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Review

It Is a Wild World in the City: Urban Wildlife Conservation and Communication in the Age of COVID-19

Ioana A. Coman [1], Caitlyn E. Cooper-Norris [2], Scott Longing [3] and Gad Perry [2,*]

[1] Department of Public Relations and Strategic Communication Management, College of Media and Communication, Texas Tech University, Lubbock, TX 79409, USA; ioana.coman@ttu.edu
[2] Department of Natural Resources Management, Texas Tech University, Lubbock, TX 79409, USA; caitlyn.e.cooper@ttu.edu
[3] Department of Plant and Soil Science, Texas Tech University, Lubbock, TX 79409, USA; scott.longing@ttu.edu
* Correspondence: gad.perry@ttu.edu

Abstract: Most ecosystems are increasingly being degraded and reduced by human activities at the local and global scales. In contrast, urban environments are expanding as increasing portions of humanity move into cities. Despite the common perception among biologists that urban areas are biological deserts, cities offer habitat for many non-human species, but their ecology and conservation remain poorly studied. In this review, we first provide an update on the current state of knowledge on urban wildlife, then briefly examine the indirect effects of the COVID-19 pandemic on urban wildlife and add four components not previously included in comprehensive reviews. (1) We show that by reducing human activity, COVID-19 has temporarily enhanced urban habitat quality for some species and diminished it for others. (2) Thoughtful horticulture can contribute to urban wildlife by providing complex habitat structures that benefit biodiversity while enhancing human wellbeing. (3) Recent literature on urban invertebrate biodiversity has grown, though is still focused on pollinators. (4) Finally, employing insights from the discipline of communication can enhance the success of urban biodiversity conservation among both biologists and the public.

Keywords: urban ecology; urban conservation; urban vegetation; public perceptions; communication strategies

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1. Introduction

Cities first emerged thousands of years ago and, in recent decades, became the predominant human habitat [1]. Increasingly numerous and geographically widespread, they offer diverse habitats and species. Although urban plant diversity can decline as compaction increases, similar numbers of species may be found in adjacent urban and rural settings (e.g., [2]), though urban floras are more likely to have large non-native components. More floristically diverse urban landscapes support a greater diversity of animal species (e.g., [3]) and traits (e.g., [4]). Despite increasing attention, the biodiversity of cities, and especially the conservation value of urban ecosystems, remain poorly studied [1,5]. The value that cities provide to humans, especially in poorer countries, and their potential to contribute to improved human wellbeing and the potential of new technologies to change the nature of urban natural resource management are also often under-appreciated [6,7]. Likewise, the relevance of human socioeconomic factors to urban biodiversity patterns is understudied [8]. In contrast, the relevance of urban wildlife consumption and the trade between urban and rural areas and among cities have received growing attention in light of the COVID-19 pandemic. Likewise, urban ecology, with a focus on biogeochemical cycles, has recently received increased attention [9].

Perry et al. [1] surveyed the literature on urban wildlife and their interactions with the human population and noted that human-wildlife interaction in urban settings may be divided into "good"—those that provide benefits to humans and/or wildlife—and

"bad"—instances where the interaction is detrimental to at least one side. On the "good" side, for example, humans provide habitat for many other species by creating structures or providing food. For example, a picture in the Israeli newspaper Haaretz [10] shows a woman in Kiev, Ukraine, feeding street pigeons with bread bought during the ongoing war there, despite food shortages. Such positive interactions clearly can have large significance for people, but urban wildlife can also become a nuisance or carry diseases. How those trends, surveyed through 2017, would develop as urbanization continues, automation expands, and climate change worsens were open questions [1]. Here, we first survey recent worldwide, English-language peer-reviewed literature and some popular news items, mainly in English, to update previous work, then expand the discussion in four related areas not included in [1]: (1) the indirect effects of the COVID-19 pandemic on urban wildlife; (2) the importance of urban vegetation (and especially native vegetation [11]) as a component contributing to urban biodiversity in general and supporting urban wildlife and human wellbeing in particular; (3) the growing literature on urban invertebrates; and (4) the crucial need for understanding and addressing public perceptions of urban biodiversity. We hypothesized that the relatively short period since the review of Perry et al. [1] would not allow for major new insights on urban ecology to emerge but that the decreases in human activity in public spaces as a result of the pandemic would allow some species to expand their activity—an example of second-order impacts of COVID-19 (e.g., [12]). We also predicted that the literature on both urban plants and invertebrates will be growing and not be focused on the conflict aspect that overwhelmingly dominates the vertebrate literature [1]. Finally, we hypothesized that media reporting of urban wildlife will show the same sensation- and conflict-driven focus that coverage of other issues typically does, possibly helping drive some negative perceptions among both professionals and, especially, the general public.

2. Urban Biodiversity Conservation: An Update, with Particular Attention to COVID-19

2.1. Recent Work on Urban Wildlife

2.1.1. Invertebrates

Urban wildlife studies have traditionally focused on vertebrates, though invertebrates are by far the more numerous on Earth. Human alterations to natural landscapes still allow us to receive benefits from invertebrates (e.g., ecosystem services of pollination and pest control) and provide opportunities for invertebrates to compete for resources (e.g., herbivory in agricultural crops and structural pests). Invertebrates such as mosquitoes and ticks also serve as vectors for disease-causing organisms and more directly impact human health. This has led to insects often being considered "pests", though only approximately 10,000 insects of over one million described species deserve the title, even from an anthropocentric perspective, and many are beneficial to humans [13]. Some flagship insect species, such as the honeybee and the monarch butterfly, serve as conduits by which humans are linked to nature and conservation actions. Because invertebrates have relatively small functional resource requirements, cities serve as refuges for some insects [14]. However, the impacts of urbanization are not limited to the terrestrial world. For example, aquatic insects with terrestrial life stages have been shown to be affected by characteristics of both riparian and upland landscapes, influencing stage development and dispersal [15].

In recent years, several studies have been devoted to urban invertebrates and conditions that enhance their diversity, including the roles of beneficial insects that provide ecosystem services [16] and supporting our initial prediction. The city is increasingly viewed as a complex entity that includes both vertebrate and invertebrate ecological components [17] and intermingled humans and their activities (Supplementary Material). For example, invertebrates provide food for wildlife and support ecosystem services such as pollination provides a value of USD $57 billion annually in the U.S. [18]. Similarly, the structure of the urban landscape influences the composition of insect functional groups, which in turn provide added monetary value [19,20]. Conservation and restoration of

natural resources such as native soils in order to promote urban pollinators may also benefit nearby gardens and other green spaces [21], and replacing closely mowed lawns with longer grassy vegetation leads to "substantial biodiversity benefit", including an increase in self-dispersed plant species, a positive response in soil microbiome, and an increase in invertebrate taxa [22]. This has led to some cities declaring months in which no mowing of residential lawns would occur [23]. What is gradually emerging is a move from a conflict-only perception of urban invertebrates (focusing, for example, on cockroaches) to a more nuanced view that acknowledges that such conflict exists, but that there are also benefits, some of them substantial and multifaceted. Unfortunately, invertebrate biodiversity continues to diminish in urban settings [24], a loss primarily abetted by apathy toward this important component of ecosystems. Whereas ecology journals have shown an increase in studies of community ecology, including in urban settings, the term "urban" did not emerge as important in entomological journals [25].

In what is becoming a common approach in other taxa as well, citizen monitoring has been used to integrate academia and the public in conducting citizen science invertebrate surveys [26]. During the COVID-19 pandemic, educators charged with innovating distance education sought to promote interactions in nature in response to student isolated and mental health challenges. For an example, Schirmel [27] engaged life science students to become "citizen scientists", documenting and comparing insect and plant communities across habitats. In support of such efforts, online biodiversity programs such as iNaturalist assist in linking remote and online student learning with local nature.

2.1.2. Vertebrates

The interactions of humans with urban vertebrates were extensively reviewed relatively recently [1]. Because of their relatively large size and the carnivorous habits of many vertebrates, they are often hard to miss, and their presence in an urban setting is commonly seen as troublesome (see Section 4.1 below). One traditional way to reduce such conflict has been through legislation, and this remains common. For example, Clayworth [28] reported on the ongoing process of passing a resolution banning wildlife feeding in the city of Des Moines, Iowa, USA. Originally including feral cats and any species "not normally domesticated", the ban was narrowed to only include waterfowl and deer after residents complained that the definition of "wild animal" was too broad and would have prohibited feeding species liked by many, such as squirrels and alley cats. Extending a trend to also look at the positive aspects of the urbanization/wildlife interface, Cooper et al. [29] recently showed that secondary cities offer a better habitat for wildlife than do large cities such as Los Angeles, and Dunn et al. [30] concluded that urban species residing in gray zones—areas high in built structures and low in vegetation—have a greater potential for evolutionary innovations to emerge than those residing in the green habitats more traditionally studied.

Even more common than legislation is lethal control, although that option is increasingly opposed by animal rights proponents and others [31,32]. As lethal options become less acceptable in all but the most extreme cases, managers are increasingly forced to develop ways to foster human–wildlife coexistence, emphasizing the need for effective communication with the human population [33]; see Section 4.2 below. Below we update the status of three themes brought up by Perry et al. [1]: (a) trends in publication; (b) the role of urban wildlife rehabilitation centers; and (c) notable recent research.

Trends in Publication

Perry et al. [1] showed a decadal increase in publications related to urban ecology. Here we look at annual patterns in the years since the turn of the century. A total of 167,744 papers were published in the four categories surveyed over this period, 78.3% of them in the "urban ecology" category, 9.4% in "human-wildlife conflict", 7.6% in "urban conservation", which included a substantial number of papers focusing on cultural heritage preservation, and 4.7% in "urban + "human–wildlife conflict"". Consistent with the

findings of Perry et al. [1] and Collins et al. [34], all four categories showed an increase in the number of annual publications during the first decade surveyed, numbers decreased thereafter, then stabilized in the "urban ecology" category and continued increasing in all others (Figure 1).

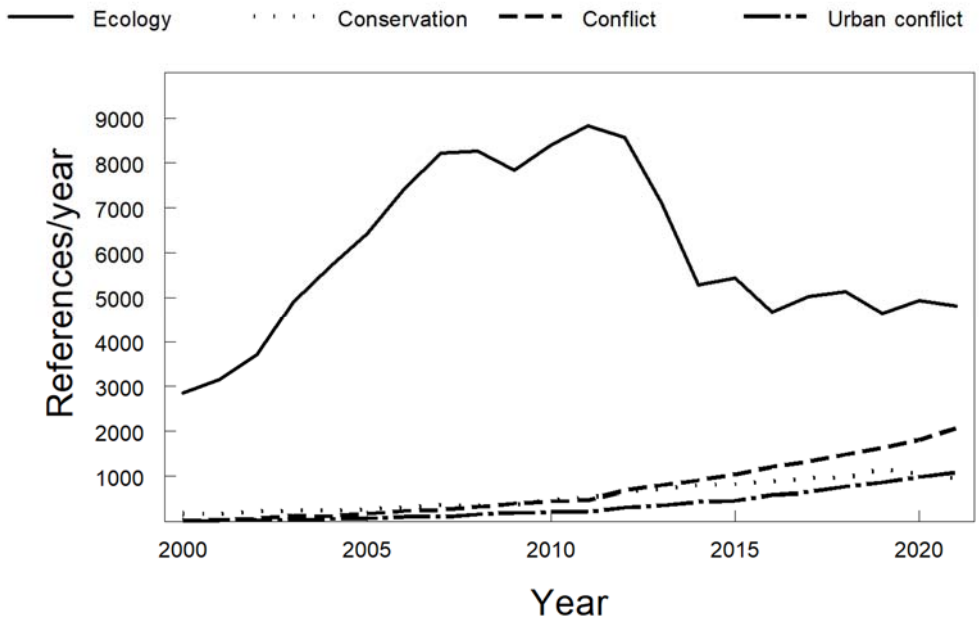

Figure 1. Trends in publications on urban ecology and conservation since 2000. Data are taken from Google Scholar searches conducted at the end of 2021. Search terms used were Ecology: "urban ecology"; Conservation: "urban conservation"; Conflict: "human-wildlife conflict"; and Urban conflict: "urban + "human-wildlife conflict"".

Urban Wildlife Rehabilitation Centers (WRCs)

A growing number of studies report on WRCs, which provide important services in urban settings, combining rescue and educational functions [1]. As such, they often receive animals that are wounded or sick. They are therefore contaminated with a wide diversity of pathogens, many of them drug resistant [35]. With the ongoing pandemic in mind, they may warrant special attention by public health programs searching for zoonoses (e.g., [36]) and the potential for transmission to humans and other wildlife [37].

WRCs pride themselves on the proportion of intakes that are ultimately released. Using that measure of success, Molina-López et al. [38] showed that in a WRC in Spain, the greatest rates of success were in the categories including animals previously held in captivity, confiscated from the public, or found in inappropriate settings. The worst return on rehabilitation investment was found in animals suffering from trauma or infectious disease, birds (particularly raptors, waders, and marine taxa), and bats. Similar results were reported from a large Australian data set [39]. In the state of New York, USA, amphibians and mammals had the highest release rates, whereas reptiles and birds had the lowest [40]. Data from Ontario, Canada, show the highest rate of release in reptiles and the lowest in birds [41]. For marine taxa in eastern North America, earless seals (family Phocidae) and stranded sea turtles were more likely to be successfully released, whereas cetaceans were the least likely to be successfully rehabilitated [42]. However, percent released may be a poor indicator of positive conservation impact. Post-release monitoring is rare [1,43] and, in some cases, shows low post-release survival rates [44]; see [45].

Perry et al. [1] provided information about the South Plains WRC and the characteristics of rehabilitators in the state of Texas, USA. We provide two updates to those data, taken from center computer records. First, their current mode of data collection allows a new category of admissions, animals shot with guns, arrows, or darts, to be identified. This category is of particular interest because it represents intentional abuse of urban animals,

a form of conflict. The result (Table 1) shows at least one animal brought in every year between 2017, when data began, and the end of 2021, most of them locally common species. Whereas most Canada geese and the sandhill crane were likely to be animals shot by hunters and not killed, others were intentionally targeted with arrows, darts, and air rifles for reasons presumed to be malicious. In addition to these, WRC staff recalled additional cases that were reported to them but where animals were not brought to the center. Few of those cases were ever reported in the local news, according to center personnel. There were multiple reports of freshwater turtles being targeted in the city park ponds, but no numbers were available. Overall, the numbers of animals shot are small (Table 1) but are doubtless an underestimate of the problem.

Table 1. Animals [1] brought or reported to the South Plains Wildlife Rehabilitation Center in Lubbock, Texas, after being shot and found in urban areas.

	2017	2018	2019	2020	2021	Reported	Total
Reptiles							
Aquatic turtles						Multiple	Multiple
Birds							
White-winged dove		1	1	1			3
Western kingbird				1			1
Canada goose	1		1	1	2	Multiple	5
Sanhill crane					1		1
Cattle egret			1				1
Sawinson's hawk					1		1
Mississippi kite				1			1
Mammals							
Black-tailed prairie dog						1	1
Total	1	0	2	2	4		9

[1] All species identifications are based on WRC records. White-winged dove: *Zenaida asiatica*; Western kingbird: *Tyrannus verticalis*; Canada goose: *Branta canadensis*; Sandhill crane: *Antigone canadensis*; Cattle egret: *Bubulcus ibis*; Swainson's hawk: *Buteo jamaicensis*; Mississippi kite: *Ictinia mississippiensis*; Black-tailed prairie dog: *Cynomys ludovicianus*.

Finally, McGaughey et al. [46] and Perry et al. [1] reported on overall admissions to the South Plains WRC. They found that admissions increased in the years after the WRC opened but then stabilized. We wanted to see how the COVID-19 pandemic affected those rates. Given changes to human activity levels (see Section 2.3 below), we envisioned two scenarios. In one, increased time spent at home would increase exposure to urban wildlife and the number of animals brought in. Conversely, reduced overall human public activity because of COVID-19 could decrease the number of animals encountered and brought in. Data from 2017 to 2021 showed neither of these patterns, with admissions remaining reasonably consistent over time (Figure 2).

Notable Recent Research on Urban Conservation and Urban Wildlife

Of necessity, this section only covers a very small portion of the extensive literature shown in Figure 1. Turo and Gardiner [47] recently touched on the complicated dance required to balance the needs and wants of human urban residents with achieving conservation targets. Two of their most important conclusions are that socioecological theory, which describes the complex conceptual interplay between societal and ecological factors and reality on the ground, may not fully intersect and that strategies appropriate for one location may not be applicable in another. This latter point is reinforced by a perspective from China [48] which emphasizes that "Urban conservation in China has been influenced by Chinese cultural and philosophical traditions" in ways that are quite different from Western perspectives. In their review, Collins et al. [34] note the growth in publications on urban social science and disease ecology and the ongoing bias toward studying mammals and birds, mostly in rich countries—problems repeatedly noted in conservation science in

general. The need to include vegetation and invertebrates in urban studies, as we are doing here, has also been emphasized by Egerer and Buchholz [49]. Finally, the need to improve urban wildlife health surveillance was brought up, just before the irruption of COVID-19, by Stephen [50].

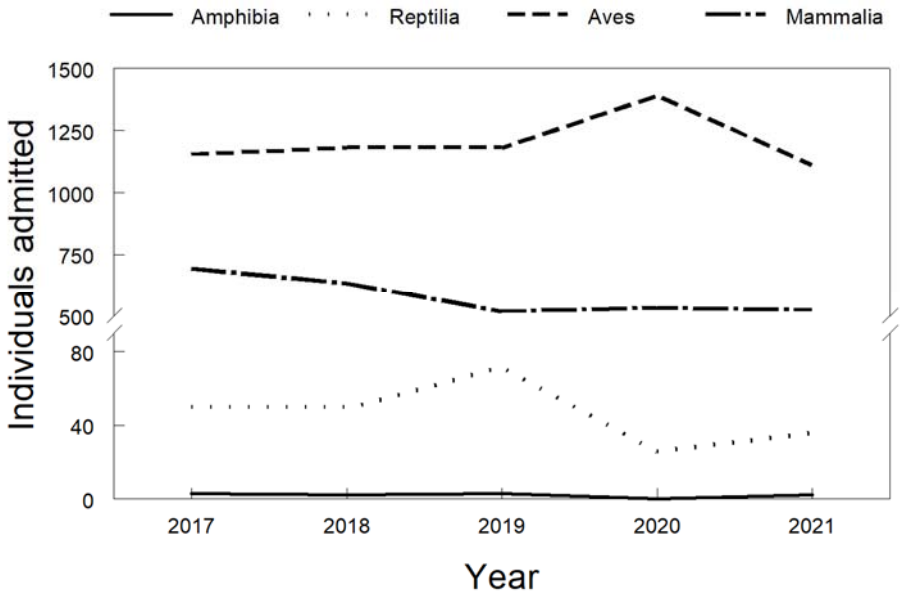

Figure 2. Five-year trends in admittance of amphibians, reptiles, birds, and mammals at the South Plains Wildlife Rehabilitation Center in Lubbock, Texas.

2.2. Progress on Automation in Urban Conservation Management

Novel opportunities for human-wildlife conflict have emerged with the increasing incorporation of drones and other automatic devices in urban environments [6]. The predictions they made have had relatively little time to be tested, but there have already been some surprises. For example, Evans [51] recently reported on urban ravens (*Corvus coronoides*) disrupting drone delivery of coffee in Canberra, Australia. Of course, the lockdown and global disruption caused by the COVID-19 pandemic have also changed the landscape, at least temporarily. Such uncertainty has led Yigitcanlar et al. [52] and Galaz et al. [53] to call for extreme care in implementing novel technologies that entail "the risk of creating new urban problems and/or intensifying the old ones instead of alleviating them", a concern we certainly share under the precautionary principle.

2.3. Second-Order Impacts of COVID-19

The global direct impacts of COVID-19 have been extensive and multifaceted. Recent work has also begun exploring second-order impacts (e.g., [12,54]), and their implications for human-wildlife interactions have been speculatively compared to those of war [55]. During the pandemic-caused "anthropause", human activity patterns drastically changed in many cities, whether because of mandated or self-enforced mobility restrictions. People increased their use of urban green spaces, with some notable differences between demographics [56]. Many news stories showed wild animals claiming empty urban places [57,58], either because of reduced competition from humans or, such as hungry monkeys being unruly in Lopburi, Thailand [59], because resources regularly provided by humans were withdrawn. These were somewhat reminiscent of reports on how wildlife has proliferated in the city of Chernobyl, Ukraine, following the nuclear disaster and the removal of human presence (e.g., [60]). However, the irruption of the pandemic is still quite recent and ongoing, so peer-reviewed evaluations have been relatively few. Zellmer et al. [61] provided a perspective on the questions being raised and tools that might be available to answer them. Their key questions had to do with measuring changes to the urban environment (e.g., noise and human activity levels) and their effect on other urban taxa, and whether differences

in policy approach to the pandemic will affect those [61]. They suggested a multi-city approach that relies on a combination of citizen science and automated technology such as trail cameras.

We also know that the pandemic has led to a heightened public awareness of nature [62]. Abd Rabou [63] reviewed reports from the media and social media, found dozens of species mentioned from around the world, and collated photos of wildlife active in urban settings from a variety of sources. His conclusions were three-fold: first, COVID-19 created opportunities for wildlife to expand their activity in areas made quiet by the reduction in human behavior and, in some cases, showed much increased reproductive success; second, more action is needed to reduce the illegal trade in wildlife, much of it ending up in urban areas, that has likely led to the current pandemic in conjunction with high rates of global mobility; and third, that in the poorer areas worst economically hit by the global downturn, "poaching and hunting of wildlife have increased". Support for that final conclusion also comes from recent work in Mexico [64]. Abd Rabou [63] also collated reports of COVID-19 infecting pets and wild animals. Le Page [65] summarized recent studies on this, noting that the virus is now "rife among the 30 million white-tailed deer in North America", raising concern about the "risk of deer infecting other species, and also of new variants emerging in other animals and jumping back to people". In Chile, anecdotal observations of güiña (*Leopardus guigna*) and southern river otter (*Lontra provocax*) provide evidence of increased activity during the pandemic [66]. Similarly, Shome et al. [67] report the presence of many species of birds in Jamalpur, Bangladesh. However, no conclusive support exists in either study for the hypothesis that these reflect the effects of the shutdown [66].

Wearing face masks on urban streets had no effect on flight initiation distance (FID) of European urban birds [68] but did affect FID in desert-dwelling Nubian ibex (*Capra nubiana*) in Israel [69]. In Spain, bird activity documented in an ongoing citizen science project did not increase during the lockdown, but the authors did note an increase in bird detectability associated with a change in activity times [70]. iNaturalist citizen-science data from North American cities likewise provided a mixed picture, with most species of mammalian predators showing little change in documented behavior, whereas other taxa increased their urban range [71]. Although mountain lions (*Puma concolor*) expanded into previously unexplored regions of the Los Angeles area in the United States, they reduced their activity levels [72]. Similarly, a diverse set of data allowed Manenti et al. [73] to identify increases in the species richness of some taxa in locations where human activity declined, but also that the lockdown hampered or prevented some ongoing conservation efforts in Italy.

Finally, reduced traffic resulted in a reduction in roadkills in some urban and non-urban settings and species but not in others, perhaps because increased animal activity in response to decreased traffic sometimes made animals more susceptible to remaining vehicular motion [74–77].

3. Urban Vegetation: Benefits, Constraints, and Effects on Urban Wildlife

Plants are important constituents that provide ecosystem services such as heat mitigation, cooling, and filtration of pollutants and particulate matter in urban landscapes. Urban plants provide habitat and food sources for wildlife and contribute to human well-being. Urban green (typically parks) and gray (often vegetation associated with denser construction) areas provide substantial urban plant biodiversity, encompassing both native and non-native species [78,79]. They include a variety of vegetated areas, including remnant natural areas; managed areas such as parks, home gardens, and yards; heavily maintained "terraformed" areas and green roofs; bioswales and rain gardens; and unmanaged brownfields and vacant lots. However, non-native vegetation often has negative impacts on native vegetation and urban wildlife [11].

Urban areas can provide substantial plant biodiversity, but greater abundance and species richness do not always equate to suitable quality habitat for urban wildlife. Between 30% and 50% of urban plant species are non-native [79–82]. Non-native plant species abundance and richness increase in more urbanized environments [83], a process driven

by human-mediated trade and transport, whether that be unintentional or intentional [84]. Non-native plant species also tend to be more tolerant of the altered soil structure, hydrology, and microclimates characteristic of urban areas and benefit from reduced pressure from competing species and natural enemies (i.e., pests, herbivores) [83]. Effects of alien vegetation on urban wildlife range from positive, to negative, to negligible [11,85]. Generally, native plant species benefit urban wildlife, with native animal species benefiting (e.g., greater abundance, diversity, occupancy, and richness) more frequently from native than exotic plant species [11]. Non-native animals tend to benefit more from introduced plant species. Wildlife responses to plants' "nativeness" are complex, however. Requirements for habitat and food resources are highly variable across species, and the provision of necessary resources is ultimately more important than plant origin [86,87]. The ability of wildlife to acclimate to suboptimal resources thus plays a major role in determining species' success in urban environments. Additionally, even if an urban space contains primarily native plant species, native wildlife abundance and richness may be low due to competition with better-adapted nonnative biota.

Four primary vegetational factors shape urban habitat use by wildlife: (1) plant community composition, (2) plant species richness, (3) vertical and horizontal vegetation structure, and (4) plant community successional stage [88]. Urban vegetation management (e.g., pruning, mowing, removal of dead or diseased vegetation) directly alters vertical and horizontal vegetation structure but also affects vegetative species recruitment and age structure. Because each animal species has a unique set of requirements, it is important for cities to use a "differential management" approach that aims to balance traditional intensive horticultural and landscape management practices with more natural, environmentally friendly practices such as varying mowing heights and decreasing mowing frequency [89]. In 2004, the city of Paris started using a "differential management" program in which gardeners and park managers could choose to apply a variety of practices from a set of guidelines. This resulted in management variance across a network of interconnected habitat patches. Public gardens using enough differential management practices to become certified as "biodiversity-friendly" had greater bird and pollinator richness than non-certified public gardens. Wild plant and butterfly diversity also increased in certified gardens [89]. Green spaces, nature, and biodiversity are valued by city dwellers [90]. This became particularly apparent during the COVID-19 pandemic [56]. During lockdowns associated with the pandemic, urban outdoor recreation activities were reported to increase [91,92]. Similarly, survey respondents reported that having indoor plants in their households during the pandemic benefited their emotional welfare [93]. More than half of respondents reported taking more care of houseplants while being confined, and more than 60% communicated a desire to take more time caring for houseplants once normality resumed. The extent to which citizens experience and benefit from biodiversity in urban green spaces is debated. For example, Dallimer et al. [94] found inconsistent relationships between actual plant, butterfly, and bird species richness and the psychological well-being of urban greenspace visitors. However, for many urban residents, visiting urban green spaces is the primary or even sole means of encountering biodiversity. Urban green spaces thus provide residents opportunities to connect with nature, view ecological processes in person, and potentially become better capable of making decisions about conservation initiatives and policies in and away from the urban setting. Though humans value urban green spaces and the plant and animal resources they provide, increasing the availability of urban vegetation and habitat may increase human-wildlife conflict. Areas with "good" habitats have a greater abundance and occupancy of wildlife, which in turn results in increased potential for human-wildlife interactions. The vegetative composition and structure of urban green spaces can ameliorate desired interactions or exacerbate negative interactions. For example, increasing tree density in parks should decrease human-squirrel interactions [95]. Low tree density results in fewer places for arboreal wildlife to take refuge and increases their exposure to humans. Finally, the abundance of vegetation may decrease urbanites' sense of safety, especially at night [96].

The ability of urban plants to provide essential ecosystem services must also be considered in the context of climate change. Impervious surfaces such as roads and rooftops absorb solar radiation and emit heat, creating urban heat islands that are significantly warmer than surrounding rural areas. Urban parks and preserves may form "cool islands", which are buffered from heat- and pest-related stress and, in turn, help mitigate the surrounding urban heat island effects [97]. Urban trees shade buildings, sidewalks, and the sides of roadways, moderating radiant heat and improving outdoor human and animal thermal comfort [98]. Woody and herbaceous vegetation provide natural air cooling through transpiration. Urban plants filter air as well, absorbing pollutant gases and trapping particulate matter [99,100]. Rain gardens and bioswales reduce stormwater runoff by slowing flow and increasing infiltration while also filtering out pollutants. Urban plants are often under abiotic stress and may suffer severe pest infestations. Warmer temperatures may benefit urban arthropod pests by either directly increasing their survival or fecundity or by indirectly increasing host plant stress, making plants more suitable for infestation and subsequent loss of ecosystem services [101]. The urban heat island effect is associated with reductions in soil moisture and increases in vapor pressure deficit, which may reduce plants' photosynthetic rates and water use efficiency [102].

4. Urban Wildlife and the Media

4.1. How People Perceive Wildlife

As encounters of humans with wild animals are becoming more common in urban settings, public scrutiny of urban wildlife and coverage in the popular media are also increased [103,104]. Abundant research has shown that public opinions and views are influenced by media frames (e.g., [105–107]). Often, the media will also help set the public agenda [108]. This includes influencing attitudes about wildlife and conservation outcomes and policies [109]. Thus, media coverage of human-wildlife interactions results from the overlap between the activities of humans and other species but also helps set public perceptions of those interactions [110]. Indeed, "it is equally important for biologists and ecologists to understand the social context of media and learn to communicate their conservation messages through them to gain public support for effective management [110] (p. 346). Gore and Knuth [111] explored the effect of a communication campaign about wildlife-related risks and found that news exposure influenced the level of public acceptance of risks from black bears. They also highlighted the importance of media effects for wildlife professionals. More recently, Wang et al. [112] studied the interaction of news agenda and public agenda as they relate to COVID-19 and found dynamic and reciprocal interactions on social media.

Since "[a]nimals doing what animals do normally are topics not well-suited for the average newspaper or TV newscast" [113] (p. 399), the stories that emerge are unlikely to always be positive in nature or suggest benefits to wildlife presence in the human arena. After all, the classic aphorism exemplifying newsworthiness in journalism states, "if a dog bites a man is not news, if a man bites a dog, it is news". This suggests that the essence of the news story is in its reversed relationship between animals and humans. Since it is critical to understand how these issues are portrayed in the media, we provide two specific examples and more systematically review how recent news stories around the world portrayed urban wildlife. Popular press stories can be categorized into three main types:

I. **Wild animals who break into human settings.** We have found three subcategories:

- *Aggression*, such as stories of wild boars in Barcelona (see I.1 below) or Israel; bears in Colorado or Romania; bites from raccoons or coyotes; etc. In these types of stories, the media often presents animals as wilder or more aggressive than they really are, reinforcing the idea that they should be chased, relocated, or killed. Most of the time, this occurs without saying much about human responsibility (e.g., do not feed the bears). These stories also include the ones about animals who ended up somewhere where they are not native/usually seen.

- *Non-aggression*, such as wild turkeys reported roaming the paths of Harvard University (see I.2 below). These are typically funny, "Disney"-type stories where cute animals such as deer harmlessly walk near people.
- *Nuisance*, species that live in urban areas and become an irritation, such as rats or pigeons. Periodically an irruption is reported where they are "suddenly" seen "everywhere".

These categories extend into popular culture as well, with movies such as *Jaws* and *The Birds* emphasizing the potential for wildlife aggression in or near urban settings, *Ratatouille* showing the potential for nuisance.

I.1. An example: Shakira and the wild boars (*Sus scrofa*). In the second half of 2021, singer Shakira visited Barcelona, Spain. The presence of boars (*Sus scrofa*) in the city is not new, but populations have grown and become increasingly habituated in recent decades [83]. In September, Instagram posts described how "two wild boars . . . attacked me in the park were taking my bag to the woods with my phone in it. They've destroyed everything." The story was widely reported in outlets such as BBC, CNN, El País, Fortune, HuffPost, LA Times (Spanish and English versions), NBC, The Hill, Vanity Fair, and the Washington Post, among others (e.g., [114]). One of the more lurid titles read, "Boar-celona! Shakira clashes with purse-snatching hogs as the feral pigs upend European city life" [115]. Another referred to them as "a bullet-proof and puncture-proof plague". Luckily, as some of the stories put it, the singer and her son "survived" the "attack." Across multiple news stories and countries, the wild boars were similarly personified and vilified as thieves and bullies.

I.2. Another example: Thanksgiving turkeys. Also in 2021, turkeys (*Meleagris gallopavo*), once common in North America but greatly reduced by overhunting in the late 1800s and early 1900s [116], appeared in the news around the Thanksgiving holiday when they are a traditional food. Greatly increased populations following protection have spread to cities, where they are not hunted and where their presence is a source of both amusement and annoyance [117,118]. Hutton's [117] story begins, "There's a violent gang stalking urban America. In New Hampshire a motorcyclist crashed after being assaulted. In New Jersey, a terrified postman rang 911 after a dozen members attacked at once. In addition, in Michigan, one town armed public workers with pepper spray". Smith was less alarmed: "Across the nation, from the riverbanks of the University of Minnesota to the forests of the University of California, Santa Cruz, wild turkeys have gone to college. And they seem to like it. Maybe too much". Other stories fell somewhere in between.

II **Domestic animals** are typically covered when they escape (e.g., the escape of three captive-kept zebras (*Equus zebra*) in Maryland, USA, in late 2021 [119]) or when there is an entertaining aspect, as with most dog stories. Aggressive domesticated animals also sometimes appear—for example, feral dogs (e.g., the Romanian press is full of stories where stray dogs bit or even killed people [120]). Stories focusing on domestic animals also feature in many movies, such as *Beverly Hills Chihuahua*, focusing on "cute" features. There are many other examples, but domestic animals will not be covered here further.

III **Animals that are not typically covered** but appear in stories about diseases, viruses, and pandemics caused by human consumption of animals (e.g., swine flu, avian flu, etc.). These animals are present in the news when the consequences of industrialization are negative, as in disease outbreaks. This is a somewhat gray area in the sense that media will mention the underlying human causes, but at the same time, animals are seen as the source of the aggressions (sickening people). Examples here abound: the avian flu, the swine flu, mad cow disease, and of course, COVID-19, still causing misery as we write this manuscript.

Quantitative Survey

We conducted a non-exhaustive analysis of 200 news stories from late 2020 to early 2022. Stories came from the US and across the world and were extracted from specific news media (e.g., New York Times, BBC News, Haaretz), news aggregators (e.g., Yahoo), and repeated searches of the News feature in Google, Stories (Supplementary Material) were examined to make sure they met the criterion of reporting about wildlife in an urban setting but were not otherwise selected for content. Our findings (Figure 3) show some concerning trends but also some good news. Often, the media will focus on wildlife attacks or incidents. When that happens, most of the time, animals are vilified, and words like "terrorizing", "violent", "aggressive", and "angry" are used. Even in stories not focused on the animal's aggressiveness, there is still negativity—they may be "trashing the city" or "annoying residents", for example. In these stories, residents will be quoted explaining how hard it is to cope with the animals or how scared or annoyed they are. Often, the species in these stories are perceived as unpleasant—reptiles, predators, and so on. However, these "aggressive" depictions (Figure 3, green) are not as common as ones where animals are portrayed as non-aggressive (Figure 3, red). In the remainder of the stories (Figure 3, blue), animals are also portrayed negatively, but this time as nuisances rather than threats. It is important to note that the aggressive type events are usually covered by multiple media outlets, often in multiple news stories. As we did not exhaustively include all stories on the same topic here, it is possible that the aggressive stories numerically dominate. Either way, no matter the category, the negative frames clearly dominate news stories.

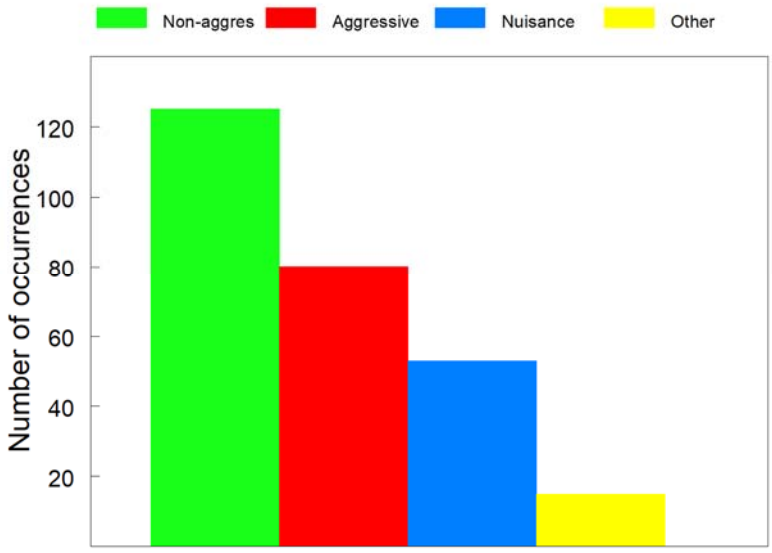

Figure 3. A breakdown of 200 popular media news stories about urban wildlife. Some stories encompassed more than one perspective and so appear more than once. See Supplementary Material for sources.

In terms of disciplinary emphases, more than a third of the news stories we assessed used no conservation experts or scientists as sources. When conservationists *were* interviewed, they were not always quoted in full nor allowed to present the contexts of mitigation, solution, or education. Sometimes they were quoted just to explain a phenomenon. However, there were stories where scientists had more prominence and where public education received a more prominent role. A few stories went as far as focusing on interviewing biologists or prominently using them as sources in stories focused on better urban wildlife integration and coexistence.

4.2. Importance of Urban Culture to Wildlife Conservation

Most coverage of urban wildlife in the popular media is negative (Figure 3, red and blue bars). If our goal is to improve public perceptions and willingness to share the urban environment with other species and perhaps even encourage activities that create wildlife-friendly habitats, then some kind of countermeasure is needed. In addition, although much wildlife interaction (e.g., hunting, birdwatching) occurs outside of cities, "the city is the centre of decision-making for wildlife management as the headquarters location for various government agencies" [113]. Thus, activities that modify public opinions within cities can have much wider impacts on wildlife conservation. Below we use two urban wildlife communication education campaigns as case studies (Sections 4.2.1 and 4.2.2) and two examples of issues where campaigns that target urban audiences could increase engagement for non-urban animal wellbeing (Sections 4.2.3 and 4.2.4).

4.2.1. Wildlife NYC

New York City (USA) launched this campaign in 2016 to increase awareness about wildlife in the city. With deer and coyote populations in the city increasing, it encouraged "New Yorkers to appreciate wildlife from afar—and not panic when they encounter a critter" [121]. The campaign (https://www1.nyc.gov/site/wildlifenyc/index.page, accessed on 20 December 2021) includes posters showing various species of charismatic urban animals, shown with the caption "New Yorker. City dwellers take many forms" and providing a brief informational text. Additional information, though not very extensive, is available on a dedicated web page. To the best of our knowledge, the efficacy of the program has yet to be evaluated.

4.2.2. Respect Wildlife

This collaborative coastal program [122] that involves agencies from the state of California in the U.S., as well as federal agencies and non-government organizations, shares some characteristics (as well as the name) with a mountain-oriented Swiss program. The California program provides a media kit, as well as meme-like pictures (see https://www.respect-wildlife.org/about, accessed on 20 December 2021), with messages centered around respecting wildlife and understanding that what you perceive as benign might feel different or even be toxic to animals.

4.2.3. Advocacy in Urban Settings for Humane Use of Wildlife in Food Production

Urbanites are less likely than rural dwellers to hunt and consume wildlife [123]. Within the animal rights community, much of which is urban, objection to the use of farmed animals for food, particularly because of perceived cruelty of agricultural practices, had been a staple for decades (e.g., [124]). In a recent twist, a Spanish multinational announced plans to commercially breed and market octopus [125,126]. The company argues that it is "firmly committed to aquaculture [farming seafood] as a method to reduce pressure on fishing grounds and ensure sustainable, safe, healthy, and controlled resources, complementing fishing". A seemingly mostly urban coalition of scientists and conservationists is objecting on the grounds that octopi are sentient, "extremely complex beings". As this is written, it remains too early to assess the impact on wildlife or even on relevant legislation, but the potential for urban populations to affect broad change in wildlife regulations is apparent.

4.2.4. Advocacy in Urban Settings for Wildlife Conservation

The general view of cities is the opposite of conservation. As pointed out by Light [127], "it has even been argued, urban dwellers suffer from a moral corruption". Here we highlight two North American programs aimed at an urban audience but primarily raising funds for rural species. Many such programs exist elsewhere and, together with the points made here, strengthen Light's [127] conclusion that urbanites are an essential part of an ethical response to environmental challenges:

- LA cougars fundraising campaign. #SaveLAcougars [128] is a multi-stakeholder fundraising campaign to raise funds for erecting a wildlife crossing over a highway at Liberty Canyon in order to build a wildlife crossing over the freeway. This campaign was successful, went viral on social media, and rapidly raised money.
- #RelistWolves [129] enlists actor Jason Momoa in support of relisting wolves as an endangered species. A call for advocacy as well as funds, this program was promoted on Instagram, as well as more traditional electronic media.

Better strategies and more interactions with the public and media are needed if we are to successfully reduce human-wildlife conflict in urban areas and instead leverage the potential of urban wildlife to inspire broader support for biodiversity conservation. Since scientists are usually poorly trained in these areas, increasing collaborations with science communication experts is advisable [130].

5. Discussion and Conclusions

COVID-19 has had broad, if mostly indirect, impacts on urban wildlife, which have only been partially documented to date and provide a mixed signal [58]. The ongoing course of the disease, and the ever-evolving policy response to it, will likely determine how long-lasting these effects are. The enforced isolation of people during lockdowns has led to increases in pet ownership and activities related to wildlife, such as gardening, hiking, and creating backyard bird feeders [131]. Whether these will enhance the long-term interest in biodiversity among urbanites [132] remains to be seen. For all the pain it continues to cause, the pandemic might provide us data to assess what form a wildlife-friendly city of the future might take [61]. Certainly, many of the preliminary studies reviewed here, as well as the overall conclusions of Bates et al. [58] and Soga et al. [133], suggest that reducing some human activities can have beneficial impacts on other species, but that high level of tolerance by traditional urban taxa makes some of those changes less impactful. However, long-term negative impacts, such as the tradeoffs local and national governments may face between promoting economic recovery and environmental regulations necessary for conservation, may persist [55]. Our own data show that intakes at the South Plains Wildlife Rehabilitation Center in Lubbock, Texas (see Notable Recent Research on Urban Conservation and Urban Wildlife above), have not changed as a result. Doubtlessly there are many studies now in the process of being conducted and in the publication pipeline, and a more complete picture should emerge over time. We look forward to seeing a more complete picture emerge over time.

Much less is known about the human dimensions of urban ecology and the implications of how these interact with biology to determine the conservation potential of urban habitats. Perhaps a paradigm shift toward new human-nature connections is on the horizon. For example, The Xerces Society maintains resources on invertebrate conservation in communities, and The Great Sunflower Project (https://www.greatsunflower.org/) (accessed on 20 June 2022) facilitates observations of pollinators on sunflowers for comparisons among K-12 schools. Digital citizen science platforms such as iNaturalist facilitate interactions among groups and could be a valuable tool for recording biodiversity observations in urban settings. Although vertebrates remain the focus of attention, invertebrates and plants are abundant groups whose contributions to human quality of life could be a promising entry point for further engaging public interest. However, interest is not enough in all cases. For example, Renkl [134] recently described how the mass roosting of purple martins, a popular bird in downtown Nashville (TN, USA), put at odds bird lovers and tree lovers who saw the roost trees being damaged and became candidates for removal, the neighboring symphony orchestra whose visitors were being negatively impacted, and more. In this kind of situation, urbanization creates a conflict between multiple legitimate perspectives, one that cannot be resolved by public relations alone. Making urban environments more welcoming for wildlife requires careful, long-term planning. More research on how to best address urban stakeholders could lead to better policy recommendations.

Concerningly, the growing waves of mis/dis-information and even science denial, coupled with the decrease in trust in science and scientists during the COVID-19 pandemic [135], show what occurs when science communication and education fail. However, effective communication in this realm is still poorly studied and desperately needed. Ultimately, "we will only have a fully environmental ethic, which covers all environments, when we turn our attention to the preservation of richly textured urban spaces as often as we do to old growth forests" [127]. Targeted education and advocacy campaigns are key, but individual-level actions and strategies can also be taken. First, creating and maintaining relationships with local, state, and national journalists would help increase the number of educational news stories and balance those news stories about "aggressive" or "annoying" urban wildlife. There is already a call to action in terms of journalists' training and education [136,137]. Second, creating and maintaining relationships with the public—especially locally but also beyond—allows residents to be informed and educated before falling into the "all wild animals are bad" or "let us feed all animals" traps. Individuals use social media to obtain their news and information, and the content they are exposed to on those platforms influences their understanding and attitudes. Scholars are starting to understand the importance of becoming active on social media for better public education, as well as the need to address mis/dis-information [138]. For example, Wu et al. [139] suggested that conservation experts should use social media to educate the public on conservation issues such as the potential negative impacts of human activity and to encourage public participation. However, at the moment, most academic positions do not reward faculty for participating in community outreach through workshops or the creation of social media content on platforms such as Instagram or TikTok—despite occasional claims to the contrary. Moreover, our training of professional biologists normally provides poor preparation for such engagement styles and needs to improve.

Urban environments offer resources to many non-human inhabitants. Human activities provide an evolutionary landscape where selection can be intense, and other impacts such as habitat fragmentation and the resulting reduction in geneflow can be extreme. For example, Eggenberger et al. [4] showed that urban living in two species of bumblebees (genus *Bombus*) has led to the evolution of smaller size as well as greater phenotypic diversity. We need additional studies of the unique evolutionary landscape offered by cities and of the potential evolutionary consequences. With the exception of the impacts of the pandemic and resulting "anthropause" [57], however, the broad outlines of urban wildlife ecology increasingly seem well understood. Progressively sophisticated assessments and reviews of causative factors such as light pollution (e.g., [140]) and noise pollution (e.g., [141]) and a rapidly growing body of work document the biology of various species and locations. Nonetheless, data for urban invertebrates and flora remain sparse, perhaps because cities are seldom perceived as worthwhile sites for conservation [1]. Documentation of species that do particularly well in urban settings, sometimes despite declining in their native range [142], could also stand to be expanded upon. Much work remains to be carried out, but it seems likely that most of it will involve filling in details rather than discovering completely new processes.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d14070539/s1, Supplementary Material: 200 news stories—source information. Figure S1. Three pollinator-oriented flower gardens from Lubbock, Texas.

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