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Short Note

The cost of living in the city. Causes of incidents with mammals and factors that influence their frequency in Warsaw

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Abstract

Numerous wild species have managed to adapt to the specific conditions of the urbanized environment. Wild animals take advantage of the microclimate conditions and the available hiding places or food; however, they are also exposed to various risks in this environment. The aim of this study was to determine the causes of incidents between wild mammals and human infrastructure and activity in the city of Warsaw and to evaluate the effectiveness of an animal rehabilitation center. The second aim was to assess the factors (weather and land cover) that influence incidents involving wild mammals in Warsaw. We found that human infrastructure and activity cause most of the wild mammal incidents in the city. The frequency of small mammal incidents in Warsaw was dependent on the weather, mainly the ambient temperature. The proportion of built-up areas was usually associated with the number of such incidents. This relation was positive for species that tend to live in cities, and it was negative for species that avoid human proximity.

Numerous species have managed to adapt to and take advantage of the specific conditions of the urbanized environment. The benefits include the milder microclimate, which makes it easier to survive and get food, especially during winter (Bateman and Fleming, 2012); the opportunities for wintering without the need for seasonal migration (Partecke and Gwinner, 2007); the better reproduction conditions due to the extended reproductive season (Dominoni, 2013); and convenient breeding sites (McCleery et al., 2007). In the urban environment, animals are also subject to less pressure from natural predators (Shochat, 2004). In anthropogenic habitats, they can find shelter (Herr et al., 2010) and highly calorific food ad libitum, even during winter (Bateman and Fleming, 2012). This causes an increase in the body weight of individuals, an increase in female fertility, and may also result in a higher survival rate (Łopucki et al., 2019; Oro et al., 2013). This result in ability of some wild species to adapt to city life (McKinney, 2008; Francis and Chadwick, 2012).

However, the specificity of urban conditions is also associated with many negative effects. Parasites and diseases can spread faster (Bradley and Altizer, 2007), animals may be more susceptible to disease due to reduced immunity (Birnie-Gauvin et al., 2016), and they are also subject to pressure from domestic animals (Jokimäki et al., 2017). Heavy traffic in cities often leads to collisions involving wild animals, and roads cause habitat fragmentation as they act as spatial barriers with further consequences, like limited mobility and access to preferred habitats or limited gene exchange between populations (Seiler and Bhardwaj, 2020; Fahrig, 2003). Increased vehicle or pedestrian traffic and light pollution also affect wild animals' activity, foraging patterns and reproduction (Gaston et al., 2014; Longcore and Rich, 2004). Noticeably higher levels of noise in the city negatively affect animals, causing stress, reduced immunity, and changes in gene expression (Francis and Barber, 2013; Kight and Swaddle, 2011). Urban animals are more exposed to various types of pollution (Murray et al., 2019) which result in reducing the efficacy of the immune system and causing abnormalities in the development of individuals (Serieys et al., 2018). Eating anthropogenic food may also have negative consequences in terms of increased risk of disease due to infection with pathogens (Oro et al., 2013) and consumption of plastic packaging (Bateman and Fleming, 2012). Less pronounced effects are also noticed, e.g., changes in behavior, circadian rhythms and habitat use (Bonier, 2012; Gaynor et al., 2018; Mikula et al., 2018; Santangelo et al., 2018; Łopucki et al., 2021).

The decrease in species diversity is regarded as the main consequence of cities' development (Luniak, 2004). About 320 species of vertebrates, including 40 mammal species, were found in Warsaw, which is a similar number to other large cities (Luniak, 2008). However, species diversity and general numbers of vertebrates is lower compared to smaller towns (Łopucki et al., 2020; McKinney, 2008), where the proportion of built-up areas is lower (McKinney, 2002), but higher number of ecological corridors (Beninde et al., 2015). However, the reaction to urbanization process is species dependent (Tait et al., 2005) and depend also on city location and other factors (Beninde et al., 2015).

An important issue in urban environments is minimizing the effects of living in cities for animals that are adapted to urban conditions. For this purpose, animal rehabilitation centers have been established in many larger cities. However, city rehabilitation centers are poorly known comparing to these on non-urban areas (Perry et al., 2020). Little is also known about the causes of incidents with animals and factors that influence their frequency in cities (e.g., Molina-López et al., 2017; Grogan and Kelly, 2013; Tribe and Brown, 2000). Therefore,

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the aim of our study was to determine the causes of incidents resulting from interactions between wild mammals and human infrastructure and activity in the city of Warsaw and to evaluate the activities of animal rehabilitation centers. The second aim was to assess the factors (weather and land cover) that influence wild mammal incidents in Warsaw.

The study area covered Warsaw within its administrative borders (52°15′ N; 21°0′ E). The area of the city covers 517.2 km^2; it has 1780000 inhabitants and is divided into 18 districts. Built-up areas cover 57% of this area, but there is great variability among these districts. The data for the analysis came from various sources: "Marysieńka" Animal Rehabilitation Center, City Forests — Warsaw (www.lasymiejskie.waw.pl), which is the only mammal rehabilitation center in the city; the website "Animals on the Road, National Register of Road Collisions with Animals" (www.zwierzetanadrodze.pl); City Guard of the Capital City of Warsaw (www.strazmiejska.waw.pl); the Regional Directorate for Environmental Protection in Warsaw (www.warszawa.rdos.gov.pl); and the Veterinary Clinic at OAZA Exotic Animals Hospital in Warsaw (www.oaza-wet.pl). The information covered the three-year period from 1 January 2017 to 31 December 2019. Only wild mammals from the city of Warsaw were taken into account. The data included the date of the event, the species, sex and age of the animal, the cause and location of the event, and the end result (death, injury, etc.).

In order to present the causes of incidents involving wild mammals in Warsaw, we selected only incidents whose exact cause was known. In total, 3151 individuals were included in this comparison. Specific cases were divided into five groups: (1) Injured — animals that had suffered various types of injuries (often with partial paralysis) after collisions with traffic and other (mostly unknown) incidents; (2) Occasional — animals that did not show any symptoms of disease, had no injuries, and were found in apartments, buildings, gardens, etc. (e.g. animals were entangled in nets or fencing and required only temporary care or a place for hibernation, etc.); (3) Orphans — orphaned, dependent individuals that fell out of the nest or whose nest was destroyed, or young animals that were taken from their natural environment or cared for by humans but did not require intervention; (4) Sick — animals with disease symptoms, weakened, dehydrated, apathetic, with neurological disorders; (5) Hunted — individuals that had been attacked by, for example, dogs or cats.

In order to analyze the impact of weather conditions on incidents, four species of animals and one order were selected: red squirrel *Sciurus vulgaris* (L., 1758); European hedgehog *Erinaceus europaeus* (L., 1758); bats Chiroptera (Blumenbach, 1779); wild boar *Sus scrofa* (L., 1758); and roe deer *Capreolus capreolus* (L., 1758). These mammals were the subject of the highest numbers of recorded incidents whose precise dates were known. We analyzed the frequency of incidents with regard to weather conditions: (a) Temperature — average daily ambient temperature [°C]; (b) Precipitation — daily sum of precipitation [mm]; (c) Wind — average daily wind speed [$m\,s^{-1}$]. Weather values for each day from 2017 to 2019 were obtained from the database of the Institute of Meteorology and Water Management — National Research Institute. Due to large differences in weather throughout the year, we analyzed the incidents separately for the four seasons: spring (March 1 – May 31); summer (June 1 – August 31); autumn (September 1 – November 30); winter (December 1 – February 28). A generalized linear binary model was used for the analysis. The occurrence of an event involving an individual of a given species was marked as a dependent variable. For each day and for a particular species, the lack of an event was indicated as "0"; the occurrence of an event was marked as "1". The covariates in each model were Temperature, Precipitation and Wind. In order to select the best-fitted model, the values of the Akaike information criterion (AIC) were compared. In each selection procedure, we compared all models and the null model; the model with the lowest AIC value was selected. We analyzed only seasons in which the frequency of events for a given species exceeded 30% of days.

As event locations were imprecise and were often limited to the district, further analysis was based at the district level. To analyze the

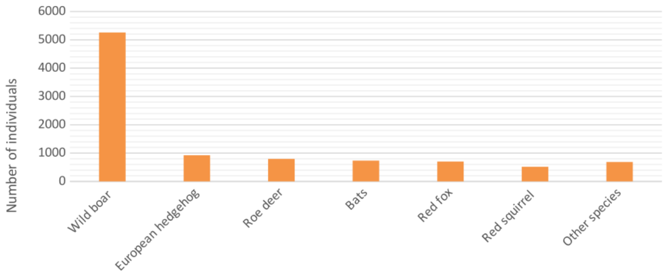

Figure 1 – The number of incidents involving mammals in Warsaw in 2017–2019.

impact of land cover on incidents with mammals, three variables were selected: the proportions of built-up areas and green areas, and the number of inhabitants in each district. The variables were checked with regard to correlation; all were found to be highly correlated, therefore the number of mammal-related events was analyzed only with regard to the proportion of built-up areas. We built five linear or nonlinear regression models for the five mammal species/orders: squirrel, hedgehog, bats, wild boar, roe deer. Only records which contained information concerning the location and outcome of the relevant incident could be included in the analysis. Information on the proportion of built-up areas in districts came from the Statistical Reviews of Warsaw for the fourth quarters of 2017, 2018 and 2019. The number of documented incidents with selected animal species was calculated per 1 km^2 of each district. The number of cases (per km^2) was a dependent variable; the percentage of built-up areas was an independent variable. All statistical analyses were performed using SPSS software (version 26.0. Armonk, NY: IBM Corp).

In total, 9618 incidents with wild mammals were documented in Warsaw in 2017–2019. Over half of all incidents involved wild boar (54%), followed by four other mammal species and one order with a share of 5% to almost 10%: European hedgehog, roe deer, red fox, red squirrel and bats (Fig. 1). The remaining 16 species accounted for around 7% of incidents: four-toed hedgehog *Atelerix albiventris* (Wagner, 1841), European badger *Meles meles* (L., 1758), European beaver *Castor fiber* (L., 1758), fallow deer *Dama dama* (L., 1758), red deer *Cervus elaphus* (L. , 1758), raccoon dog *Nyctereutes procyonoides* (JE Gray, 1834), European water vole *Arvicola amphibius* (L., 1758), European mole *Talpa europaea* (L., 1758), beech marten *Martes foina* (Erxleben, 1777), Eurasian moose *Alces alces* (L., 1758), American mink *Neovison vison* (Schreber, 1777), common vole *Microtus arvalis* (Pallas, 1778), brown rat *Rattus norvegicus* (Berkenhout, 1769), gray wolf *Canis lupus* (L., 1758), European otter *Lutra lutra* (L., 1758), European hare *Lepus europaeus* (Pallas, 1778).

Of all the events, 3151 could be attributed to specific causes (Fig. 2). Over 40% of mammals were injured, mostly as a result of road collisions. Individuals in this group usually died; only about 9% survived. The Occasional group accounted for about 30% of all known causes of incidents, and almost all these animals were successfully released. Orphaned specimens constituted about 15% of all mammals, about half

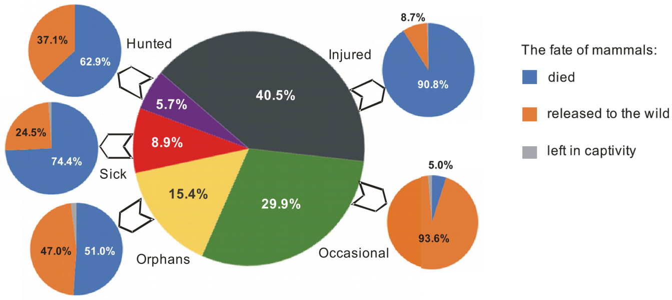

Figure 2 – Causes of incidents with mammals by groups (large circle) in Warsaw in 2017–2019, and the fate of animals (small circles).

Table 1 – Impact of weather conditions (temperature, precipitation and wind) on the probability of the occurrence of events involving wild mammals (squirrel, hedgehog, bats, wild boar, roe deer) in particular periods (spring, summer, autumn, winter) in the generalized linear models (in the table, the values of the B coefficient for a given predictor are shown; E – excluded; shaded columns – unexplored correlations).

	Red squirrel	European hedgehog	Bats	Wild boar	Roe deer
Spring					
Intercept	-1.268*	-0.243		0.663*	-
Temperature	0.102*	0.058*		E	E
Precipitation	E	-0.094*		E	E
Wind	E	E		-0.202*	E
Best model (AIC)	358.5	371.6		382.2	-
χ^2	25.256	13.741		4.207	-
p	<0.001*	0.001*		0.040*	-
Null model (AIC)	381.8	381.3		384.4	379.9
Summer					
Intercept	-2.584*	-		-	-
Temperature	0.084*	E		E	E
Precipitation	E	E		E	E
Wind	0.291*	E		E	E
Best model (AIC)	379.2	-		-	-
χ^2	8.897	-		-	-
p	0.012*	-		-	-
Null model (AIC)	384.1	341.2		369.6	362.3
Autumn					
Intercept		-1.595*	-0.064	-	
Temperature		0.109*	0.052*	E	
Precipitation		E	E	E	
Wind		E	E	E	
Best model (AIC)		348.4	362.5	-	
χ^2		18.923	4.796	-	
p		<0.001*	0.029*	-	
Null model (AIC)		365.3	365.3	373	
Winter					
Intercept			-	-	-
Temperature			E	E	E
Precipitation			E	E	E
Wind			E	E	E
Best model (AIC)			-	-	-
χ^2			-	-	-
p			-	-	-
Null model (AIC)			372	367	344.3

of which did not survive despite rehabilitation measures. The smallest groups (8.9% and 5.7%, respectively) were sick and hunted individuals, most of which died, but higher mortality was noticed in sick animals: almost 75% compared to hunted individuals (about 37%).

The analysis of the impact of weather conditions on five selected taxa of mammals (squirrel, hedgehog, bats, wild boar and roe deer) showed that they significantly affect small animal species (squirrel, hedgehog, bats) (Tab. 1). The probability of an incident affecting a small species was significantly higher on days with higher temperature. In the case of squirrels, the temperature significantly influenced the frequency of incidents in spring (B=0.102) and summer (B=0.084). In the case of hedgehogs, temperature significantly influenced the frequency of incidents in spring (B=0.058) and autumn (B=0.109), while bats were affected only in autumn (B=0.052). Only hedgehogs were affected by precipitation. In spring, the probability of an incident involving a hedgehog was significantly lower on days with heavy rainfall (B=-0.094). The analysis also showed that the probability of incidents affecting squirrels was significantly higher on summer days with higher wind speed (B=0.291). The results also showed the influence of this weather factor on wild boar. In this case, however, stronger wind decreased the probability of events affecting wild boar in the spring (B=-0.202). No effect of temperature and rainfall was found for this species. On the other hand, in the case of roe deer no relation between the tested weather conditions and the occurrence of incidents was confirmed.

The analysis of the impact of the proportion of built-up areas on the occurrence of incidents in the selected mammal species showed a relation with four of the five studied groups: hedgehogs, bats, wild boar and roe deer. This relation was not found for squirrels (p>0.05) (Tab. 2). In the case of hedgehogs and bats, as the proportion of built-up areas increased, the frequency of incidents increased significantly (Fig. 3). The highest number of incidents per 1 km² occurred in districts characterized by a high proportion of built-up areas (Praga Południe — 84%; Praga Północ — 80%; Żoliborz — 92%). On the other hand, the number of incidents involving wild boar and roe deer was higher in districts with a lower proportion of built-up areas (Fig. 4). The highest number of incidents per 1 km^2 occurred in districts with a high proportion of green areas (Białołęka — 41% of buildings; Bielany — 59%; Rembertów — 47%; Wawer — 33%). For bats, wild boar and roe deer, the simple linear regression presented the best results; for hedgehogs, incidents were better presented by polynomial regression (Fig. 3).

During the study period, averaged 3200 events with mammals were found annually, which gives an average of approximately 9 incidents per day. While this value seems large, it should be noted that it is the minimum value and the actual number of such events is probably much higher. This is mainly evidenced by the underrepresentation of small mammals in the reports, as was shown on the example of animal collisions with traffic (Pagany, 2020). This underrepresentation is also evident in our results as most of the recorded events concerned large or medium-sized mammals (Fig. 1), which generally account for a much smaller percentage of all mammals (Seiler and Helldin, 2006). The higher number of large and medium-sized mammals was an effect of the high proportion of traffic collisions.

The first two categories of events (injured and occasional) are mainly related to human impact as they are primarily the effects of collisions with vehicles and collisions between animals and man-made infrastruc-

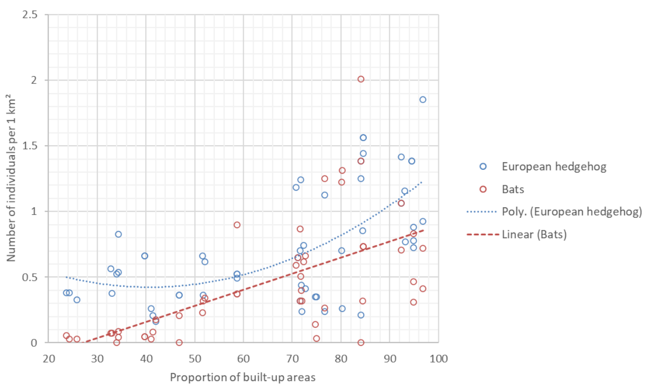

Figure 3 – Distribution of incidents involving hedgehog and bats per 1 km^2, depending on the proportion of built-up areas (regression fit lines for each species).

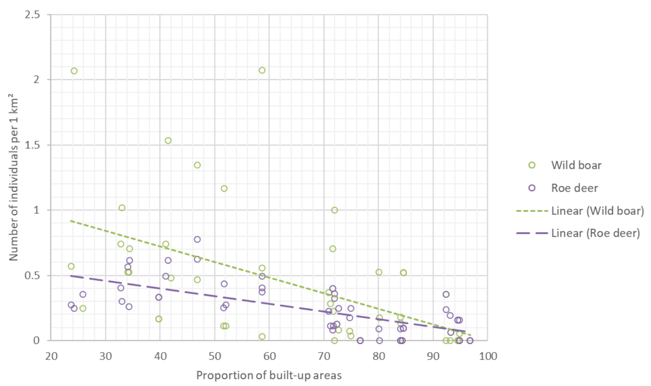

Figure 4 – Distribution of incidents involving wild boar and roe deer per 1 km^2, depending on the proportion of built-up areas (regression fit lines for each species).

Table 2 – Impact of the proportion of built-up areas on the number of incidents involving wild mammals (squirrel, hedgehog, bats, wild boar, roe deer) in regression models (in table, the values of the B coefficient for a given predictor are shown).

	Red squirrel	European hedgehog	Bats	Wild boar	Roe deer
R^2	0.043	0.406	0.378	0.299	0.467
F	2.313	17.428	29.223	22.210	44.693
p	0.134	0.000	0.000	0.000	0.000
Intercept (SE)		0.855 (0.395)	-0.332 (0.155)	1.2 (0.179)	0.633 (0.062)
Proportion of built-up areas (SE)		-0.021 (0.014)	0.012 (0.002)	-0.012 (0.003)	0.006 (0.001)
Proportion of built-up areas^2 (SE)		0.000 (0.000)			
N	54	54	50	54	53

ture. This is consistent with a study conducted in Kraków, where the most common human-wildlife conflicts occurred with roe deer and other large or medium-sized animals, while less events involving small animals were recorded (Basak et al., 2020). The other three categories (orphans, sick and hunted) may also be partially human related. Orphaned individuals may be partly the result of the events of the aforementioned categories; for example, a nursing female is killed on the road or entangled in a fence. Likewise, hunted individuals may be partially preyed on by domestic animals such as cats or dogs, which have been shown to be an important factor in causing mortality in wild animals and reducing their numbers (Krauze-Gryz et al., 2019; Jokimäki et al., 2017). Loss et al. (2013) estimated 12.3 billion animals are killed annually in the United States as a result of hunting by cats. Numerous studies have shown that mammals are their most common prey (Loyd et al., 2013). Pets can also transmit many diseases to wild mammals (Bradley and Altizer, 2007; Hughes and Macdonald, 2013). The mentioned facts indicate, that the human infrastructure and activity were the main reasons of incidents with the wild mammals in Warsaw. The activities of the Marysieńka Center allowed the release of more than half (53%) of brought mammals. It is true that the percentage was low in the "injured" category, but in the other categories it was significant. In Spain, this success was over 50% (Molina-López et al., 2017); in RSPCA centers in the UK, it was 40% (Grogan and Kelly, 2013); in Australia, the percentage of animals released ranged from 38 to 45% (Tribe and Brown, 2000). The existence of rehabilitation centers seems to be important but their actual impact on wild mammal populations in cities is unknown. Moreover, the effectiveness of rehabilitation, i.e., the survival of animals after release, is poorly understood (Mullineaux, 2014).

The occurrence of events involving mammals in Warsaw was dependent on the weather, but this was confirmed mainly for small mammals. The effect of weather on smaller mammals is probably mainly related to their activity (Wauters and Dhondt, 1987). The basic factor that affects the probability of an event is temperature, which significantly influenced squirrels (spring and summer), hedgehogs (spring and autumn) and bats (autumn) (Tab. 1). Squirrels are diurnal and their longest active period occurs in spring and summer (Wauters and Dhondt, 1987), therefore it is likely that there was a significant influence of temperature during this period. Higher temperatures probably induce animals to leave their hiding places and actively search for food more often. In both species (squirrels and hedgehogs), an influence of temperature on activity was found (Babińska-Werka and Żółw, 2008) while in hedgehogs the influence of temperature in spring and autumn mainly means that this animal starts or ends hibernation, because this process depends mainly on this factor (Morris, 2018). In spring, the sum of rainfall was important, a decrease of which was related to the increased probability of incidents with hedgehogs. This confirms the influence of warm, sunny days on activity in this species, and thus its increased exposure to incidents. Bats, for which an influence of temperature was observed only in the autumn, show the highest activity in this period (Russ et al., 2003), and temperature is the basic factor determining their activity (Heim et al., 2016)

Incidents with particular species are spatially related to the proportion of built-up areas. Species that are usually associated with humans clearly tend to have more incidents in areas with a greater proportion of built-up areas (Fig. 3). This applies to hedgehogs and some species of bats, which tend to reside in built-up area more often than outside them (Russo and Ancillotto, 2015; Van de Poel et al., 2015). There was no relationship between buildings and the number of incidents involving squirrels. This may be due to the fact that most urban squirrels are found in parks (Kopij, 2014). Depending on the location of such parks, more squirrels can be expected there, so their presence cannot be directly associated with a city's buildings. Large mammals showed the opposite tendency: the greater the proportion of built-up areas, the lower the frequency of events. This also corresponds to the tendency of these species to avoid built-up areas (Jasińska et al., 2021; Stillfried et al., 2017). Because they are game species, wild boar and roe deer tend to avoid interaction with humans. Therefore, it has been shown that these species use forests more often during the day as potentially protective habitats and resting places. At night, however, their activity increases when they go out into open spaces as there is less human activity at this time of day (Bonnot et al., 2013; Podgórski et al., 2013).

To conclude, our study shows the human infrastructure and activity cause the majority of wild mammal incidents. Events with small species are related to the weather conditions that determine their activity. In contrast, incidents with large mammals showed no dependence on weather conditions. The proportion of built-up areas was usually associated with the number of incidents. This relationship was positive for species that tend to live in cities, while it was negative for species that avoid human proximity.

References

Babińska-Werka J., Żółw M., 2008. Urban Populations of the Red Squirrel (*Sciurus vulgaris*) in Warsaw. Ann. Zool. Fennici 45(4): 270–276.

Basak S.M., Wierzbowska I.A., Gajda A., Czarnoleski M., Lesiak M., Widera E., 2020. Human-Wildlife Conflicts in Krakow City, Southern Poland. Animals (Basel) 10(6): 1014.

Bateman P.W., Fleming P.A., 2012. Big city life: carnivores in urban environments. J. Zool. 287(1): 1–23.

Beninde J., Veith M., Hochkirch A., 2015. Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol. Lett. 18 (6): 581–592.

Birnie-Gauvin K., Peiman K.S., Gallagher A.J., Bruijn R.D., Cooke S.J., 2016. Sublethal consequences of urban life for wild vertebrates. Environ. Rev. 24(4): 416–425.

Bonier F., 2012. Hormones in the city: endocrine ecology of urban birds. Horm. Behav. 61: 763–772.

Bonnot N., Morellet N., Verheyden H., Cargnelutti B., Lourtet B., Klein F., Hewison A.J.M., 2013. Habitat use under predation risk: hunting, roads and human dwellings influence the spatial behaviour of roe deer. Eur. J. Wildl. Res. 59(2): 185–193.

Bradley C.A., Altizer S., 2007. Urbanization and the ecology of wildlife diseases. Trends Ecol. Evol. 22(2): 95–102.

Dominoni D., Quetting M., Partecke J., 2013. Artificial light at night advances avian reproductive physiology. Proc. R. Soc. B. 280: 20123017.

Fahrig L., 2003. Effects of Habitat Fragmentation on Biodiversity. Annu. Rev. Ecol. Evol. System. 34: 487–515.

Francis C.D., Barber J.R., 2013. A framework for understanding noise impacts on wildlife: an urgent conservation priority. Front. Ecol. Environ. 11(6): 305–313.

Francis R.A., Chadwick M.A., 2012. What makes a species synurbic? Appl. Geogr. 32: 514–521.

Gaston K.J., Duffy J.P., Gaston S., Bennie J., Davies T.W., 2014. Human alteration of natural light cycles: causes and ecological consequences. Oecologia 176: 917–931.

Gaynor K.M., Hojnowski C.E., Carter N.H., Brashares J.S., 2018. The influence of human disturbance on wildlife nocturnality. Science 360: 1232–1235.

Grogan A., Kelly A., 2013. A review of RSPCA research into wildlife rehabilitation. Vet. Rec. Open 172(8): 211–211.

Heim O., Schröder A., Eccard J., Jung K., Voigt C.C., 2016. Seasonal activity patterns of European bats above intensively used farmland. Agric. Ecosyst. Environ. 233: 130–139.

Herr J., Schley L., Engel E., Roper T.J., 2010. Den preferences and denning behaviour in urban stone martens (*Martes foina*). Mamm. Biol. 75: 138–145.

Hughes J., Macdonald D.W., 2013. A review of the interactions between free-roaming domestic dogs and wildlife. Biol. Conserv. 157: 341–351.

Jasińska K.D., Jackowiak M., Gryz J., Bijak S., Szyc K., Krauze-Gryz D., 2021. Habitat-Related Differences in Winter Presence and Spring-Summer Activity of Roe Deer in Warsaw. Forests 12: 970.

Jokimäki J., Selonen V., Lehikoinen A., Kaisanlahti-Jokimäki M.-L., 2017. The role of urban habitats in the abundance of red squirrels (*Sciurus vulgaris*, L.) in Finland. Urban For. Urban Green. 27: 100–108.

Kight C.R., Swaddle J.P., 2011. How and why environmental noise impacts animals: an integrative, mechanistic review. Ecol. Lett. 14(10): 1052–1061.

Kopij G., 2014. Distribution and abundance of the Red Squirrel *Sciurus vulgaris* in an urbanised environment. Acta Musei Sil. Sci. Natur. 63(3): 255–262.

Krauze-Gryz D., Gryz J., Żmihorski M., 2019. Cats kill millions of vertebrates in Polish farmland annually. Glob. Ecol. Conserv. 17: e00516.

Longcore T., Rich C., 2004. Ecological light pollution. Front. Ecol. Environ. 2(4): 191–198.

Loss S.R., Will T., Marra P.P., 2013. The impact of free-ranging domestic cats on wildlife of the United States. Nat. Commun. 4: 1396.

Loyd K.A.T., Hernandez S.M., Carroll J.P., Abernathy K.J., Marshall G.J., 2013. Quantifying free-roaming domestic cat predation using animal-borne video cameras. Biol. Conserv. 160: 183–189.

Luniak M., 2004. Synurbization — adaptation of animal wildlife to urban development. Proceedings of the 4th International Symposium Urban Wildlife Conservation of Tucson. 50–55.

Luniak M., 2008. Fauna of the Big City — Estimating Species Richness and Abundance in Warsaw Poland. In: Marzluff J.M., Shulenberger E., Endlicher W., Alberti M., Bradley G., Ryan C., Simon U., ZumBrunnen C. (Eds.) Urban Ecology: An International Perspective on the Interaction Between Humans and Nature. Springer US, Boston, MA. 349–354.

Łopucki R., Klich D., Kiersztyn A., 2021. Changes in the social behavior of urban animals: more aggression or tolerance? Mamm. Biol. 101: 1–10.

Łopucki R., Klich D., Kitowski I., Kiersztyn A., 2020. Urban size effect on biodiversity: The need for a conceptual framework for the implementation of urban policy for small cities. Cities 98: 102590.

Łopucki R., Klich D., Ścibior A., Gołębiowska D., 2019. Hormonal adjustments to urban conditions: Stress hormone levels in urban and rural populations of *Apodemus agrarius*. Urban Ecosystems, 22: 435–442.

McCleery R.A., Lopez R.R., Silvy N.J., Kahlick S.N., 2007. Habitat Use of Fox Squirrels in an Urban Environment. J. Wildl. Manage. 71(4): 1149–1157.

McKinney M.L., 2002. Urbanization, Biodiversity, and Conservation: The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. BioScience 52(10): 883–890.

McKinney M.L., 2008. Effects of urbanization on species richness: A review of plants and animals. Urban Ecosyst. 11: 161–176.

Mikula P., Šaffa G., Nelson E., Tryjanowski P., 2018. Risk perception of vervet monkeys *Chlorocebus pygerythrus* to humans in urban and rural environments. Behav. Process. 147: 21–27.

Molina-López R.A., Mañosa S., Torres-Riera A., Pomarol M., Darwich L., 2017. Morbidity, outcomes and cost-benefit analysis of wildlife rehabilitation in Catalonia (Spain). PLOS ONE 12(7): e0181331.

Morris P., 2018. Hedgehog. William Collins, London, UK. No. 137.

Mullineaux E., 2014. Veterinary treatment and rehabilitation of indigenous wildlife. J. Small Anim. Pract. 55(6): 293–300.

Murray M.H., Sánchez C.A., Becker D.J., Byers K.A., Worsley-Tonks K.E., Craft M.E., 2019. City sicker? A meta-analysis of wildlife health and urbanization. Front. Ecol. Environ. 17(10): 575–583.

Oro D., Genovart M., Tavecchia G., Fowler M.S., Martínez-Abraín A., 2013. Ecological and evolutionary implications of food subsidies from humans. Ecol. Lett. 16(12): 1501–1514.

Pagany R., 2020. Wildlife-vehicle collisions — Influencing factors, data collection and research methods. Biol. Conserv. 251: 108758.

Partecke J., Gwinner E., 2007. Increased sedentariness in european blackbirds following urbanization: a consequence of local adaptation? Ecology 88(4): 882–890.

Perry G., Boal C., Verble R., Wallace M., 2020. "Good" and "Bad" Urban Wildlife. In: Angelici F., Rossi L. (Eds.) Problematic Wildlife II. Springer, Cham. 141–170.

Podgórski T., Baś G., Jędrzejewska B., Sönnichsen L., Śnieżko S., Jędrzejewski W., Okarma H., 2013. Spatiotemporal behavioral plasticity of wild boar (*Sus scrofa*) under contrasting conditions of human pressure: primeval forest and metropolitan area. J. Mammal. 94(1): 109–119.

Russ J.M., Briffa M., Montgomery W.I., 2003. Seasonal patterns in activity and habitat use by bats (*Pipistrellus* spp. and *Nyctalus leisleri*) in Northern Ireland, determined using a driven transect. J. Zool. 259(3): 289–299.

Russo D., Ancillotto L., 2015. Sensitivity of bats to urbanization: a review. Mamm. Biol. 80(3): 205–212.

Santangelo J.S., Rivkin L.R., Johnson M.T.J., 2018. The evolution of city life. Proc. Roy. Soc. B Biol. Sci. 285: e20181529.

Seiler A., Helldin J.O., 2006. Mortality in wildlife due to transportation. In: Davenport J., Davenport J.L. (Eds.) The Ecology of Transportation: Managing Mobility for the Environment. Springer Netherlands, Dordrecht. 165–189.

Seiler A., Bhardwaj M., 2020. Wildlife and Traffic: An Inevitable but Not Unsolvable Problem? In: Angelici F., Rossi L. (Eds.) Problematic Wildlife II. Springer, Cham. 171–190.

Serieys L.E.K., Lea A.J., Epeldegui M., Armenta T.C., Moriarty J., VandeWoude S., Carver S., Foley J., Wayne R.K., Riley S.P.D., Uittenbogaart C.H., 2018. Urbanization and anticoagulant poisons promote immune dysfunction in bobcats. Proc. R. Soc. B. 285: 20172533.

Shochat E., 2004. Credit or debit? Resource input changes population dynamics of city-slicker birds. Oikos 106(3): 622–626.

Stillfried M., Gras P., Börner K., Göritz F., Painer J., Röllig K., Wenzler M., Hofer H., Ortmann S., Kramer-Schadt S., 2017. Secrets of Success in a Landscape of Fear: Urban Wild Boar Adjust Risk Perception and Tolerate Disturbance. Front. Ecol. Evol. 5: 157.

Tait C.J., Daniels C.B., Hill R.S., 2005. Changes in species assemblages within the Adelaide Metropolitan Area, Australia, 1836–2002. Ecol. Appl. 15(1): 346–359.

Tribe M.A., Brown M.P.R., 2000. The role of wildlife rescue groups in the care and rehabilitation of Australian fauna. Human Dimensions of Wildlife 5(2): 69–85.

Van de Poel J.L., Dekker J., van Langevelde F., 2015. Dutch hedgehogs *Erinaceus europaeus* are nowadays mainly found in urban areas, possibly due to the negative effects of badgers *Meles meles*. Wildlife Biol. 21(1): 51–55.

Wauters L., Dhondt A.A., 1987. Activity budget and foraging behaviour of the red squirrel (*Sciurus vulgaris*, Linnaeus, 1758) in a coniferous habitat. Z. Säugetierkd 52(6): 341–353.

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