4a). The distribution of hot spots for wild boar conflicts was thus more concentrated in these areas (Fig. 4b). Although reports of wild boar conflicts in Gdansk were mostly concentrated in the central part of the city (Fig. 4c), there were only small patches of hot spot conflict zones in the centre of the city (Fig. 4d). Similar spatial distribution maps of wildlife conflicts and their hot spots were reported for roe deer (SI Figure 1) and red fox (SI Figure 2).

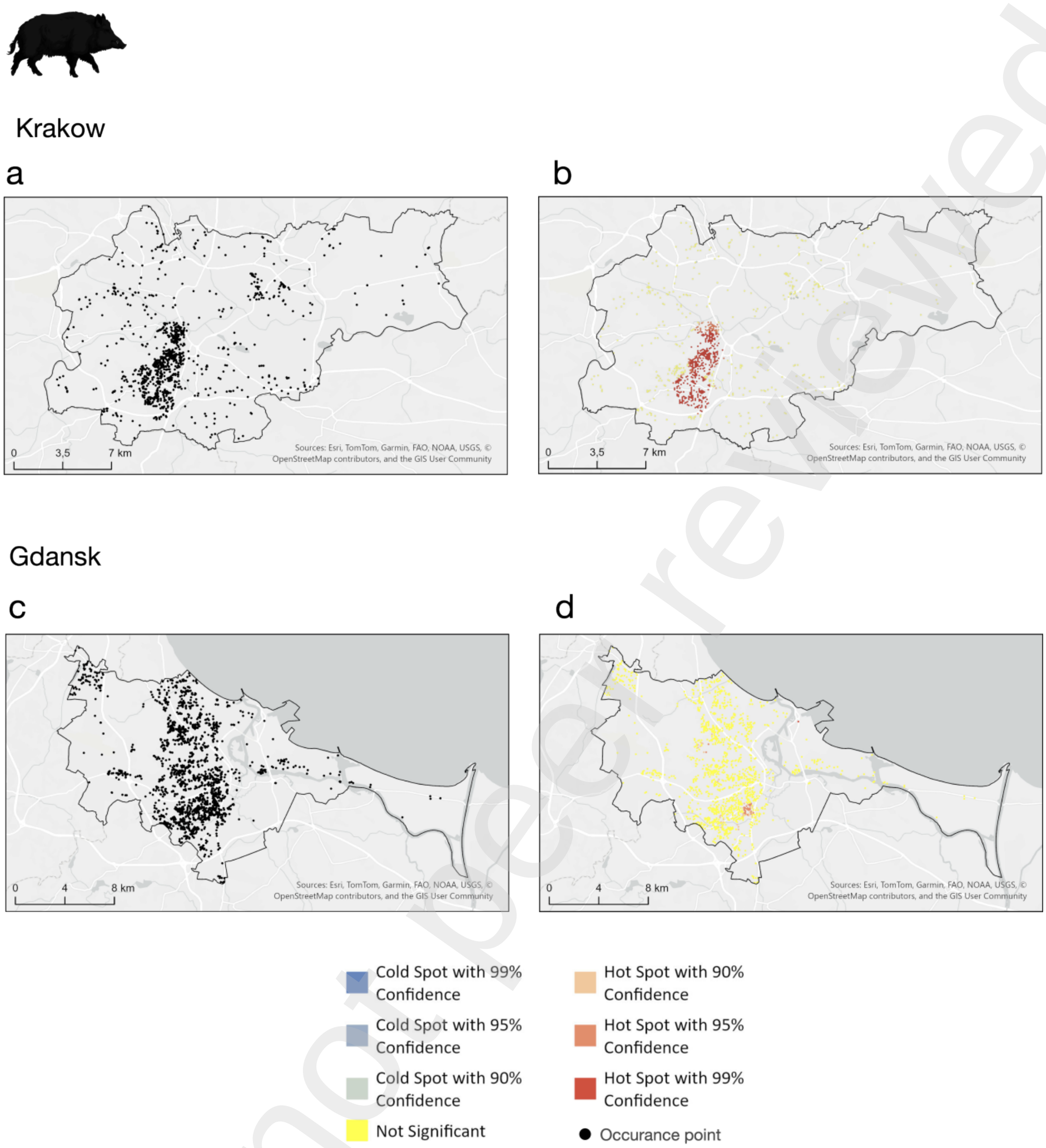

Figure 4. Spatial distribution of conflicts with wild boars. (a) Map of Krakow with black dots representing specific locations of reported conflicts. (b) Hot spot mapping of conflicts with wild boars in Krakow. (c) Map of Gdansk with black dots representing specific locations of reported conflicts. (b) Hot spot mapping of conflicts with wild boars in Gdansk.

3.2 Residents' attitudes towards urban wildlife and conflictual species

A total of 100 respondents participated in the questionnaire survey for both Krakow and Gdansk. Of the 100 respondents in Krakow, 48 respondents were male and 50 were female, while 2 respondents preferred not to disclose their gender, with the mean age of the respondents (±SD) being 35 years (±13.21). Similarly, in Gdansk, out of the 100 respondents, 44 were male, 52 were female, and 4 preferred not to disclose. The mean age of the respondents (±SD) in Gdansk was 36 years (±12.96).

When surveyed, 92 and 98 respondents in Krakow and Gdansk, respectively, reported encountering wildlife within their cities over the past year. In Krakow, the most frequently observed species was wild boar (n=55), followed by red squirrel (n=42), hedgehog (n=33), mallard (*Anas platyrhynchos*) (n=28), roe deer (n=26), red fox (n=18), swan (*Cygnus olor*) (n=13) and stone marten (n=9). Similarly, in Gdansk, wild boar was the dominant observed species (n=83), followed by red fox (n=49), hedgehog (n=28), red squirrel (n=26), roe deer (n=21), swan (n=11), mallard (n=10) and stone marten (n=9). However, the perception of wild animals as problematic within the cities differed between the two cities. Over 50% of the participants (n=54) in Gdansk expressed the view that the presence of wild species was problematic, whereas less than 35% (n=34) conveyed a similar sentiment in Krakow (Fig. 5a; SI Table 3).

The first canonical axis (CCA1), which accounted for 72.13% of the explained variation, reflects a continuum in how urban wildlife is perceived along with their behaviour, ranging from problematic to friendly ($p<0.01$) (Fig. 5b). Species on the negative end of this axis, such as the stone marten, wild boar, bat and red fox, were more frequently associated with negative interactions in urban contexts, including no fear, aggressive and running away. In contrast, species like the mallard, roe deer, swan, red squirrel and hedgehog positioned on the positive end, were generally associated with positive behaviour such as being friendly or asking for food. The second axis (CCA2) explained 15.63% of the variation (Fig. 5b). Species with higher scores on this axis, such as those associated with behaviours like approaching or attacking humans (e.g., wild boar), are perceived as more aggressive or confrontational, whereas lower values reflect more neutral or avoidant behaviours.

The questionnaire results indicated that respondents in Krakow identified wild boar (n=21), red fox (n=8), stone marten (n=8) and roe deer (n=6) as the most problematic wildlife species encountered. Interestingly, while Gdansk respondents also highlighted wild boar as the most problematic (n=56), the level of reported conflicts was significantly higher compared to Krakow ($\chi2 = 7.94$, $p = 0.004$). Other species deemed problematic in Gdansk included red fox (n=12), roe deer (n=9) and stone marten (n=8). Notably, four species were consistently reported as both frequently observed and sources of conflict in both cities: wild boar, stone marten, red fox, and roe deer (Fig. 5c).

When the respondents in Krakow were queried about their perceptions of urban wildlife, they expressed a generally favourable outlook. A considerable majority (n=50) were either “very positive” (n=18) or “rather positive” (n=32). About a little more than 25% of respondents (n=26) were “indifferent” towards wildlife. Although none reported a “very negative” attitude, some respondents (n=26) were “rather negative” towards wildlife (SI Table 3). Overall, the residents of Krakow demonstrated a moderately positive attitude towards the wildlife inhabiting their urban environment. In contrast, in Gdansk, 41 respondents were generally positive with either "very positive" (n=16) or "positive" (n=25) attitudes. A few (n=17) indicated an "indifferent" attitude towards wildlife. Similarly, about 42 respondents indicated a negative attitude towards wildlife, which included both "very negative" (n=19) and “rather negative" (n=23) attitudes (SI Table 3). This distribution indicates a more polarised range of attitudes in Gdansk compared to Krakow (Fig. 5d), with a noticeable segment expressing negative sentiment.

When surveyed about (statements) people's attitudes towards wildlife within the city (ranging from -2 to +2), respondents from Krakow and Gdansk exhibited some significant differences in perspective (Table 2). While both groups generally maintained a neutral stance on whether wildlife posed a threat to people, Krakow residents tended to hold a slightly more positive view (-0.12) on this matter compared to their counterparts in Gdansk (0.08) (Table 2). Despite this slight difference of opinion, respondents across both cities preferred to coexist with urban wildlife, as long as human safety was not compromised. However, there was a stronger consensus among Gdansk respondents (0.72) that wildlife should be relocated to their natural habitats outside the city limits than Krakow respondents (0.33). Interestingly, both Krakow and Gdansk residents largely disapproved of more extreme measures, such as shooting or using pharmaceutical methods, to manage wildlife populations. Yet, Krakow respondents demonstrated a greater level of non-acceptance for such approaches compared to Gdansk residents (Table 2). Amidst these differences, one common thread emerged - respondents in both cities generally felt a sense of connection to nature when observing wildlife within the urban environment. The general distribution of the responses from both cities is depicted in Fig. 5d.

Table 2. Results of the survey participants' attitudes toward wildlife conducted in Krakow (n=100) and in Gdansk (n=100), showing descriptive statistics, differences in attitudes using linear model (FDR correction), where n=number of respondents

Statements	Krakow		Gdansk		p-value
Wild animals in the city…	Mean †	SD	Mean †	SD	
… are a source of danger to people	-0.12	1.04	0.08	1.46	**<0.01**
… should be killed by shooting	-1.45	0.95	-1.2	1.29	**<0.01**
… should be killed pharmacologically	-1.29	1.01	-1.2	1.21	**<0.01**
…should be relocated to their natural habitat outside the city	0.33	1.28	0.72	1.29	**<0.01**
…make me feel connected to nature	0.25	1.44	0.24	1.53	0.624
…appear as a result of shrinking their natural habitats	1.44	0.98	0.94	1.32	**<0.01**
…can live in this city without interfering with the interests of humans	0.14	1.17	-0.03	1.43	**<0.01**

† Range based on a 5-point scale: −2 (definitely no) to +2 (definitely yes). Bold font indicates significant p values, $p < 0.05$.

Respondents from both cities identified wild boar as the most conflictual, yet the number was significantly different for the two cities. Respondents from Gdansk identified wild boar (n=140 incidents) as more problematic than in Krakow (n=30 incidents) (Fig. 5e). Destruction of crops (n=14 incidents) was identified as the major concern, followed by fear (n=13 incidents) in Krakow. On the other hand, fear (n=51 incidents), noise (n=26 incidents), destruction of property (n=21 incidents) and aggression (n=20 incidents) were the major concerns for the respondents in Gdansk (Fig. 5e).

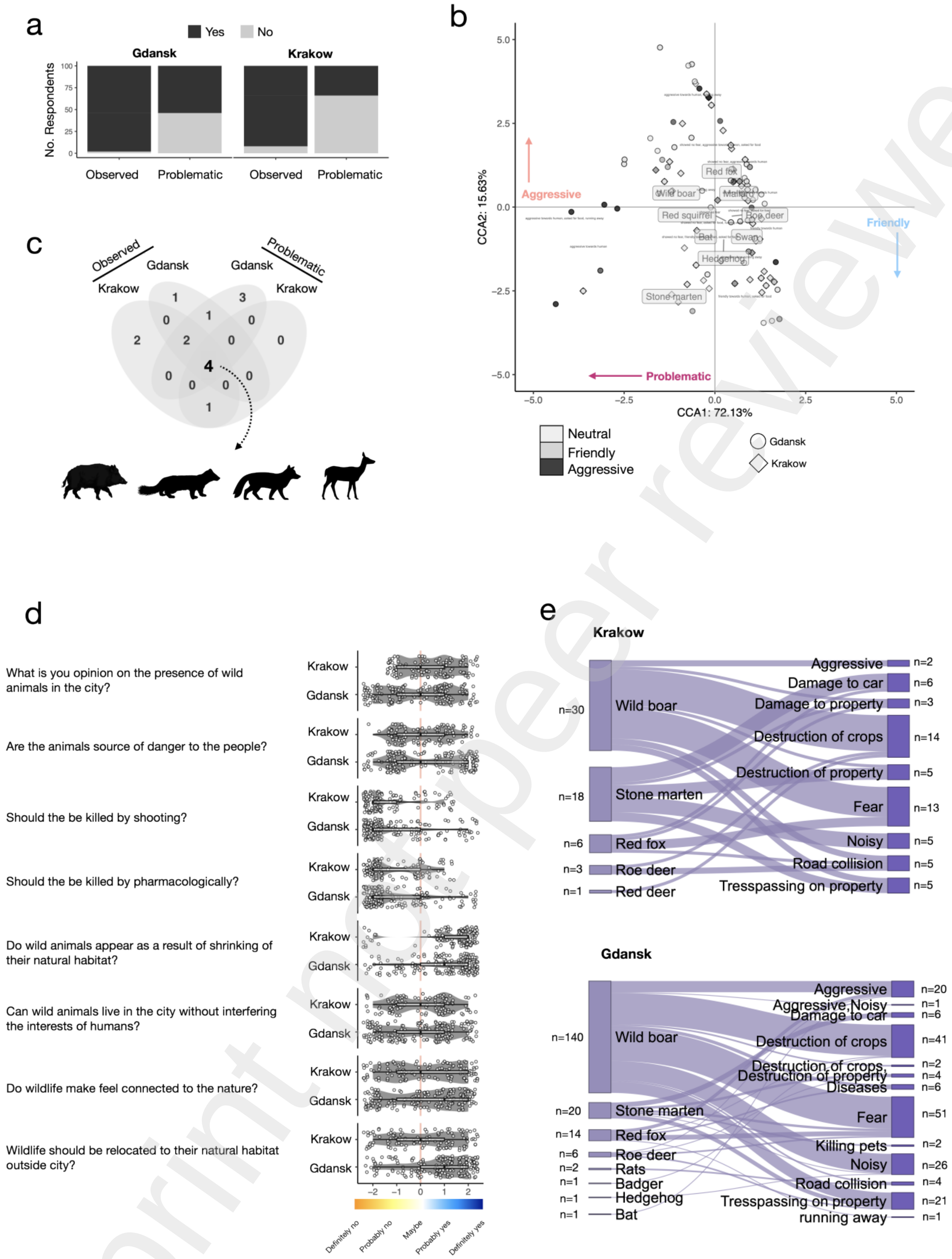

Figure 5. Questionnaire responses. (a) Stacked bar graph showing responses for the observed and problematic species in both cities, with the number of respondents on the y-axis. (b) Canonical correlational analysis (CCA) ordination biplot of wildlife and their reaction while observing residents as recorded in Krakow and Gdansk. (c) Venn diagram showing the overlapping of observed and

problematic species in Krakow and Gdansk. (d) Violin plots representing the distribution of responses to various statements ranging from -2 (definitely no) to +2 (definitely yes) for both cities. The red vertical line represents 0 (neutral). (e) Sankey diagram showing the linkage between wildlife in the city and the type of conflicts as identified by urban residents of Krakow and Gdansk, with n representing the number of incidents reported.

3.3 Comparative analysis between official conflict reports and public opinions

Official reports from Krakow and Gdansk indicated that wild boar, roe deer, and red fox were the species most often involved in conflicts. Residents' questionnaire responses from both cities confirmed these findings and additionally identified stone martens as a source of conflict (Fig. 5e). The number of reported conflicts with wild boar was higher in Gdansk (n=3558) than in Krakow (n=2318) during the study period, which supports the questionnaire results showing that Gdansk respondents (n=140) viewed wild boar as a significantly greater problematic species than did Krakow respondents (n=30). One of the primary types of conflict reported in both urban areas was property intrusion, a concern that was similarly voiced by the residents of both cities in the surveys conducted. The greater number of conflict reports with wild boars (n=3558) may explain why respondents in Gdansk exhibited less tolerance toward the species, in comparison to respondents in Krakow.

4. Discussion

Our study contributes to the growing body of knowledge on HWI in urban environments, providing insights from the officially reported conflicts as well as perceptions and attitudes of residents in two major Polish cities, Krakow and Gdansk. The study underscores the relevance of understanding local contexts in shaping human-wildlife relationships, highlighting differences between the cities, and emphasises the need for tailored management strategies (Wierucka et al., 2023) that consider both ecological and socio-cultural factors.

4.1 Reports concerning conflicts with urban wildlife

Our results indicated that wild boar, roe deer, and red fox were the wildlife species most frequently involved in conflicts with humans throughout the year and across seasons in both Krakow and Gdansk, with wild boar being the most conflictual. This can be attributed to wild boars being highly adaptable to urban environments (Marin et al., 2024). Habitat loss and increased urban food availability (trash) have caused frequent interactions of wild boars with humans and a corresponding increase in conflict (Stillfried et al., 2017). Similarly, urban red foxes are known to be bolder (Morton et al., 2023) , with their population densities several times higher in urban landscapes than in rural counterparts (Padovani et al., 2021), a potential reason for rising conflicts. Increasing conflicts with roe deer in urban matrix can be attributed to the species having flexible habitat choices (Ciach & Fröhlich, 2019) and digestive plasticity (Brucks et al., 2022).

Our finding that Kraków reported a greater diversity of conflictual species compared to Gdansk, yet Gdansk experienced a higher number of reported conflicts, may stem from variations in urban green space characteristics, wildlife management strategies, or public awareness and reporting systems (Fidino et al., 2021). Although cities are the hallmark of urbanisation, they each have their structural signature penned by land-use policy, coastlines or inland waterways, and topography (Magle et al. 2019). Furthermore, the unique reports of conflicts with red squirrels, hedgehogs, and bats in Krakow, as well as moose in Gdansk, highlight the importance of considering local contexts when developing strategies to mitigate HWC in urban areas. It is an interesting finding that species occupancy patterns are different among cities, as it implies that growing cities can be planned in such a way as to reduce the negative influence of urbanisation on biodiversity (Fidino et al., 2021).

The HWC conflict categories in Krakow and Gdansk provided valuable insights into the nature of these interactions. Consistent with the existing literature, the predominance of property intrusion cases highlights the adaptability and urban encroachment of certain wildlife species, such as wild boar, roe deer, and red fox (Bateman & Fleming, 2012; Soulsbury & White, 2015). The significant differences in the distribution of conflict types between the two cities suggest that local factors, including urban green space characteristics, wildlife management practices, and public awareness, play a crucial role in shaping the dynamics of HWI (Bhatia et al., 2020). The finding that roe deer were not associated with any reported damage cases in either city, despite their high levels of property intrusion and involvement in AVC (Brieger et al., 2022; Märtz et al., 2024), aligns with the idea that these species may be less destructive but still disruptive to the urban environment (Ciach & Fröhlich, 2019). The distinct patterns observed in the categories of conflicts for the three common conflictual species (wild boar, roe deer, and red fox) across the two cities further highlight the importance of shaping management strategies to address the unique challenges posed by each species in their respective urban contexts (Basak et al., 2020).

The observed seasonal variations in HWC reports in Krakow and Gdansk support previous studies that have highlighted the role of seasonality in shaping these interactions

(Metz et al., 2011). The higher number of incidents during the spring and summer months can be attributed to increased wildlife activity and resource availability, as well as greater human presence and outdoor activities during these seasons (Wu et al., 2024). Conversely, the lower levels of reported conflicts during the winter season may be associated with decreased animal and human activity, as well as reduced opportunities for encounters due to environmental conditions (Jakstis & Fischer, 2024). Our findings suggest that the dynamics of HWI in urban environments are influenced by seasonal factors, which should be considered when addressing and mitigating such conflicts.

The spatial analysis of reported HWC in Krakow and Gdansk provided valuable information about the distribution and clustering of these interactions within the urban environment. Our finding that wild boar conflicts in Krakow were scattered across the city, but the hot spot is concentrated in the central and south-western regions, suggests that certain landscape features or habitat characteristics in these areas may be attracting or enabling greater interactions between wild boars and urban residents (Castillo-Contreras et al., 2018). In contrast, the more centralised distribution of wild boar conflicts in Gdansk, with a smaller hot spot zone, implies that the boars tend to avoid areas with high hunting risks (Drimaj et al., 2021). This uneven distribution can create hot spots of wild boar activity, increasing the likelihood of conflicts in these areas. The lack of distinct hot spot analysis for roe deer and red fox conflicts in both cities indicates that these species may be more widely dispersed throughout the urban matrix (Gehrt et al. 2010, Basak et al. 2020), with interactions occurring more evenly across the landscape. This result was also supported by other findings (Gehrt et al. 2010, Bateman and Fleming 2012), which reported that urban carnivores such as red foxes tend to have broad urban ranges, with diffuse spatial conflict patterns rather than concentrated hot spots. This underscores the need for specific management approaches that account for the unique spatial patterns and habitat preferences of different wildlife species within the urban environment (Magle et al., 2012; McCleery et al., 2014).

4.2 Residents' attitudes towards urban wildlife and conflictual species

Our findings revealed how urban residents differentiate wildlife not only based on general favourability but also in terms of the behaviour of wildlife. This aligns with previous research on HWI, which has identified that certain species are more closely associated with negative behaviours and are thus perceived as more problematic (Soulsbury & White, 2016; Bateman & Fleming, 2012). Our results revealed that Gdansk residents perceive wildlife as more problematic compared to Krakow. These insights underline the need for comprehensive urban wildlife management strategies that consider the specific behavioural attributes of different species and alter interventions accordingly. This understanding is critical for fostering coexistence and addressing potential conflicts between humans and wildlife in urban settings (Malley & Gorenflo, 2023).

Moreover, the observed differences in attitudes towards urban wildlife between Krakow and Gdansk residents highlight the importance of considering local contexts and shaping management strategies accordingly. While respondents in both cities generally maintained a neutral stance on the perceived threat posed by wildlife, Krakow residents exhibited a slightly more positive outlook compared to Gdansk. This variation may be attributed to factors such as urban green space characteristics (Cameron et al., 2020), wildlife management practices, and prolonged exposure to wildlife (Mohamad Muslim et al., 2018), which has an impact on public perceptions in urban settings (Basak et al. 2022, Moesch et al. 2024a). Despite this divergence, respondents across both cities expressed a preference for coexisting with urban wildlife, as long as human safety was not compromised. However, Gdansk residents demonstrated a stronger consensus that wildlife should be relocated to their natural habitats outside the city limits. This preference for relocation over lethal management approaches, such as shooting or using pharmaceutical methods, points to the balance that must be maintained between conservation goals and addressing human concerns related to safety, property damage, and negative interactions with wildlife (Magle et al. 2012, McCleery et al. 2014). Our study also found that residents found wild boars problematic, which aligns with findings from other studies where boars are either disliked (Moesch et al. 2024b) or negatively perceived (Conejero et al., 2019).

The contrasting attitudes between the two cities highlight the need for comprehensive public education and information dissemination to empower residents with knowledge about wildlife presence in the city, wildlife ecology and alternative conflict mitigation strategies (Børresen et al., 2023). Interestingly, respondents in both Krakow and Gdansk generally felt a sense of connection to nature when observing wildlife within the urban environment. This finding aligns with the growing recognition of the ecological and socio-cultural benefits (Yeshey et al., 2024) that wildlife can bring to urban areas and the importance of fostering coexistence between humans and wildlife. By adopting a context-specific approach to urban wildlife management, contrary to the one-size-fits-all concept, cities can work towards achieving a harmonious balance that considers both ecological and socio-cultural factors.

4.3 Comparative analysis between official conflict reports and public opinions

Our results were consistent with findings from both official reports and the questionnaire survey, with a higher number of concerns for the respondents in Gdansk city. While wild boar, roe deer, and red fox were identified as conflictual species in official reports, the questionnaire survey highlighted stone martens as an additional source of conflict. However, the limited number of recent studies on this species is noteworthy (Herr et al., 2009; Peeva & Raichev, 2016), given their wide geographic distribution, presence in urban settings, and the first documented cases of vehicle damage dating back to the 1970s (Harrison et al., 2004). Thus, the probable reason why stone martens were not accounted in the official conflict reports could be because they are perceived by residents as more of a nuisance species, similar to that of urban raccoons (*Procyon lotor*) (Mazzamuto et al., 2020) or urban rats (*Rattus* spp.) (de Cock et al., 2024), which do not cause significant materialistic damages. Such species are generally described as 'nuisance species' which take advantage of anthropogenic resources (Diquelou & Griffin, 2020) and create annoyance (Lazure & Weladji, 2024) with the surrounding human communities. Understanding that the conflict between humans and martens is largely neglected in scientific literature (Moesch, Jeschke, et al., 2024; Tóth et al., 2009), future research should prioritise urban stone martens to assess their status regarding risks, nuisances, and conflicts.

5. Conclusion

This study provides valuable insights into the complex dynamics of HWI in urban environments. The differing perceptions and attitudes of residents in each city, influenced by factors such as urban landscapes, management practices, and historical relationships with nature, underscore the importance of context-specific management strategies. The study also highlights the importance of recognising the nuanced differences in how urban residents perceive and interact with wildlife. These differences are rooted in ecological, socio-cultural, and historical factors, underscoring the need for tailored management strategies that address the specific needs and concerns (Basak, Hossain, et al., 2022). Effective urban wildlife management should consider not only the ecological aspects but also the perceptions and attitudes of local communities, as human-wildlife encounters can significantly influence people's views and behaviours (Makumbe et al., 2022). Public education and community engagement are essential components of successful coexistence strategies. By empowering residents with knowledge about wildlife behaviour, ecology, and alternative mitigation strategies, cities can promote a more informed and tolerant approach to urban wildlife, reducing conflicts and fostering a sense of shared responsibility for conservation. As urbanisation continues and wildlife habitats are increasingly encroached upon (Dudzińska & Dawidowicz, 2021), adopting holistic, context-specific approaches to urban wildlife management becomes ever more critical to ensure a harmonious balance that benefits both humans and wildlife (Mekonen, 2020).

AUTHOR CONTRIBUTIONS

Sayantani M. Basak: Conceptualisation, Methodology, Data processing, Data analysis, Writing - original draft. **Michał Strączyński**: Data processing, Writing – Original draft. **Arpan Kumar Basak**: Data analysis, Writing - original draft. **Karolina Piech**: Spatial analysis, Writing – Original draft. **Izabela A. Wierzbowska**: Conceptualisation, Supervision, Data acquisition, Data processing, Writing - original draft.

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DATA AVAILABILITY

The data and code that support the findings of this study are openly available at github at: https://github.com/SAYANTANI26/HWC-Poland

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List of Figures

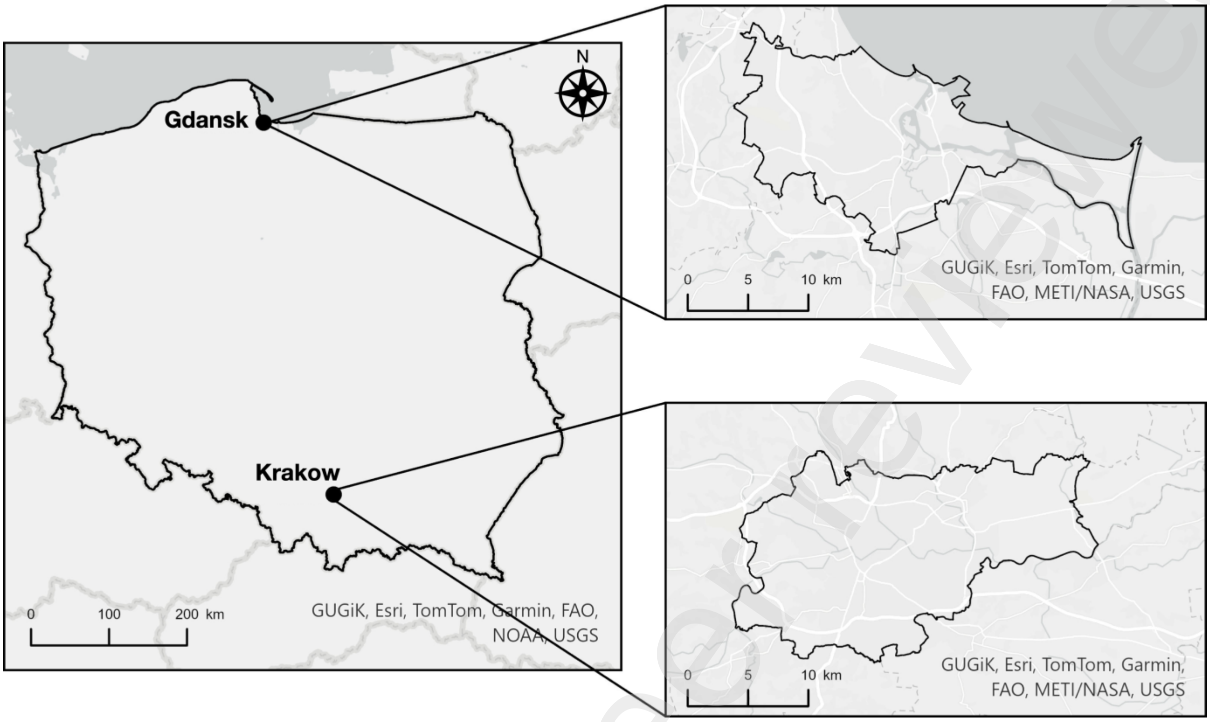

Figure 1. The location map of the cities of Krakow and Gdansk in Poland.

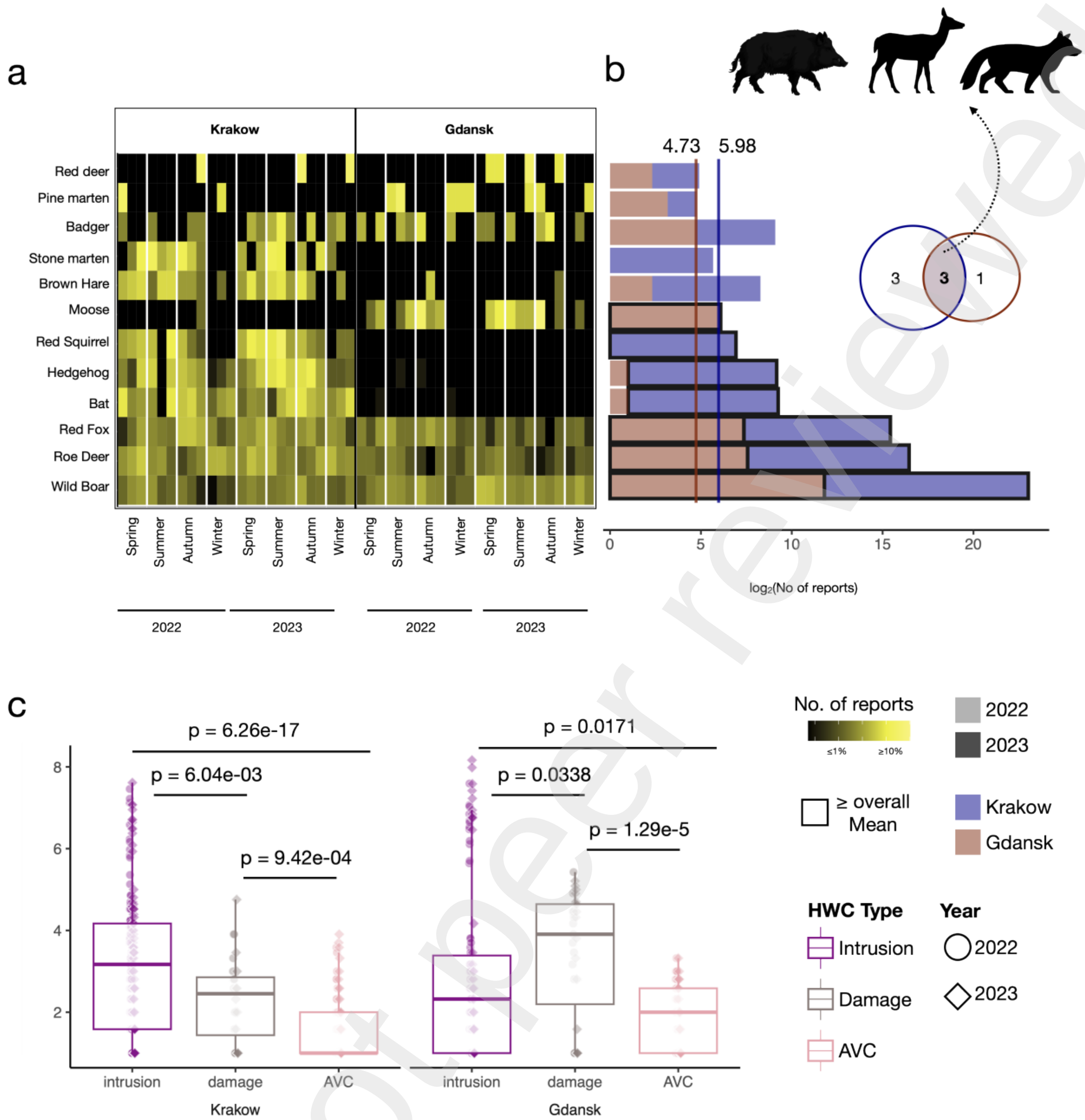

Figure 2. (a) The heatmap showing the percentage of conflict reports for the wildlife reported (y-axis) over season and months (x-axis) across two years for the two cities. The intensity of colour ranges from black (low values) to yellow (high values). (b) Stacked bar graph showing the number of conflict reports (log2) for each wildlife, with the vertical lines representing mean values for Krakow (in purple) and Gdansk (orange). The black box in the stacked bar graph indicates those wildlife which are higher than the threshold value for each city. The Venn diagram shows the number of wildlife species over the mean values in each city and the overlapping species. (c) Boxplots showing distribution of types of conflicts, representing the 25th, 50th (median) and 75th percentiles of the data; the whiskers represent the lowest (or highest) datum within 1.5 × interquartile range from the 25th (or 75th) percentile.

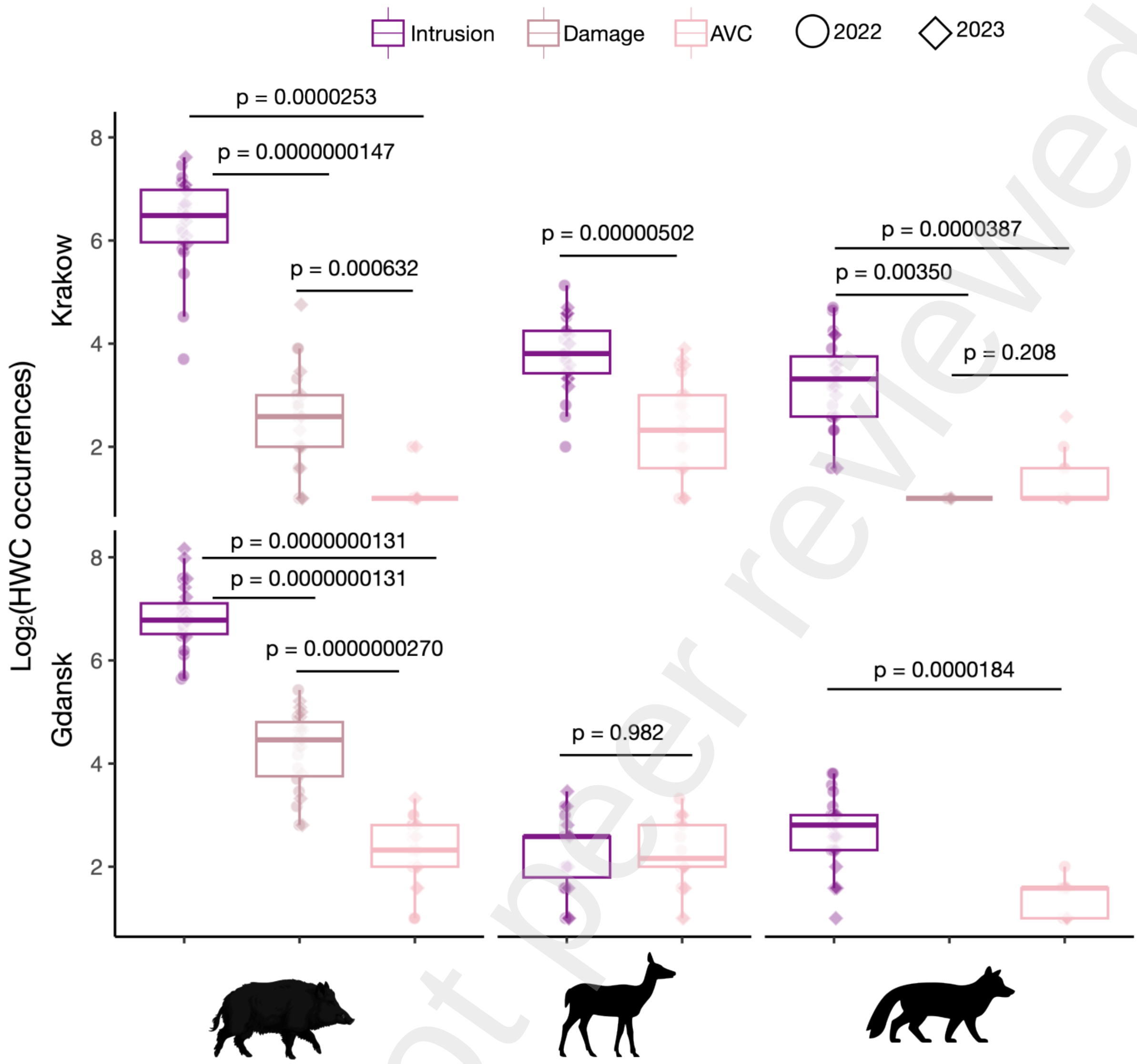

Figure 3. Boxplots showing distribution of types of conflicts of the three common overlapping species in both cities, representing the 25th, 50th (median) and 75th percentiles of the data; the whiskers represent the lowest (or highest) datum within 1.5 × interquartile range from the 25th (or 75th) percentile.

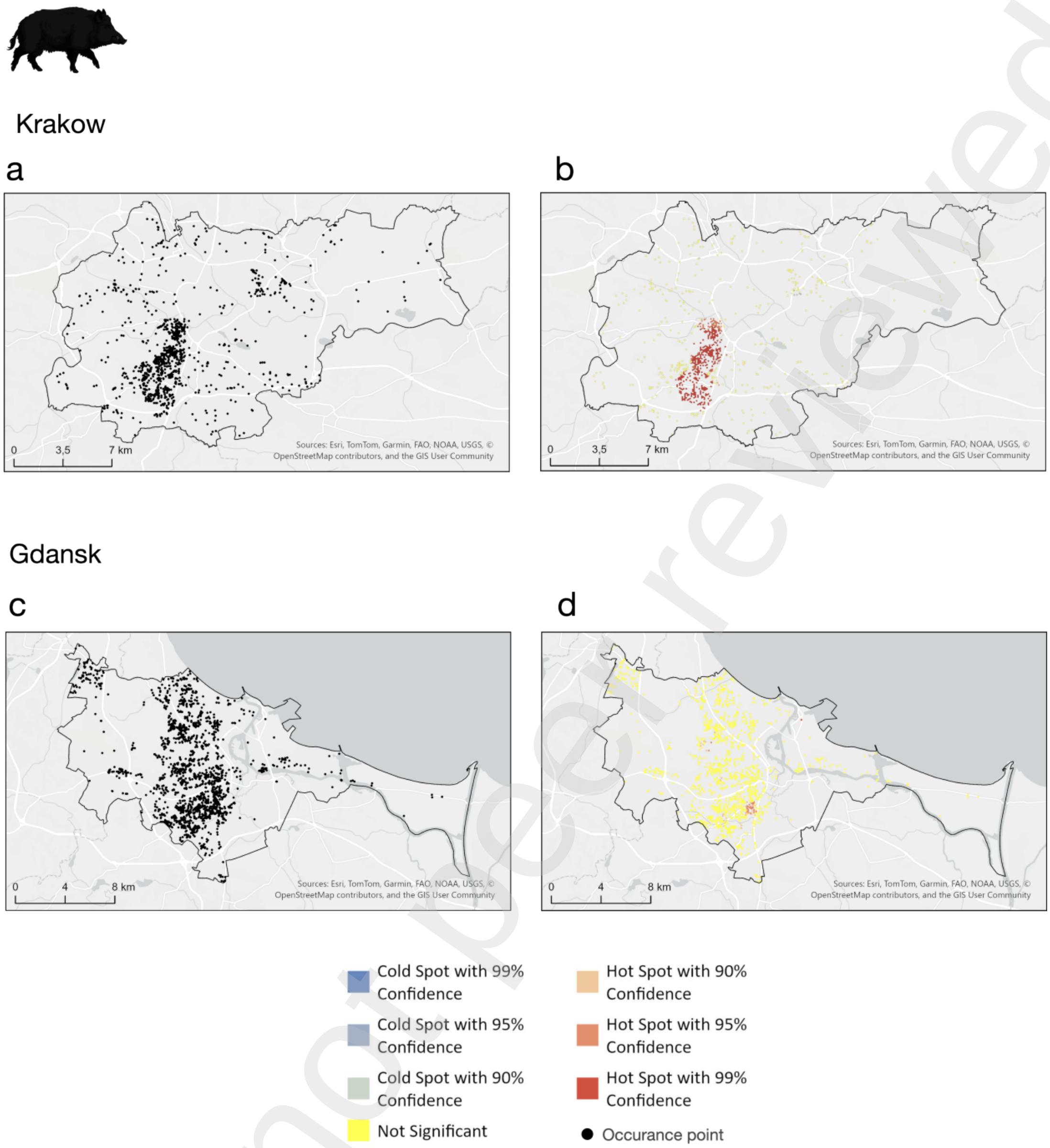

Figure 4. Spatial distribution of conflicts with wild boars. (a) Map of Krakow with black dots representing specific locations of reported conflicts. (b) Hot spot mapping of conflicts with wild boars in Krakow. (c) Map of Gdansk with black dots representing specific locations of reported conflicts. (b) Hot spot mapping of conflicts with wild boars in Gdansk.

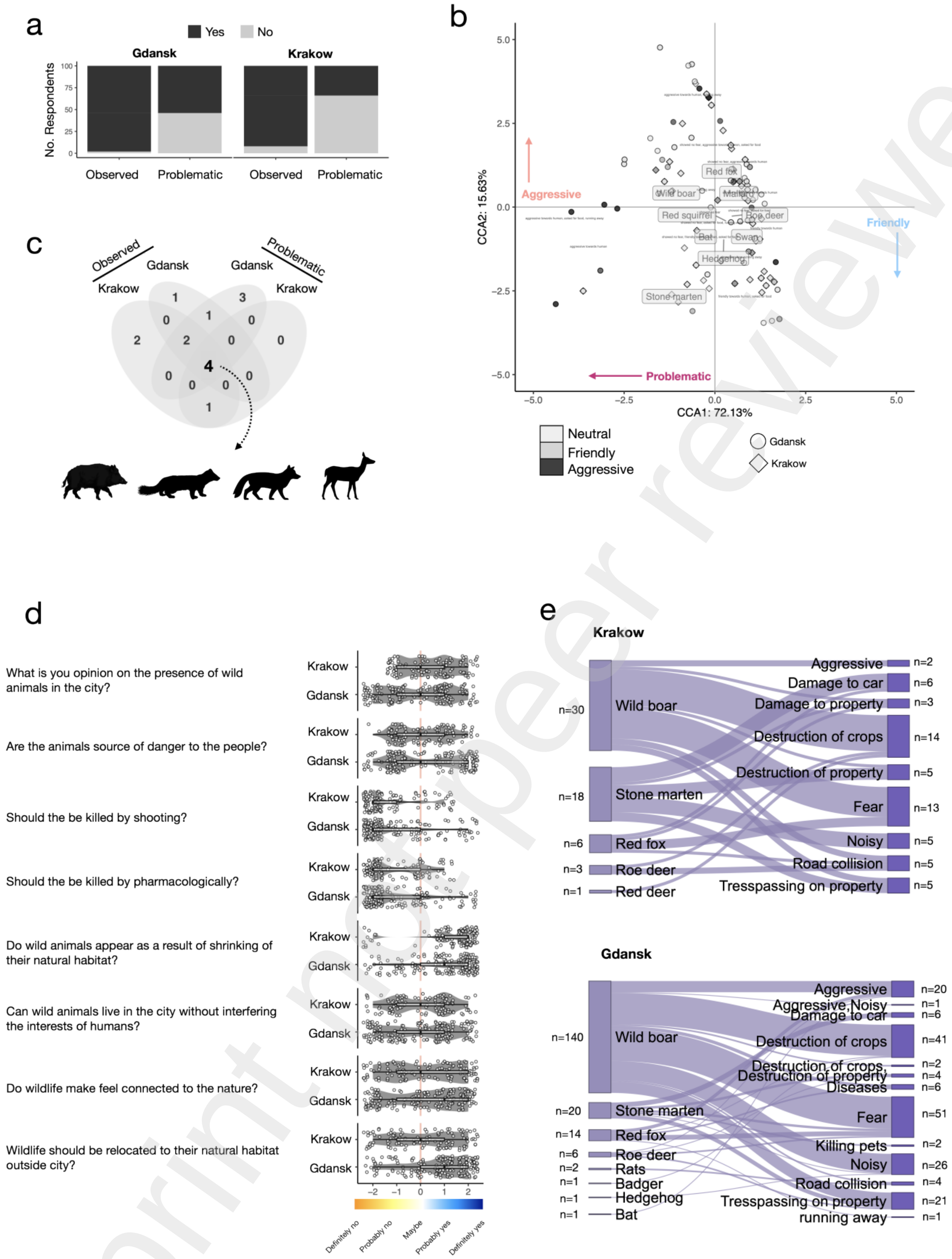

Figure 5. Questionnaire responses. (a) Stacked bar graph showing responses for the observed and problematic species in both cities, with the number of respondents on the y-axis. (b) Canonical correlational analysis (CCA) ordination biplot of wildlife and their reaction while observing residents as recorded in Krakow and Gdansk. (c) Venn diagram showing the overlapping of observed and

problematic species in Krakow and Gdansk. (d) Violin plots representing the distribution of responses to various statements ranging from -2 (definitely no) to +2 (definitely yes) for both cities. The red vertical line represents 0 (neutral). (e) Sankey diagram showing the linkage between wildlife in the city and the type of conflicts as identified by urban residents of Krakow and Gdansk, with n representing the number of incidents reported.