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Public perceptions and attitudes toward urban wildlife encounters – A decade of change

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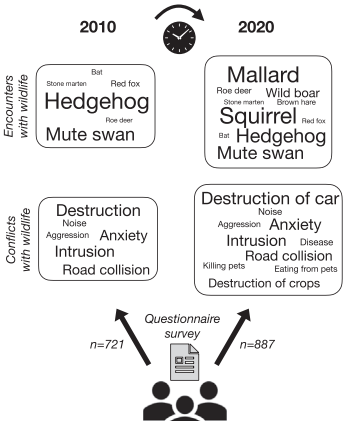
HIGHLIGHTS

- Longitudinal study was effective to analyse decadal changes in perception.
- Urbanites encountered more wildlife in 2020 than a decade earlier.
- Anxiety, damages, road collision and noise were the major problems with urban wildlife.
- Wild boar were the conflictual urban wild animals in 2020.
- Urbanites were aware that wildlife increased in the city due to the shrinkage of natural habitats.

GRAPHICAL ABSTRACT



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ABSTRACT

Europe is currently undergoing dynamic land use changes causing the expansion of urban habitat, which is driving wildlife species to colonise conurbations, resulting in an increased likelihood of human-wildlife conflict (HWC). Understanding people's attitudes toward wildlife is essential to manage these conflicts. This study assessed people's attitudes toward urban wildlife, the types of conflicts that existed, preferences for managing conflict situations, and determined any changes in perceptions of urban wildlife over a decade. A questionnaire survey of residents of Krakow, the second-largest city in Poland, was conducted in 2010 (n = 721) and repeated in 2020 (n = 887). We found that encounters with certain urban wildlife such as wild boars, red squirrels, roe deer, brown hares, and red foxes had increased significantly in 2020 compared to 2010. Respondents reported that wild boar and beavers did not show fear when encountering humans. Stone martens were considered the most nuisance wildlife species in 2010, while in 2020 wild boar were the most conflictual wildlife species. There were additional reports of conflicts with roe deer and red foxes. The most frequent HWC responses were personal anxiety, intrusion into property and destruction of crops, which increased significantly over the decade, independent of respondents' gender. Respondents preferred non-lethal methods to mitigate conflicts. The study provides valuable information and knowledge on changes in people's

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attitudes toward urban wildlife that can help with wildlife management in urban areas. Incorporating perception and attitude data from the public, along with a multi-stakeholder approach that includes wildlife professionals, in the planning and design of future urban environments is critical to minimise HWC.

1. Introduction

We inhabit a human-modified planet that is most pronounced and apparent in cities around the world (Magle et al., 2019). Within the next 30 years, more urban areas will be constructed than ever before (McPhearson et al., 2016), with an estimated increase of 1 million global urban dwellers every 10 days (Acuto et al., 2018). There are currently more than 4 billion humans residing in urban areas, accounting for 55% of the global population, a proportion that is expected to grow up to 68% by 2050 (Ritchie and Roser, 2018). This trend is especially strong in Europe, North America, and Latin America, where more than 70% of the population is already urban. Therefore, the conversion of land to urban habitat is transforming environments at unprecedented rates, creating increased opportunities for human interactions with wildlife (McKinney, 2008; Seto et al., 2012; Magle et al., 2019). Such human interactions with wildlife can produce either negative i.e., conflict or positive outcomes (Nyhus, 2016). Interactions that generate a negative outcome for either humans or wildlife or both are termed human-wildlife conflict (HWC) (König et al., 2021). HWC can intensify when humans and wildlife compete for similar resources such as food or space (König et al., 2021). The dearth of space due to the rapid expansion of urban areas increases these human encounters with wildlife (Soulsbury and White, 2015).

Humans and wildlife have existed in urban settlements throughout history (Soulsbury and White, 2015). However, given the rate at which the world is becoming urbanised, cities can no longer exist solely to meet the demands of humans, but must also provide a habitat for wildlife, highlighting the need to find ways for coexistence between people and wildlife (Magle et al., 2019). Urban wildlife species interact frequently with humans, due to the high density of the human population in cities (Magle et al., 2019; Soulsbury and White, 2015). On the other hand, as the newest and fastest-growing ecosystems on the planet, cities also represent a unique opportunity to understand this need to share landscapes between humans and wildlife (Miller and Hobbs, 2002). Therefore, realising how individuals and communities perceive wildlife forms a key part of understanding and dealing with potential HWC situations in urban areas (Soulsbury and White, 2015).

1.1. Perceptions and attitudes toward wildlife

Perception may be defined as a unique individualised experience, drawn from something that is known to oneself (McDonald, 2012). Furthermore, Bennett (2016) defined perception as "the way an individual observes, understands, interprets, and evaluates a referent object, action, experience, individual, policy, or outcome." Thus, direct observation of wild animals can influence the perception of wildlife. People tend to have positive perceptions of certain wildlife if it is frequently observed (Liordos et al., 2020). On the contrary, it is highly likely that an encounter with certain wildlife, especially large carnivores, may yield a negative perception when people are accompanied by children (Johansson et al., 2021, 2019). However, it should also be acknowledged that perceptions are not solely based on personal experience, but also on social and cultural norms or beliefs (Dickman, 2010). For example, stories of wolves (*Canis lupus*) attacking humans are common in Norway, and 48% of Norwegians surveyed said they were very afraid of wolves, despite the last documented wolf attack occurring prior to 1882 (Linnell et al., 2003). Despite such social and cultural beliefs, it is not possible to rule out personal experiences that might influence perception.

On the other hand, an attitude is "an association, in memory, of an evaluation with an object or activity" (p. 341 in Fazio et al., 1982). Attitudes can also be defined as the culmination of thoughts, feelings or opinions either about a particular object or personal experiences (Perry et al., 2022) and can be regarded as positive or negative thoughts, feelings or behaviour about something (Almeida et al., 2014). Therefore, "attitude" is the evaluation of an object i.e., the tendency (either favourable or unfavourable) toward something. Thus, perception and attitudes are closely related (Pickens, 2005), however, attitudes often include evaluation based on the perception. Therefore, it is important to know people's perceptions of and attitudes toward wild animals, as these two concepts together influence not only behaviours toward wildlife (Almeida et al., 2014), but also communities' plans for future wildlife management decisions (Cooke, 2002).

1.2. Longitudinal studies in wildlife research

Generally, urban planning does not typically incorporate wildlife, although many species of wildlife can thrive and use the habitats provided by cities (Magle et al., 2019). Wildlife, therefore, to some extent, should be considered a constant living component of such urban ecosystems. However, the term "urban wildlife" did not appear in scientific discourse until the 1990s to describe wild species found in human proximity (Adams, 2016). Simultaneously, we are also aware that in recent years, the shrinking of the natural habitat is forcing wildlife species to colonise urban areas (Smith et al., 2014). This calls for further research in this domain to understand the changing dynamics of HWC in urban areas. Although there have been an increasing number of studies focused on urban wildlife (Mormile and Hill, 2017; Conejero et al., 2019; Hansen et al., 2020), existing studies on urban wildlife ecology are not without limitations (Magle et al., 2019). Research studies on a single species or of short duration are among the most limiting aspects of current urban wildlife research (Magle et al., 2012; Magle et al., 2019). Therefore, long-term or longitudinal studies can help bridge the gap by detecting changes over a prolonged period, allowing stronger conclusions (Treves et al., 2013). Longitudinal research aims to understand a system through repetition in a systematic way over two or more time points (de Silva, 2016). Longitudinal studies do not necessarily require the study of a system over a very long duration, but of sufficient length to understand the process of change and make appropriate inferences. Additionally, residents of urban areas are key sources of information who can provide valuable insight into changes that have taken place in the diversity and abundance of local wildlife (FitzGibbon and Jones, 2006). With rapidly increasing urbanisation, researchers need to take advantage of the growing number of urban residents to engage people in research with public-policy implications (Soulsbury and White, 2015), especially for species that encroach on human-dominated landscapes (Behr et al., 2017).

1.3. Aim of the study

The proportion of the human population living in conurbations in Poland was 60% in 2020, higher than the global proportion (56.2%), which is expected to increase to 70.4% by 2050 (United Nations, 2019). Therefore, understanding the perception and attitude of people in Polish cities about wildlife is necessary to successfully manage urban green spaces. To our knowledge, our study is the first initiative to understand the decadal change in the perception of urban residents about the sharing of landscapes with wildlife in Poland, or, indeed, Europe more generally. Therefore, the aim of the research was to understand residents' perceptions and attitudes toward urban wildlife in a Polish city and to assess the changes between 2010 and 2020. The aim was achieved by conducting questionnaire surveys that compared the following over the decade:

(1) Encounters with wildlife and their reported behaviour
(2) Perceptions of conflictual wildlife and their associated problems

(3) Attitudes toward wildlife in the city
(4) Attitudes toward managing conflict situations with wildlife

The outcome of this study will enable us to understand any change in the frequency and type of conflicts with urban wildlife, emergence of new conflictual wildlife and finally, change in attitudes toward wildlife and its management over the decade. Ultimately, the results of this study may deepen our understanding of the perceptions and attitudes of urban residents and improve the conservation of urban wildlife in Poland and other urban areas around the world.

2. Materials and methods

2.1. Description and selection of the study area

The study was carried out in Krakow (50°02′59″ N and 19°56′40″ E), the second-largest city in Poland, which encompasses an area of 327 km^2, has a human population of 779,115 (GUS, 2021), and is an important transportation hub for major national and international roads. The city is bisected by the Vistula River, a natural migration corridor for many wildlife species (Romanowski, 2007). The city is comprised of 18 administrative districts with varying land use and land cover. This differentiated land cover consists of urban land, agricultural areas, green patches (mainly parks, orchards, meadows, and woodlots), and watercourses, encompassing 42.6%, 46.4%, 9.3% and 1.7%, respectively (Chełstowska and Filip, 2010). Forests and shrubs comprise 11% of the vegetation (Dubiel et al., 2015). The fauna of Krakow is diverse and rich in species, with 75 invertebrates, 12 amphibians, 5 reptiles, 226 birds, and 42 mammal species recorded (Walasz, 2017). The city is inhabited by wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*), and medium-sized carnivores such as red fox (*Vulpes vulpes*) and stone marten (*Martes foina*) (Basak et al., 2020). Since the 2000s, there has been a constant increase in sightings in the city for all the above-mentioned species (Wierzbowska et al., 2017; Baś et al., 2017). All of these are considered game species that are being hunted on four hunting grounds located in the northern and south-western parts of the city. In 2013, the estimated numbers of roe deer, wild boar, red fox and stone marten in these hunting grounds were 410, 100, 145 and 52, respectively, which had changed to 492, 59, 111 and 49 respectively in 2020 (Polish Hunting Association in Krakow, n.d.). In the city of Krakow, between 2000 and 2012, agricultural areas have been greatly reduced by an estimated 8.89% and artificial surfaces have increased by 8.08% (Cegielska et al., 2018). Regarding the size of artificial areas, the largest increase was observed in the Krakowski district (over 93% of agricultural land loss was converted to artificial surfaces) and in the city of Krakow (Cegielska et al., 2018). The primary component of the expansion in Krakow city has been built-up areas that occupy almost all the available space between the dense network of roads (Cegielska et al., 2017). This substantial change in the land cover of Krakow over the last decade has led to frequent sightings of wildlife in the city. Thus, it was necessary to identify how the perception of residents has changed to develop adaptation strategies toward a new perspective on wildlife management (Liordos et al., 2017a).

2.2. Sampling method

The population of the city of Krakow in 2020 is 779,115 while it was 747,317 in 2010 (GUS, 2021). The sample size was estimated using Eq. (1) (Krejcie and Morgan, 1970) and Eq. (2) (Cochran, 1977).

$$n_0 = \chi^2 P(1-P)\left(1 + \frac{N}{d^2\,(N-1)}\right) \quad (1)$$

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \quad (2)$$

where N is the population size, n_0 is the initial sample size, n is the corrected sample size, χ^2 (df = 1) at 0.99 significance level is 3.841, P is the population proportion (0.50), and d is the margin of error (0.05).

Using the equation above, the minimum estimated sample size required to be surveyed was 666. We distributed 1600 and 2000 questionnaires in 2010 and 2020, respectively. Finally, 721 responses in 2010 and 887 responses in 2020 were returned, which covered our minimum required sample size. We surveyed all the 18 districts of Krakow city from February 2010 to October 2010 and again repeated the survey from February 2020 to November 2020. The questionnaires were systematically distributed in public primary schools located in all districts of Krakow city to be completed by parents or guardians (i.e., >18 years old) after receiving the consent of the school directors. Primary schools were selected to ensure that data could be collected from all the districts of Krakow, covering the entire city. We conducted the survey in the same 18 schools that were completed in 2010 to avoid biases in sampling design and were 83.33% successful in repeating the survey, except for three schools that had permanently closed. We chose 3 new primary schools in those 3 districts. This stratified survey design enabled us to target residents from every district with a higher percentage of response rate. The responses to the questionnaire surveys were translated from Polish into English by members of the research group who were fluent in Polish.

2.3. Questionnaire design

The initial design of the questionnaire was modified based on the results of a pilot study on 10 doctoral students at the Institute of Environmental Sciences of Jagiellonian University and a total of 10 adult residents of Krakow. The revised questionnaire had four 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
4. Attitudes toward managing conflict situations with wildlife.

The first section of the questionnaire addressed the sociodemographic information of the respondents, such as age group, educational qualification and place of residence. Additionally, we also enquired whether they observed 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 his previous declarations which were enforced through indications. For example, if the respondents opined negatively about observing wildlife in the city, they were asked to proceed. On the other hand, if the respondents chose “yes” or “I don't know” for the same question, they were asked to identify the wildlife. To help respondents recognise wildlife, we attached colour pictures of wildlife along with the names (Appendix A). These animals are commonly found in urban areas of Poland (Wąsik, 2011). The respondents were further asked to identify the three most recently 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 was not afraid”, “wildlife was aggressive” or “wildlife was friendly”. Multiple behaviour options for one wildlife were not accepted. For example, if one specific wildlife was aggressive, it would not be friendly. However, we did not ask about the number of individuals observed.

The second section of the questionnaire was intended to identify any problems associated with wildlife in the city, where respondents identified the species and the associated problems they faced. For example, if respondents declared that they have problems with specific 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 can choose multiple problems with one specific wildlife.

The third section of the questionnaire aimed to understand the attitudes of respondents toward wildlife and their preferences for managing conflict situations over the decade. Firstly, the respondents were enquired about their attitudes on observing wildlife in the city and then to provide a reason for the same. 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 is a potential source of danger to people", if "an injured or sick wild animal should be helped and taken home" or if, "an injured or sick wild animal should be translocated outside the city". Multiple choices were not approved. However, a 5-point response scale was not formulated for data collection in 2010 and instead we used a 3-point response scale on the same questions while residing with wildlife in the city. In the system, −1 would indicate 'not', 0 would indicate "neutral" and +1 would indicate "yes". As there were differences in scales (i.e., 3 or 5) between the studied years, we modified the 5-point response scale to a 3-point response scale, so that the results in 2020 are comparable to 2010. We have assigned negative responses (−2 and −1) to −1 and positive responses (1 and 2) to 1.

The final section of the questionnaire identified the attitude of people toward resolving conflict situations with wildlife. For example, if "they consulted with any organisation to solve wildlife conflict" or "they are aware of any organisation responsible for solving HWC in the city".

2.4. Data analysis

Statistical differences among the sociodemographic variables of the respondents between the two years (2020 and 2010) were tested using one-way ANOVA. The sample sizes were weighted, calculated considering the sampling rate, response rate, age/sex proportions, and educational level of the reference population to provide representative estimates of the city's population. Chi-square tests were used to identify the differences (between years) in the frequency of wildlife in the city, changes in conflicts over the years and the attitudes of the respondents toward wildlife. Furthermore, the effect size was used to evaluate the magnitude of difference between the years. Generally, effect sizes are helpful to present the strength of the reported effects in a standardized metric that can be understood regardless of the scale, allowing not only to report statistical significance but also practical significance (Lakens, 2013). The most commonly used measures of effect size for Chi-square tests is Cramer's V (McHugh, 2013). Based on the benchmarks suggested by Cramér (1946), we interpreted the effect sizes based on the degrees of freedom. We analysed the relationship between 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 $\alpha = 0.05$. Although frequently used by ecologists (Yan et al., 2015; Zhang et al., 2013), the CCA approach is not uncommon in sociological analysis (Pătru-Stupariu et al., 2019; Niță et al., 2015) or in studying human-wildlife interactions (Mustățea and Pătru-Stupariu, 2021). CCA, a multivariate statistics, is useful in revealing the relationship between two sets of variables (Paliy and Shankar, 2016), grouped into two categories: explanatory variables 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 within the study period. Furthermore, to determine the difference in attitudes of the respondents between 2020 and 2010, we conducted a linear model for each statement. The *p*-value was adjusted using FDR correction. Statistical analyses were performed in R (R Core Team, 2020) using the *vegan* package (Oksanen et al., 2019), and the data were structured and visualised using the *tidyverse* package (Wickham et al., 2019).

3. Results

3.1. Questionnaire response

In 2010, a total of 721 questionnaires were returned of 1600 copies of questionnaires that were distributed, yielding a response rate of 45.1%. The number of female respondents ($n = 599$) was greater than male respondents ($n = 122$). The mean age (±SD) of the respondents was 38.3 years (±4.12 SD).

A total of 887 people participated in the questionnaire survey in 2020 of the 2000 questionnaires sent, yielding a response rate of 44.3%. There were more female ($n = 680$) than male ($n = 207$) respondents, as well as a predominance of intermediate age classes and people with high academic qualifications (Table 1). The mean age of the respondents (±SD) was 38 years (±4.24 SD). The detailed sociodemographic characterisation for both 2020 and 2010 is given in Table 1. There were no significant differences (gender: ($F(1,2) = 0.03$, $p = 0.87$); age: ($F(1,6) = 0.03$, $p = 0.85$); academic qualification: ($F(1,6) = 0.03$, $p = 0.86$)) between sociodemographic variables of respondents between the two years (2010 and 2020).

3.2. Encounters with wildlife and their reported behaviour

In total, 29 faunal species were reported from 2877 records in 2010. Records of birds ($n = 733$) accounted for 10 of the described species, but mammals (18 identified species) were reported more frequently ($n = 2139$). Other taxa included reptiles (snakes $n = 5$) (Table S1). The wildlife most frequently observed in the city was reported as hedgehogs (*Erinaceus roumanicus*) ($n = 601$), followed by mute swans (*Cygnus olor*) ($n = 490$), red foxes ($n = 276$), roe deer ($n = 271$), bats (Chiroptera) ($n = 257$) and stone martens ($n = 256$) (Table 2).

In 2020, there was a considerable increase in the diversity of wildlife species encountered, comprising 41 species of fauna from 5455 records. There were 22 species recorded for mammals and 16 species for birds, with more records of mammals ($n = 3837$) than of birds ($n = 1610$). Other recorded taxa included reptiles (snakes $n = 3$), amphibians (frogs $n = 3$) and invertebrates (earthworm n = 2) (Table S1). The most common wildlife observed by urban residents in 2020 was red squirrel (*Sciurus vulgaris*; $n = 791$), followed by mallard (*Anas platyrhynchos*; $n = 703$), hedgehog ($n = 701$), mute swan ($n = 651$), red fox ($n = 444$), roe deer ($n = 409$), brown hare (*Lepus europaeus*; $n = 344$), wild boar ($n = 308$) and stone marten ($n = 394$) (Table 2).

In general, there was an increase in the frequency of wildlife encounters over the last decade. Wild boar, red squirrel, mallard, brown hare, and red fox encounters had increased significantly ($p < 0.01$) in the city in 2020 compared to 2010 (Table 2) The overall effect size of the changes in the observation of wildlife was medium ($V = 0.32$). In 2020, there was an increase in red squirrel encounters by 751%, brown hare by 421%, wild boar by 137%, red fox by 61%, and roe deer by 51% compared to 2010. The only exception was bat species that did not show significant differences

Table 1
Sociodemographic characteristics of respondents in 2020 and 2010 along with the weighted samples. AQ – academic qualification; M – male; F – female.

Year	Total respondents (n)	Characteristics		Participants unweighted		Participants weighted (n)
				n	%	
2010	721	Gender	M	122	16.92	5905
			F	599	83.08	30,908
		Age	<30	25	3.47	6500
			30–45	590	81.83	23,600
			45–60	85	11.79	2125
			>60	21	2.91	315
		AQ	Graduate	520	72.12	20,800
			Technical/vocational	110	15.26	1320
			Under-graduate	61	8.46	2135
			Primary/basic	30	4.16	390
2020	887	Gender	M	207	23.33	10,019
			F	680	76.66	35,088
		Age	<30	37	4.17	740
			30–45	688	77.56	27,520
			45–60	130	14.66	3250
			>60	32	3.61	480
		AQ	Graduate	530	59.75	21,200
			Technical/vocational	268	30.21	3216
			Under-graduate	59	6.65	2065
			Primary/basic	30	3.39	390

Table 2
The top 10 number (n) of observed wildlife in the city of Krakow as reported in 2010 (n = 721) and 2020 (n = 887) along with mean (±SD) and p-value (after Bonferroni correction). The observed wildlife in the city is based on the presence of wildlife and not on the population size. SD = Standard deviation. Chi-Square test-χ^2 and effect size (V = 0.32 based on Cramer's V).

Wildlife	2010 (n)	2020 (n)	Mean (±SD)	χ^2	p-Value
Red squirrel (*Sciurus vulgaris*)	93	791	442 (±493.56)	551.13	**<0.001**
Hedgehog (*Erinaceus roumanicus*)	601	701	651 (±70.71)	7.68	0.005
Red fox (*Vulpes vulpes*)	276	444	360 (±118.79)	39.20	**<0.001**
Roe deer (*Capreolus capreolus*)	271	409	340 (±97.58)	28.00	**<0.001**
Wild boar (*Sus scrofa*)	130	308	219 (±125.87)	72.34	**<0.001**
Stone marten (*Martes foina*)	256	394	325 (±97.58)	29.30	**<0.001**
Mute swan (*Cygnus olor*)	490	651	570.5 (±113.84)	22.72	**<0.001**
Bat (*Chiroptera*)	257	286	271.5 (±20.51)	1.54	0.213
Mallard (*Anas platyrhynchos*)	29	703	366 (±476.59)	620.60	**<0.001**
Brown hare (*Lepus europaeus*)	66	344	205 (±196.58)	188.50	**<0.001**

χ^2: $p < 0.05$; Bonferroni correction: $p < 0.025$. Italic: significant in Chi Square test, bold: significant after Bonferroni correction, bold and italic: significant in Chi Square test and Bonferroni.

between the two years (Table 2). The 12 fauna species that were observed additionally in the city in 2020 included moose (*Alces alces*), red deer (*Cervus elaphus*), raccoon dog (*Nyctereutes procyonoides*) and raccoon (*Procyon lotor*) among mammals, along with European green woodpecker (*Picus viridis*), magpie (*Pica pica*), Eurasian jay (*Garrulus glandarius*), feral pigeon (*Columba livia domestica*), peregrine falcon (*Falco peregrinus*) and common swift (*Apus apus*) among birds. In addition, frogs and earthworms were reported in 2020.

The species and their behaviour, as reported by the respondents in 2010 (F-statistics = 20.92, $p < 0.01$, Fig. 1a) captured 98.5% of the variation in the dataset in the first two axes (axis 1 = 57.07%, axis 2 = 39.68%) of constrained variability, thus, reflecting most of the behaviour. Axis 1 reflected significant differences between hedgehog and badger compared to the other reported species ($p < 0.01$), displaying mostly friendly, aggressive and no fear emotions. Responses to the behaviour of other wildlife were mainly running away. Axis 2 ($p < 0.01$) reflected a gradient that separated the 'no fear' behaviour of wildlife such as badger, pheasant (*Phasianus colchicus*), stone marten, least weasel (*Mustela nivalis*), brown hare, European beaver (*Castor fiber*) and roe deer from other reported behaviours. Similarly, in 2020, the species and their behaviour, as reported by respondents (F-statistics = 18.12, $p < 0.01$, Fig. 1b) explained 66% of the variation in the dataset on the first two axes (axis 1 = 36.73%, axis 2 = 29.62%) of the constrained variation. Axis 1 reflected a separation of friendly, asking for food and running away behaviour ($p < 0.01$) observed mostly in badger, red squirrel, roe deer, brown hare, stoat (*Mustela erminea*) and birds (pheasant, mallard, mute swan). Responses to the behaviour of other wildlife were mainly associated with not being afraid or injured/sick. Axis 2 ($p < 0.01$) reflected a gradient separating behaviour (such as friendly, asking for food and no fear) of wildlife such as wild boar, beaver and mostly birds (Northern goshawk *Accipiter gentilis*, peregrine falcon, buzzard *Buteo buteo*, mallard, mute swan). Other wildlife mainly exhibited the behaviour of running away or being sick/injured. Therefore, it was observed that in 2020, respondents identified more species (e.g., red squirrel, mallard, mute swan, roe deer, brown hare, ermine) exhibiting other behaviours such as friendly, asking for food or not being afraid, than a decade earlier, when wildlife mostly ran after encountering humans (except for hedgehogs).

3.3. Perceptions of conflictual wildlife and their associated problems

Urban residents of Krakow reported different types of conflict with diverse wildlife species in the city over the decade. The most common nuisance wildlife identified were wild boar, stone marten, red fox and roe deer, which were common in both 2010 and 2020 (Fig. 2). However, there was a significant difference in both the number and types of nuisance wildlife over the decade. In 2010, stone marten (n = 66) was identified as the most nuisance

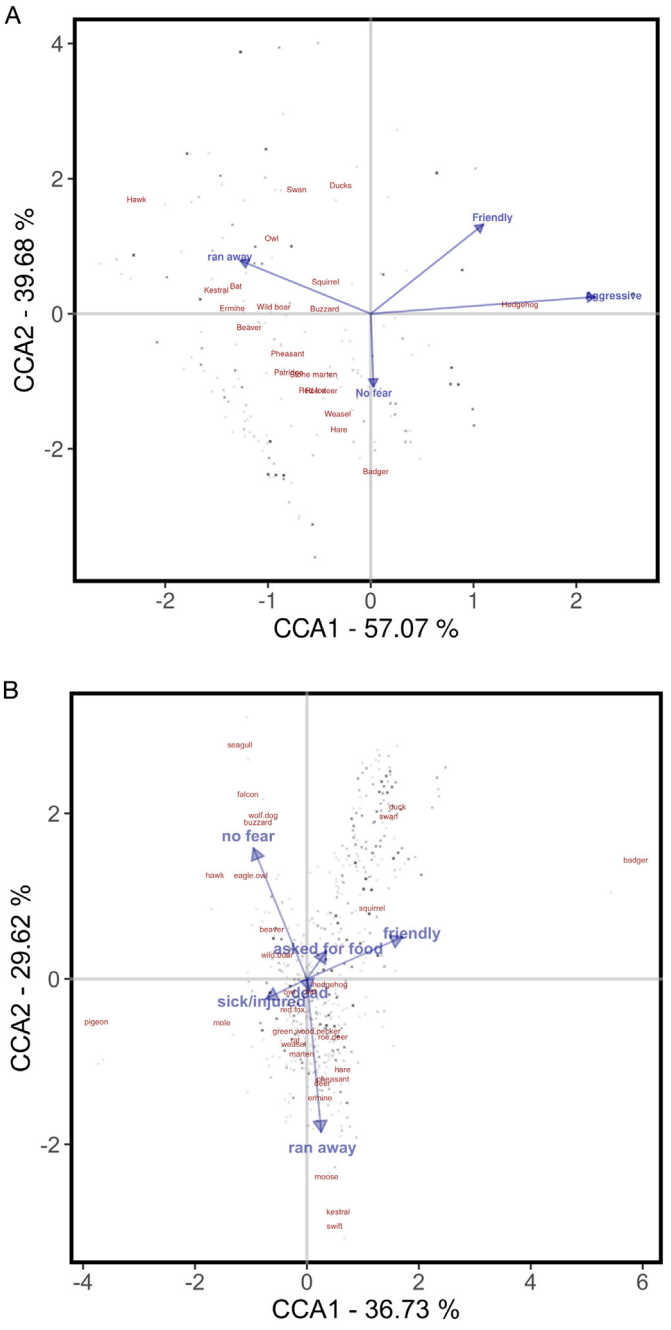

Fig. 1. Canonical correlational analysis (CCA) ordination biplot of wildlife (in red) and their reaction while observing residents (blue arrows) as recorded in Krakow in 2010 (A) and 2020 (B). CCA plots to determine the relationship between wildlife and their observed behaviour.

wild animal (Fig. 2A), while in 2020, wild boar (n = 216) had become the most conflictual wild animal (Fig. 2B). There was a significant increase ($p < 0.01$) in wild boar conflicts from only 23 incidents reported in 2010 to 216 incidents in 2020 (an increase of 839%) by the respondents. Similarly, there was a significant increase in conflicts in 2020 with stone marten (103%; $p < 0.01$), roe deer (150%; $p < 0.01$) and red fox (254%; $p = 0.01$).

Among the several conflicts with urban wildlife stated by the respondents, the most common problems that increased significantly between 2010 and 2020 were identified as "personal anxiety" (χ^2 (3, n = 103) = 22.02, $p < 0.01$), "intrusion to property" (χ^2 (3, n = 85) = 21.15, $p < 0.01$) and "destruction of crops" (χ^2 (3, n = 114) = 65.09, $p < 0.01$). Additionally, in 2020, respondents further identified other types of conflicts

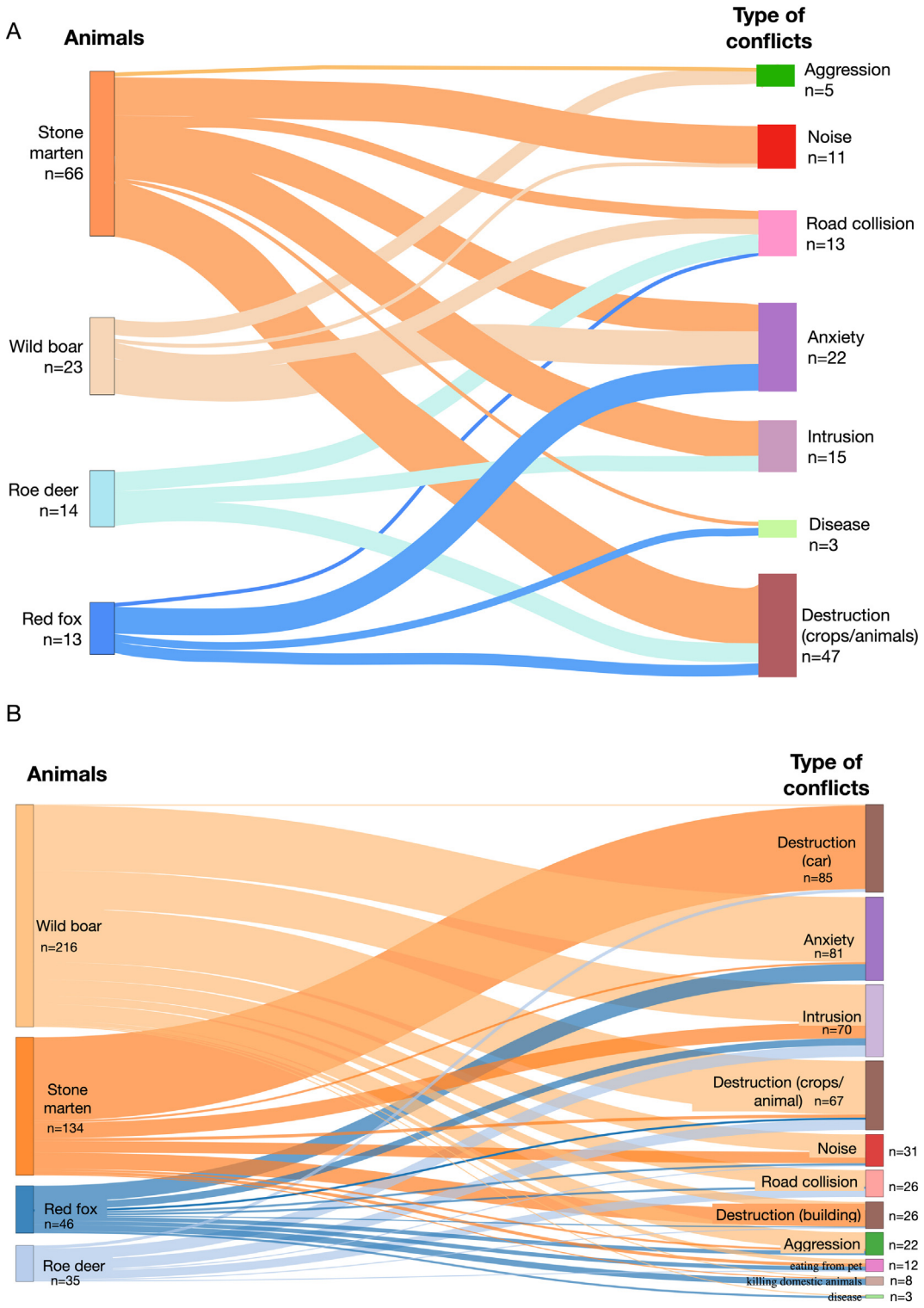

Fig. 2. Sankey diagram showing linkage between wildlife in the city and the type of conflicts as identified by urban residents of Krakow in 2010 (A) and 2020 (B). Here n = number of incidents reported.

appearing, such as "destruction of building and/or car" (n = 93) along with "problems of eating pet food" (n = 12) and "predation on domestic animals by wildlife" (n = 8; Fig. 2B).

3.4. Attitudes toward wildlife in the city

In 2020, approximately 11.10% (n = 80) of the respondents were very positive, 22.80% (n = 165) were positive, 36.06% (n = 260) were neutral, 24.97% (n = 180) were negative and 4.99% (n = 36) were very negative toward the presence of wildlife in the city. In 2020, people generally had ambivalent attitudes toward wildlife in the city. Around 10.1% (n = 90) of the respondents were very positive, 32% (n = 284) were positive, 27.4% (n = 243) were neutral, 24.6% (n = 218) were negative and 5.86% (n = 52) were very negative about the presence of wildlife in the city. There was a significant difference in the attitudes provided by the respondents in both years (χ^2 (4, n = 1608) = 22.34, $p < 0.01$). However,

the overall effect size of changes in attitudes toward wildlife was small (V = 0.12).

Of the respondents who had a very positive or positive attitude toward wildlife in 2010, 46% (n = 113) indicated that "aesthetics" were the main reason. Approximately 22% of respondents (n = 54) could not justify any reason for the positive attitude, another 20% (n = 49) believed that wildlife played a major role in cleaning the environment while the rest of the respondents (12%; n = 29) were positive toward wildlife provided they did not harm humans. Similarly, the respondents who reported negative or very negative attitudes toward wildlife, more than half (60%; n = 130) viewed wildlife as a potential threat, 20% (n = 43) considered wildlife carriers of diseases and the remaining 20% (n = 43) did not justify the reason for the negative attitude. The same questions when asked in 2020, respondents who showed a very positive or positive attitude toward wildlife, 40% (n = 150), indicated that "aesthetics" were the main reason. Approximately 23% of the respondents (n = 89) believed that wildlife played a major role in the cleaning of the environment, another 20% of the respondents (n = 75) were positive as long as wildlife did not harm humans, while the rest of the respondents (16%; n = 60) could not justify any reason for the positive attitude. On the contrary, people who reported negative or very negative attitudes toward wildlife, more than half (67%; n = 180) viewed wildlife as a potential threat, 30% (n = 82) considered wildlife as carriers of diseases and the remaining 3% (n = 8) did not justify the reason for the negative attitude. Therefore, there was a significant difference in the positive (χ^2 (3, n = 619) = 11.06, p = 0.01) and negative attitudes (χ^2 (2, n = 486) = 38.73, $p < 0.01$) toward wildlife, however, with small (V = 0.13) and medium (V = 0.28) effect sizes respectively.

Furthermore, in 2010, respondents generally considered wildlife a source of danger (mean ± SD: 0.69 ± 1.01), whereas in 2020, they thought otherwise (−0.22 ± 0.91), thereby having a significant difference in the attitude between the years (p = 0.04) (Table 3). Although in 2010, respondents did not approve of killing wildlife in the city by shooting (−0.32 ± 0.62) or pharmacologically (−0.32 ± 0.86), the degree of disapproval was higher in 2020 for both (−0.89 ± 0.39; − 0.85 ± 0.44). Therefore, there was a significant difference in attitudes toward the killing of wildlife by shooting (p = 0.04) and pharmacologically (p = 0.04). However, none of the other statements differed significantly over the years (Tables 3, 4 and 5; SI Table 2). Respondents did not approve sterilising or putting up injured animals for scientific research (Table 5). Although, respondents were in favour of coexisting with wildlife as long as humans were not harmed (Table 3), the general agreement was that wildlife, whether injured or not, should be resettled in their natural environment outside of the city (Tables 3, 5).

3.5. Attitudes toward managing conflict situations with wildlife

Interestingly, in 2010, 54% (n = 389) of respondents were not familiar with any unit or organisation in Krakow that could help injured wildlife, and this ignorance increased to 91% (n = 808) by 2020. Again, in 2010, more than 65% (n = 476) of the respondents felt there was a need to spread information related to these institutions among local people, which increased further to 84.9% (n = 753) by 2020.

Table 3
Results of the survey participants' attitudes toward wildlife conducted in 2010 (n = 721) and in 2020 (n = 887) showing descriptive statistics, differences in attitudes using linear model (FDR correction) where n = number of questionnaires returned.

Statements	2010		2020		p-Value
	Mean[a]	SD	Mean[a]	SD	
Wildlife is a source of danger to people	0.69	1.01	−0.22	0.91	**0.04**
Wildlife should be killed by shooting	−0.32	0.62	−0.89	0.39	**0.04**
Wildlife should be killed pharmacologically	−0.32	0.86	−0.85	0.44	**0.04**
Wildlife should be resettled to their natural environment outside the city	0.80	1.01	0.84	0.83	0.97
Wildlife makes me feel connected with nature	0.83	1.05	0.89	0.79	0.98
Wildlife appears as a result of shrinking their natural habitats	0.94	1.14	0.84	0.65	0.91
Wildlife can live in Krakow without colliding with people's interests	0.76	0.89	0.69	0.90	0.91

[a] Range based on 3-point scale: −1 (no) to +1 (yes). Bold font indicates significant p values, $p < 0.05$.

Table 4
Results of the survey participants' attitudes toward resolving conflicts with injured wildlife conducted in 2010 (n = 721) and in 2020 (n = 887) showing descriptive statistics, differences in attitudes using linear model (FDR correction) where n = number of questionnaires returned.

Statements	2010		2020		p-Value
	Mean[a]	SD	Mean[a]	SD	
Injured wildlife should be taken home to help	−0.75	0.53	−0.87	0.45	0.97
Injured wildlife should be left because it poses a danger	−0.48	0.73	−0.57	0.75	0.87
Injured wildlife is a part of nature so they should be left alone	−0.35	0.79	−0.42	0.83	0.77
Injured wildlife should be captured by the relevant services that will deal with it	0.88	0.39	0.92	0.36	0.98

[a] Range based on 3-point scale: −1 (no) to +1 (yes).

4. Discussion

To our knowledge, this is the first study where the perception of urban residents toward wildlife has been conducted over 10 years in Poland. Our results found that urban residents of Krakow have experienced increased encounters with wildlife in the city in 2020, compared to a decade earlier. Furthermore, the number and type of conflicts have risen exponentially in recent years along with the emergence of new nuisance wildlife species. Respondents generally agreed on resettling wildlife outside the city, mainly due to personal anxiety, destruction and intrusion to property. Among the respondents, there was a general agreement that injured wildlife should be provided care by relevant authorities and treated appropriately before their release. There was a general lack of information concerning how to deal with injured wildlife in the city, which had further increased over the decade.

4.1. Encounter and willingness to co-exist with wildlife

Survey respondents had mostly encountered hedgehog, red fox, roe deer and stone marten in 2020, all of which were also common in 2010, yet the frequency of their encounters had significantly increased over the decade. We also found in our study that wildlife displayed other behaviour in 2020, such as being friendly, asking for food or not being afraid, rather

Table 5
Results of the survey participants' attitudes toward resolving conflicts with injured wildlife conducted in 2010 (n = 721) and in 2020 (n = 887) showing descriptive statistics, differences in attitudes using linear model (FDR correction) where n = number of questionnaires returned.

Statements	2010		2020		p-Value
	Mean[a]	SD	Mean[a]	SD	
Injured wildlife should be cured and released at the point of capture	0.20	0.89	0.20	0.92	0.99
Injured wildlife should be killed after capture	−0.79	0.46	−0.89	0.39	0.96
Injured wildlife must be resettled outside the city	0.45	0.76	0.48	0.78	0.98
Injured wildlife sterilised after capture	−0.52	0.65	−0.60	0.66	0.97
Injured wildlife should be dewormed after capture	0.63	0.57	0.70	0.56	0.94
Injured wildlife should be put into adoption after capture	−0.39	0.67	−0.46	0.71	0.89
Injured wildlife should be put up for scientific research	−0.68	0.55	−0.78	0.52	0.96
Injured wildlife should be given to the mini zoo after capture	−0.11	0.81	−0.14	0.86	0.96

[a] Range based on 3-point scale: −1 (no) to +1 (yes).

than running away on encountering humans, as observed in 2010. This phenomenon was also found in studies in the United States where urban grey squirrels (*Sciurus carolinensis*) did not initiate flight when humans passed along the sidewalk (Bateman and Fleming, 2012) or when urban mammals had reduced responses to human presence (McCleery, 2010). Such a changing behaviour is becoming increasingly common, with urban mammals quickly adapting to cities by acclimating their movement based on environmental indicators (Ritzel and Gallo, 2020).

Additionally, in recent years, wild boar, brown hare and red squirrel emerged as some of the most frequently observed animals in the city. However, the frequency of encounters with urban wildlife does not necessarily translate into an increase in wildlife aggression (Perry et al., 2020). For example, we found that the respondents were generally appreciative of squirrels, which is consistent with previous studies conducted in Malaysia (Mohamad Muslim et al., 2018), Norway (Bjerke and Østdahl, 2004) and Slovakia (Prokop and Tunnicliffe, 2010). However, increasing sightings of wild boars in Krakow city in recent years have raised an issue of concern for residents. Interestingly, wild boars were not considered problematic wildlife a decade earlier. Thus, the adaptive capability of wild boars in urban areas indicates their behavioural elasticity to adjust to human-dominated environments (Stillfried et al., 2017), which made wild boars nuisance wildlife only in the last decade. Studies have reported that humans show a more ambivalent attitude (Johann et al., 2020) when encountering wild boars, which can range from actively feeding them to fearing them (Cahill et al., 2012). Wild boars have also been described as a “crop raider” (Thurfjell et al., 2013; Schley et al., 2008). We also found in our study that problems associated with boars included personal anxiety, intrusion and damage to crops. Furthermore, the survey respondents identified stone martens and red foxes as nuisance wildlife involved in intrusion to properties or causing anxiety in both the studied years. This can be validated by examples given in studies where it was found that most urban stone marten (Herr et al., 2009) and red foxes (Perry et al., 2020) den in buildings and inhabited constructions.

The most common reasons for considering urban wildlife problematic include damage to food, as with rats (*Rattus* spp.), or other property, as with animal-vehicle accidents in North America (Lee and Miller, 2003); creating noise or odour nuisance, as with gulls (*Larus* spp.) (Belant, 1997); danger to humans or pets by carnivores such as by red foxes or raccoons (Bateman and Fleming, 2012) or beavers (England and Westbrook, 2021; Loven, 1985). We found similar results in our study where respondents considered damage to property, noise, road accidents as well as constant anxiety to be the primary problems associated with the presence of urban wildlife in their vicinity. Thus, the common solution suggested by the survey respondents in 2010 and 2020 was nonlethal control such as translocation outside of the city. Similar behaviour has been found in the community of Amherst (in the USA), which preferred non-invasive methods of control rather than radical ways of dealing with white-tailed deer in urban areas (Loker et al., 1999; Stout et al., 1997).

4.2. Attitude of urban residents toward urban wildlife

Several studies have explicitly correlated the benefits of wildlife presence on the mood of well-being among urban dwellers (Perry et al., 2020). For example, Mumaw et al. (2017) reported “wellbeing benefits including strengthened connections with nature, place and community.” Shanahan et al. (2015) reported similar findings, that are consistent with our findings. In our study, even though encounters with conflictual wildlife have increased, the attitude toward the presence of wildlife in the city has become slightly more positive. Moreover, respondents generally felt closer to nature by observing wildlife in the city, and this attitude had not changed over the decade, even when the frequency of encountering wildlife has increased manifold. Over the decade, respondents appreciated wildlife for their aesthetic value. Generally, the presence of wildlife in urban settings benefits the conservation of natural habitats and the species that dwell in such habitats as residents appreciate such conservation practises (McKinney, 2002). Most urbanites encounter only urban species, which therefore come to represent all wildlife (Lunney and Burgin, 2004) and affect their perceptions of wildlife. Studies (Hosaka et al., 2017a, 2017b) found that childhood exposure to wildlife makes urbanites somewhat more tolerant of nuisance wildlife encountered later in life, even in the case of larger carnivores (Majić et al., 2011). In contrast, the so-called extinction of experience that comes with a lack of exposure to wildlife can also change people's attitudes toward it (Soga and Gaston, 2016). Thus, ensuring the contact of urban dwellers with even a limited biodiversity palette is likely to improve the probability that species will survive. It has been proven that interaction with wildlife in urban areas through observation or feeding of urban wildlife has significant health benefits (Soulsbury and White, 2019). In our study, residents were exposed to wildlife over the years, which could eventually have culminated in their positive attitude toward wildlife, as the majority realised that the increased presence of wildlife in the city is due to the shrinking of their natural habitat, as well as many other factors. Showing empathy and understanding toward injured wildlife revealed an affectionate and concerned outlook of urbanites in our study area, which can probably be the result of continuous exposure to wildlife in the city.

4.3. Limitations

The selection of participants in our survey was not completely random, and some of the groups were not adequately represented. For example, in Poland, men represented 51.6% and women 48.4% of the population in 2020 (Statistics Poland, 2020), while we had 76.66% of responses from women and only 23.34% from men. Similarly, female representation was 83.07% and male representation was 16.93% in 2010. Male underrepresentation could potentially result in different outcomes in attitudes toward wildlife, although in our study, the responses by gender were not significantly different. Moreover, the sample in our study is biased concerning age distribution. We cannot, however, rule out that even though the majority of respondents were reported as female, each submission did not involve a partner, child or greater family discussion or experience with urban wildlife. Additionally, a study from one city, albeit a large conurbation, may not be completely representative of other urban environments. However, cities share many common features even when they are far apart and in drastically different climatic regions (Soulsbury and White, 2015). In general, the attitudes toward wildlife species and their management often differ between stakeholder groups such as farmers, hunters, fishermen and the general public (Liordos et al., 2017b). Thus, the effect of these differences on the preferences for urban wildlife between different stakeholders should be investigated. Despite these potential limitations, this study has provided a broad spatial coverage in a large conurbation, of changes in the perceptions of and attitudes toward wildlife over a decade, which is inherently valuable to addressing the growing issue of urban human-wildlife conflict into the future.

4.4. Policy implications

With the rapid increase in urbanisation, the world is dealing with unprecedented threats to wildlife. The loss of habitat to farming, mining and new urban developments has dramatically decreased the natural space for wildlife. Our research findings have several implications for both researchers and policymakers working on mitigating HWC in urban environments.

Firstly, our results found that although urban residents' contact with wildlife has increased over the past decade, people still felt that cities were not an appropriate place for wildlife and that species should be relocated outside of the city. This highlights that it is time to include urban wildlife in urban design, deepen ecological understanding of urban ecosystems, and heighten society's appreciation of all urban wildlife across all life forms (Egerer and Buchholz, 2021). A holistic approach comprising urban wildlife of all trophic levels into the urban ecosystem has been framed by Egerer and Buchholz (2021) that advocates for public awareness campaigns and citizen science approaches. Aside from the conservation of urban wildlife, knowledge of the species composition in urban biodiversity

can be very useful as an educational tool to better understand the natural world (McKinney, 2002). An ecologically informed urban population could greatly improve the social support for the conservation of native species in all ecosystems.

Secondly, most of the Sustainable Development Goals (SDGs) of the United Nations have weak links to HWC, for example, in SDG 2: Zero Hunger, HWC links wildlife damage to food stores, crops, and livestock. However, if the international community does not adequately address HWC, it will have a considerable negative impact on the ability of countries to meet most of the other SDGs (UN Environment, 2021). Furthermore, the absence of any SDG to mitigate urban HWC is highly remiss considering the rapid expansion of urban areas and the consequent increase in conflicts, as shown in the results of our study.

Thirdly, in Poland, the Environmental Protection Act of 16 April 2004, provides opportunities to create rehabilitation centres for wildlife where treatment and rehabilitation of species requiring temporary human care could occur before being released back to nature. Currently, in Poland, there are 95 rehabilitation centres with 2 centres in the heart of the city of Krakow (GDOŚ, 2021). Interestingly, in our study, we found that in 2010, 54% of the respondents were unaware of the existence of any such institutions in the city that could help injured or sick wildlife. However, even 16 years later (from 2004 to 2020), only 8.9% ($n = 79$) of the respondents knew of any institutions that could either help injured wildlife or residents. The general need for information about such relevant institutions was even recognised in 2010 when 66% ($n = 476$) agreed on the need for such information, which increased to 84.9% ($n = 753$) by 2020. This highlights the gap between adopted wildlife conservation policies and the knowledge of their existence by residents. The need for such information about dealing with wildlife in the city arose due to the increasing conflicts with wildlife over the past decade. Moreover, it indicates that even after a decade, there is a lack of policy development to disseminate such information to the public about relevant institutions that help injured or nuisance wildlife in the city.

Finally, with climate change being inevitable (Bowles et al., 2015), policymakers are busy devising ways of adapting cities to novel and changing scenarios. Given the increasing importance of urban environments for the survival of future wildlife, planners will have to take into account the welfare of non-human species into account. Conservation biologists, who have generally disregarded urban environments, should use their knowledge to integrate wildlife in future urban design (Melles et al., 2003).

5. Conclusion

In an age when most natural habitats are declining, urbanisation stands out as an increasing habitat resource. With the rapid growth of urbanisation, studies that provide data on the ecological value of urban environments are also gradually increasing. Therefore, knowledge of people's attitudes toward urban wildlife will help to manage urban green spaces for the holistic well-being of residents and wildlife. Our research indicated that even though encounters with conflictual urban wildlife and associated problems had increased over the decade, attitudes toward wildlife were slightly more positive. However, awareness among residents regarding solving conflicts with urban wildlife was low and consequently decreased further over the decade. This highlighted the need to create awareness campaigns to provide valuable information to the residents of Krakow, which in turn can help to design conservation interventions to manage urban wildlife, especially the common conflictual ones. Such interventions will then be more effective when supported by various stakeholders in the city (e.g., residents, managers and conservationists). Conflicts are often complex, and their resolution or mitigation should be achieved through a multi-disciplinary approach. Within such an approach, longitudinal perception studies are beneficial for understanding changes in the pattern of HWC and provide context to historical and current public attitudes toward urban wildlife. In future urban environments, for urban wildlife to flourish, understanding the views and concerns of the general public is critical. Our findings can also be extended to other urban areas in Poland, especially in Central Europe and the rest of Europe where similar urban wildlife exist.

CRediT authorship contribution statement

Sayantani M. Basak: Conceptualization, Methodology, Formal analysis, Writing - original draft. **Md Sarwar Hossain**: Writing – Original draft. **Declan T. O'Mahony**: Writing - original draft. **Henryk Okarma**: Writing original draft. Elżbieta Widera: Data collection and processing. **Izabela A. Wierzbowska**: Conceptualization, Supervision, Writing - original draft.

Declaration of competing interest

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

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Appendix A. Supplementary data

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