

University of Nebraska - Lincoln

DigitalCommons@University of Nebraska - Lincoln

USDA National Wildlife Research Center - Staff Publications

U.S. Department of Agriculture: Animal and Plant Health Inspection Service

2021

The evolutionary consequences of human–wildlife conflict in cities

Christopher J. Schell

University of Washington Tacoma, cjschell@uw.edu

Lauren Stanton

University of Wyoming, lstanton@uwyo.edu

Julie K. Young

APHIS, julie.k.young@aphis.usda.gov


Lisa Angeloni

Colorado State University, angeloni@colostate.edu

Joanna E. Lambert

University of Colorado-Boulder, joanna.lambert@colorado.edu

Follow this and additional works at: https://digitalcommons.unl.edu/icwdm_usdanwrc

 Part of the [Additional Authors Commons](#), [Conservation Commons](#), [Natural Resources Management and Policy Commons](#), [Other Environmental Sciences Commons](#), [Other Veterinary Medicine Commons](#), [Population Biology Commons](#), [Terrestrial and Aquatic Ecology Commons](#), [Veterinary Infectious Diseases Commons](#), [Veterinary Microbiology and Immunobiology Commons](#), [Veterinary Preventive Medicine, Epidemiology, and Public Health Commons](#), and the [Zoology Commons](#)








Schell, Christopher J.; Stanton, Lauren; Young, Julie K.; Angeloni, Lisa; Lambert, Joanna E.; Breck, Stewart W.; and Murray, Maureen H., "The evolutionary consequences of human–wildlife conflict in cities" (2021). *USDA National Wildlife Research Center - Staff Publications*. 2422. https://digitalcommons.unl.edu/icwdm_usdanwrc/2422

This Article is brought to you for free and open access by the U.S. Department of Agriculture: Animal and Plant Health Inspection Service at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in USDA National Wildlife Research Center - Staff Publications by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

Authors

Christopher J. Schell, Lauren Stanton, Julie K. Young, Lisa Angeloni, Joanna E. Lambert, Stewart W. Breck, and Maureen H. Murray

The evolutionary consequences of human–wildlife conflict in cities

Christopher J. Schell¹  | Lauren A. Stanton^{2,3}  | Julie K. Young⁴  |
 Lisa M. Angeloni⁵  | Joanna E. Lambert⁶  | Stewart W. Breck^{7,8}  |
 Maureen H. Murray⁹ 

¹School of Interdisciplinary Arts and Sciences, University of Washington Tacoma, Tacoma, WA, USA

²Department of Zoology and Physiology, University of Wyoming, Laramie, WY, USA

³Program in Ecology, University of Wyoming, Laramie, WY, USA

⁴USDA-WS-National Wildlife Research Center-Predator Research Facility, Millville, UT, USA

⁵Department of Biology, Colorado State University, Fort Collins, CO, USA

⁶Program in Environmental Studies and Department of Ecology and Evolutionary Biology, University of Colorado-Boulder, Boulder, CO, USA

⁷USDA-WS-National Wildlife Research Center, Fort Collins, CO, USA

⁸Department of Fish, Wildlife, and Conservation Biology, Fort Collins, CO, USA

⁹Urban Wildlife Institute and Davee Center for Epidemiology and Endocrinology, Chicago, IL, USA

Correspondence

Christopher J. Schell, School of Interdisciplinary Arts and Sciences, University of Washington Tacoma, Tacoma, WA 98402, USA.
 Email: cjschell@uw.edu

Funding information

National Science Foundation, Grant/Award Number: 1923882; University of Washington Tacoma

Abstract

Human–wildlife interactions, including human–wildlife conflict, are increasingly common as expanding urbanization worldwide creates more opportunities for people to encounter wildlife. Wildlife–vehicle collisions, zoonotic disease transmission, property damage, and physical attacks to people or their pets have negative consequences for both people and wildlife, underscoring the need for comprehensive strategies that mitigate and prevent conflict altogether. Management techniques often aim to deter, relocate, or remove individual organisms, all of which may present a significant selective force in both urban and nonurban systems. Management-induced selection may significantly affect the adaptive or nonadaptive evolutionary processes of urban populations, yet few studies explicate the links among conflict, wildlife management, and urban evolution. Moreover, the intensity of conflict management can vary considerably by taxon, public perception, policy, religious and cultural beliefs, and geographic region, which underscores the complexity of developing flexible tools to reduce conflict. Here, we present a cross-disciplinary perspective that integrates human–wildlife conflict, wildlife management, and urban evolution to address how social–ecological processes drive wildlife adaptation in cities. We emphasize that variance in implemented management actions shapes the strength and rate of phenotypic and evolutionary change. We also consider how specific management strategies either promote genetic or plastic changes, and how leveraging those biological inferences could help optimize management actions while minimizing conflict. Investigating human–wildlife conflict as an evolutionary phenomenon may provide insights into how conflict arises and how management plays a critical role in shaping urban wildlife phenotypes.

KEYWORDS

adaptive management, genetic, human–wildlife conflict, phenotypic plasticity, social learning, urban evolution

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2020 The Authors. *Evolutionary Applications* published by John Wiley & Sons Ltd

1 | INTRODUCTION

The rapid expansion of urban areas worldwide is markedly increasing the frequency of encounters humans have with wildlife (Soulsbury & White, 2015). Though most encounters are positive or neutral (Soga & Gaston, 2020), encounters can result in negative outcomes (i.e., conflict) that include property loss or damage, pet loss, disease transmission, physical injury, and human or wildlife fatalities (Richardson et al., 2020; Treves et al., 2006). Human-wildlife conflict has been extensively studied, emphasizing the drivers, consequences, and associated mitigation strategies to resolve emerging conflicts. Human attitudes toward wildlife (Dickman, 2010; Dickman et al., 2013), human activities and behaviors (Penteriani et al., 2016), wildlife adaptation and exploitation of anthropogenic resources (Ditchkoff et al., 2006; Honda et al., 2018; Kumar et al., 2019), and climate-driven biotic redistributions (Pecl et al., 2017) all contribute to the spatial and temporal distribution of conflict. Coupled with urbanization and climate-induced environmental changes, the spatiotemporal extent and magnitude of conflict is increasing, with organisms under intensifying selective pressures (Donihue & Lambert, 2014; Johnson & Munshi-South, 2017; Turner et al., 2018). Moreover, conflicts have substantial financial costs, resulting in nearly \$230

million (USD) in compensation across 50 countries since 1980 (Ravenelle & Nyhus, 2017). Hence, one of the most urgent conservation and management priorities of this century is developing adaptive management strategies that integrate social, biological, and temporal variables to mitigate, resolve, and prevent conflicts (Dickman, 2010; Ives & Kendal, 2014; Jørgensen et al., 2019).

Prior work detailing adaptive wildlife management frameworks emphasizes the need for evidence-based research that incorporates the inherent social-ecological nature of human-wildlife conflict to improve management decisions (Enck et al., 2006; Richardson et al., 2020). Adaptive impact management programs (AIM, also referred to as adaptive social impact management) are built on the assumption that change is inevitable, requiring programmatic flexibility to adapt to social, cultural, and biological shifts over time (Gregory et al., 2006; Ives & Kendal, 2014; Kaplan-Hallam & Bennett, 2018). Both adaptive management and evolutionary biology are thus founded on an understanding of change over time (Lambert & Donihue, 2020). Moreover, management optimization is itself a selective pressure; management decisions impact population abundance and demography, and deter behaviors that may exacerbate conflict with people (Barrett et al., 2019; Jørgensen et al., 2019; Swan et al., 2017). As a result, management can operate as a selective force that shapes—and is shaped by—wildlife responses

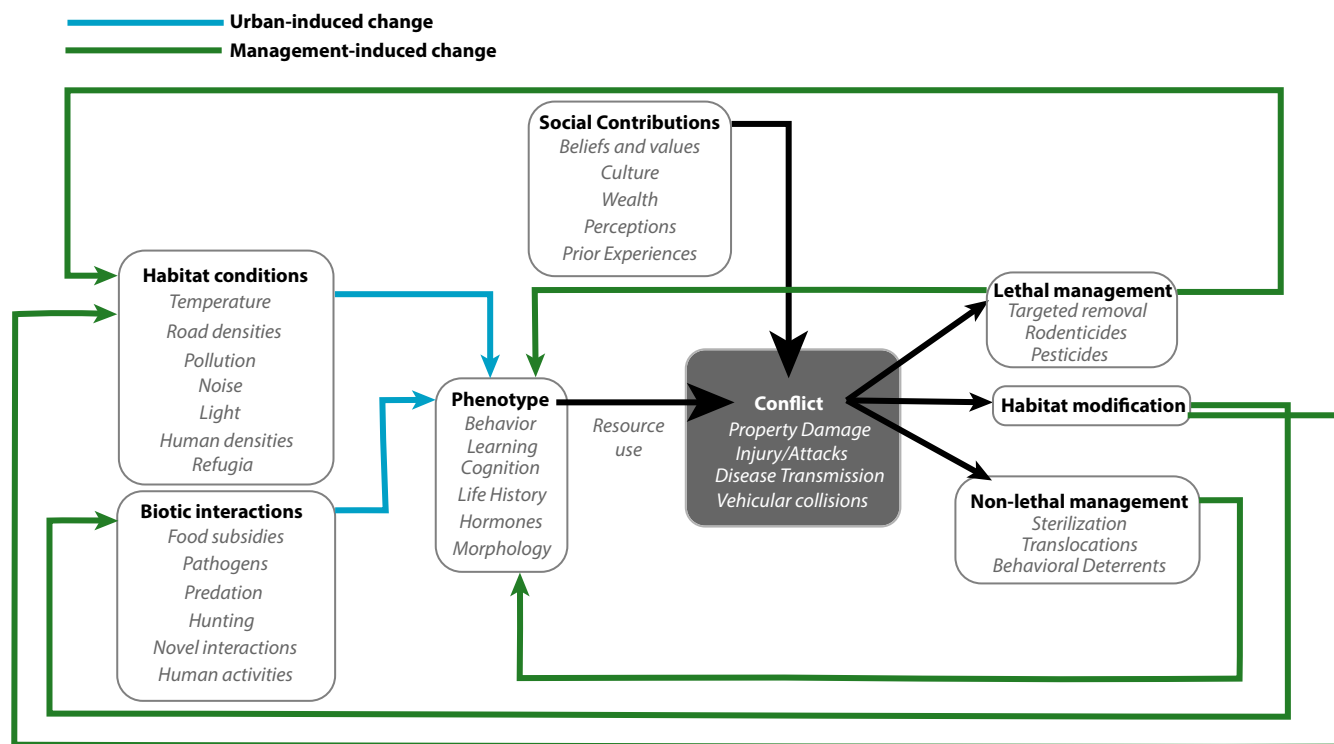


FIGURE 1 Conceptual framework illustrating the processes contributing to shaping phenotypes, human-wildlife conflict, and resulting management actions in urban systems. Habitat conditions and biotic interactions combine to produce both adaptive (i.e., natural and sexual selection) and nonadaptive (i.e., reduce gene flow, genetic drift) evolutionary changes that affect use of limited resources by urban organisms. Varying social attributes of a city, including religion, socioeconomics, political, and cultural perspectives, coalesce with urban organismal adaptation to shape human-wildlife conflict (black lines). The magnitude, severity, and frequency of those conflicts then inform the type of management decisions and actions implemented, and those actions produce evolutionary feedback mechanisms that continually refine urban phenotypes. Hence, phenotypic changes occur due to urban landscape conditions (blue lines) and management actions (green lines)

(Figure 1), yet evolutionary processes are rarely integrated into AIM frameworks explicitly.

Interactions between humans and wildlife, including competition and conflict, are not new to human history. Indeed, human commensals and domesticated species have coevolved with human societies over thousands of years, documented as far back as the Pleistocene and Holocene (Clucas & Marzluff, 2011; Hendry et al., 2017; Hulme-Beaman et al., 2016; Sullivan et al., 2017). Human behavior has had substantial evolutionary effects with measurable shifts in morphology, abundances, and community interactions (Erlandson & Rick, 2010; Kemp et al., 2020; Sullivan et al., 2017). More recently, selective breeding, removal, and hunting have acted as strong selective agents driving directional, stabilizing, or disruptive selection that shapes the evolutionary trajectories of organisms inhabiting anthropogenic habitats (Hendry et al., 2017). Relative to historical patterns of interactions among commensals and humans, selective pressures in modern cities are orders of magnitude greater due to concentrated anthropogenic drivers across space and time. Anthropogenic landscape conversion (e.g., vegetation cover and diversity, waste and pollution systems, transportation infrastructure) and human activities (e.g., lethal removal, proliferation of domestic species, recreational use of green space) compound to create strong selective agents that establish individual trait-based and species filtering (Alberti, 2015; Ellwanger & Lambert, 2018; Ouyang et al., 2018; Pagani-Núñez et al., 2019). Moreover, the dynamics of policy, governance, market fluctuations, and zoning practices generate substantial—and uniquely urban—spatiotemporal heterogeneity over relatively small scales (Liu et al., 2007; Pataki, 2015; Pickett et al., 2016). For these reasons, the convergence of human-wildlife conflict, adaptive impact management, and urban evolution provide an exceptional opportunity to articulate a framework incorporating evolving biotic interactions as key for wildlife management.

We provide a transdisciplinary synthesis that integrates principles from human-wildlife conflict and urban evolutionary ecology to illustrate that conflict and management decisions are both a signal of selection and a selective agent that directly affect evolutionary change in urban populations (Figure 1). First, we review the ecological drivers of urban conflict globally. Second, we explain how sociocultural factors underpin conflict and vary tremendously across scales (e.g., neighborhood, township, census block, city level). Third, we emphasize how management decisions in response to conflict work to select and reinforce specific wildlife traits over others. Lastly, we discuss how urban evolutionary biology can provide a toolkit to help optimize adaptive wildlife management strategies. We concurrently emphasize that high variability in urban metrics across gradients of developed and developing cities—particularly their structural, abiotic, and biotic components (Moll et al., 2019), as well as their developmental histories and trajectories—dictates the implementation and success of management strategies. We define *urban* according to the dynamic and nuanced definition articulated by Moll et al. (2019), in which the relative proportion of gray space land cover (e.g., buildings, impervious surfaces) to green and blue

structural components (e.g., parks, waterways) is high over space and time.

Our framework builds on previous syntheses (Jørgensen et al., 2019; Nyhus, 2016; Swan et al., 2017) by explaining how evolutionary concepts can be harnessed to develop broad management approaches that ameliorate conflict and promote human-wildlife coexistence in urban areas globally (Cook & Sgrò, 2018).

2 | ECOLOGICAL DRIVERS OF CONFLICT AND ASSOCIATED BIOLOGICAL OUTCOMES

The combination of human-induced habitat changes and novel biotic interactions produces divergent fitness landscapes that promote specific phenotypic traits in cities (Alberti et al., 2017; Ouyang et al., 2018). Urban wildlife exhibit increased nocturnality (Gaynor et al., 2018), cognitive and problem-solving innovations (Audet et al., 2016; Snell-Rood & Wick, 2013), heightened tolerance and habituation (Lowry et al., 2013; Sol et al., 2013), and dietary niche shifts (Murray, Lankau, et al., 2020; Pagani-Núñez et al., 2019), all of which facilitate survival and reproductive success in cities. Phenotypic shifts and plasticity in urban contexts can promote local adaptation by reducing the likelihood of human-wildlife encounters (Ditchkoff et al., 2006; Tuomainen & Candolin, 2011). However, in some instances local adaptation may increase the likelihood of human-wildlife encounters (Soulsbury & White, 2015), occasionally resulting in contentious interactions that reduce organismal fitness due to lethal removal actions (Honda et al., 2018). In addition, detecting phenotypic signals of local adaptation varies considerably by species (Santini et al., 2019) and city scale (Strubbe et al., 2020), in which variance in life histories and niche requirements establish trait-reaction norms for individuals and species (Tuomainen & Candolin, 2011). Variance in environmental conditions and management actions within and across cities can further result in niche differentiation of adjacent populations that explain the origins of trait adaptations to human-dominated landscapes (Figures 2 and 3).

Investigating the pathways by which human-driven ecological conditions shape adaptation and conflict will help illuminate how wildlife management influences evolutionary outcomes of urban wildlife. Those pathways can operate either at the landscape level (i.e., anthropogenic habitat conditions) or at the community level (i.e., biotic interactions) with projections to the organismal level that affect population growth and abundance in cities (Figure 1). In addition, phenotypic changes in response to conflict-inducing environmental factors can be adaptive, nonadaptive, or maladaptive (Brady & Richardson, 2017; Derry et al., 2019).

2.1 | Road densities and vehicle collisions

Wildlife-vehicle collisions are one of the most prominent conflicts resulting in restricted animal movement and mortality, especially when roads fragment contiguous habitats (Balkenhol & Waits, 2009;

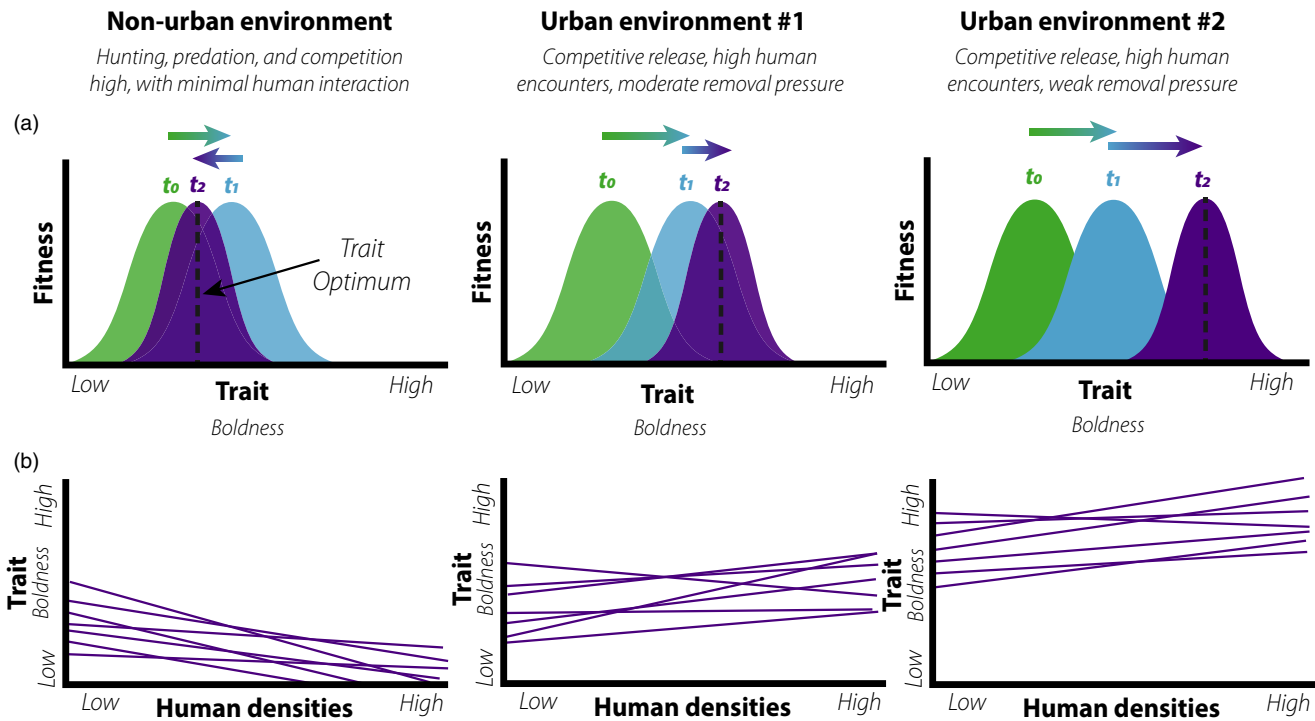


FIGURE 2 Niche differentiation and variance in selective modes, strength, and behavioral trait plasticity in response to human–animal interactions. (a) In nonurban environments, stabilizing selection over time favors low-to-moderate boldness with bolder individuals hunted or lost to predation. Conversely, in urban environments competitive release and decreased hunting promotes directional selection toward bolder phenotypes. However, between-city variance in the intensity of management action (e.g., removal pressure) can induce mean-level phenotypic variance in traits. (b) Reaction norms toward anthropogenic factors (e.g., human densities, human presence) are shaped by human–animal interactions. Though individual plasticity persists in all environments (purple lines) with similar directionality, mean-level population differences in boldness emerge due to differences in the type and frequency of human encounters across urban and nonurban environments, and between cities

Brady & Richardson, 2017; LaPoint et al., 2015). Roads are nearly ubiquitous in developed landscapes, and represent a major source of wildlife fatalities, property damage, and in many instances human injury and mortality (Brady & Richardson, 2017; Proppe et al., 2017). Heightened road densities in urban environments present a salient environmental challenge that can restrict successful colonization of viable urban habitats. Though taxa from multiple clades are affected, mortality risks are especially high for large vertebrates within cities (Edelhoff et al., 2020; Honda et al., 2018; Johnson et al., 2020) and at the urban–wildland interface (Proctor et al., 2020; St. Clair et al., 2019; Wynn-Grant et al., 2018), where human-modified attributes of the landscape and speed limits increase (Neumann et al., 2012). All these factors contribute to the reduced occupancy and population abundances of larger fauna in urban systems. Moreover, there is a rich and recent literature that suggests road densities in urban systems reduce gene flow and operate as genetic bottlenecks for an array of taxa (Kozakiewicz et al., 2019; Riley et al., 2006; Trumbo et al., 2019), highlighting the salience of roads as drivers of adaptive and nonadaptive evolutionary change (Brady & Richardson, 2017).

To circumnavigate this challenge, wildlife passages are installed over and under roads (Riley et al., 2014) and wildlife populations

increase their nocturnal activity as a means of avoiding periods of high human activity and vehicle traffic volume (Baker et al., 2007; Murray & St. Clair, 2015). Evidence across passerines additionally suggests natural selection can occur for morphological changes to wing and body size that reduce vehicle collisions (Brown & Bomberger Brown, 2013; Santos et al., 2016). In urban mammals, high mortality rates due to vehicle collisions may drive an increase in body size, litter size, and faster maturation (Santini et al., 2019), suggesting that road densities may serve to alter pace-of-life syndromes. Further, increased disturbances (e.g., road noise and anthropogenic light at night) and pollutants (e.g., heavy metals, chemical contaminants) associated with high road densities may induce adaptive genetic change or drive mutagenic effects that produce detrimental changes in genes (Brady & Richardson, 2017). The pace and spatial scale of these changes can range considerably with road densities and proximity; however, recent work in large fauna with large dispersal ranges and slow paces of life suggests rapid signals of evolution at small spatial scales (Adducci et al., 2020; DeCandia et al., 2019; Richardson et al., 2014; Schell, 2018). Determining the scale and rate of evolutionary change due to road ecology will be necessary for adaptively mitigating conflicts as they arise (Brady & Richardson, 2017).

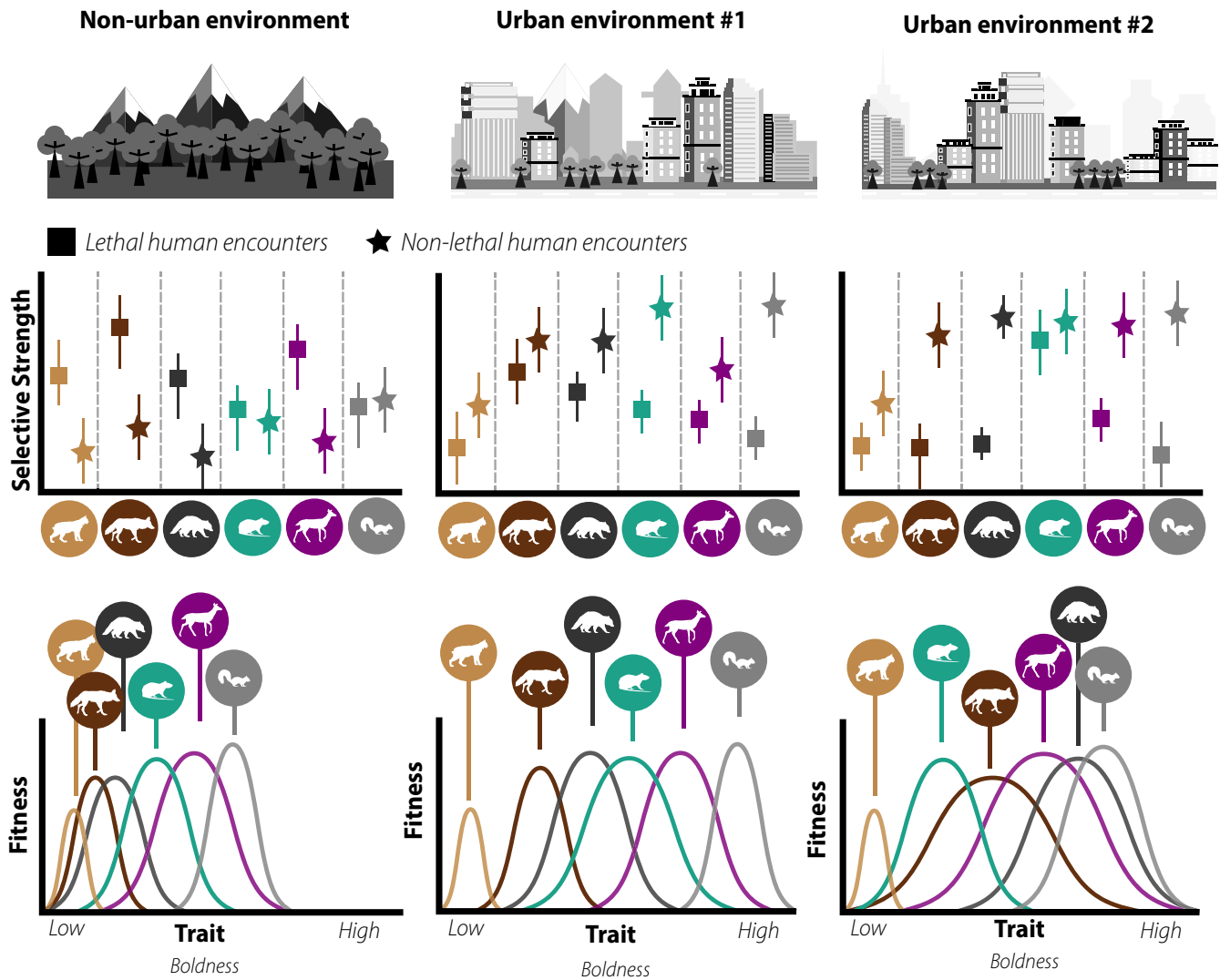


FIGURE 3 Theoretical predictions of illustrating differences in performance curves, fitness, and trait variance of urban wildlife as a function of habitat conditions and human–animal interactions. (a) Variance in the ratio of positive, neutral, or negative human–wildlife interactions (i.e., lethal vs. nonlethal human encounters) creates unique selective gradients across species, in which the degree of lethal to nonlethal human encounters promotes specific performance curves for behaviors such as boldness (b). The overall number of nonlethal human interactions substantially increases in cities, greatly contributing to urban versus nonurban differences in behavioral phenotypes. A higher proportion of lethal relative to nonlethal human encounters selects for shy phenotypes generally across all wildlife. Species differences persist due to variance in social perceptions, conflict frequency, and conflict severity of varying wildlife taxa. Increasing the relative separation between lethal and nonlethal interactions may additionally contribute to increasing phenotypic plasticity, in which large differentials between the two types of interactions allow for a larger variety of phenotypes to persist in the population. For instance, coyotes and deer in urban environment #2 have substantially more nonlethal human encounters with minimal risk of lethal interactions as compared to urban environment #1. The performance curves for those species are thus wider in city #2. Between-city differences in phenotypic signatures may be the result of selection, developmental experiences, and/or learning the sources of rewards. Error bars denote individual variance in human experiences across a theoretical population. Selected mammals in the figure are those commonly found in North American cities, including (from left to right) the following: bobcats, *Lynx rufus*; coyotes, *Canis latrans*; raccoons, *Procyon lotor*; brown rats, *Rattus norvegicus*; white-tailed deer, *Odocoileus virginianus*; and eastern gray squirrels, *Sciurus carolinensis*

2.2 | Property damage and infrastructure

The built environment can create compounding mortality risks for wildlife in two distinct ways. The first risk involves structures themselves as threats to wildlife survival. For instance, multistory commercial and industrial buildings with highly reflective windows pose a significant threat to birds, especially males and juveniles, via window

strikes (Hager et al., 2013; Kahle et al., 2016; Loss et al., 2014). A second type of mortality risk, property damage caused by wildlife, triggers targeted management actions often resulting in lethal control actions to remove selected individuals (McCleery et al., 2014; Swan et al., 2017). Various taxa damage commercial and residential properties by using structures for refugia (Murray et al., 2018; VerCauteren et al., 2010), whereas defacement of other properties

via wildlife-generated fecal waste decreases aesthetic value of the property (Soulsbury & White, 2015). Retaliatory killing and extirpation techniques used to alleviate such conflicts likely place a significant selective pressure on target wildlife involved in associated disturbances (Swan et al., 2017).

2.3 | Food provisioning

Although consumption of anthropogenic food resources is not a prerequisite of urban living (Newsome et al., 2015; Stillfried, Fickel, et al., 2017), cities likely favor species that learn to capitalize on human subsidies and refuse (Oro et al., 2013). Food provisioning of wildlife is a major source of conflict in cities (Dubois & Fraser, 2013) because animals that learn to associate humans with food may approach humans, residencies, and vehicles seeking food, increasing the likelihood of disease transmission, injury, or mortality (Cox & Gaston, 2018; Murray, Becker, et al., 2016; Oro et al., 2013; Sorensen et al., 2014; Strandin et al., 2018). Food provisioning may be especially problematic when (a) dependency on humans for food results in a decrease in natural behaviors and a more docile or tame phenotype (Geffroy et al., 2015; Lamb et al., 2017; St. Clair et al., 2019), or (b) habituation and increased boldness leads to a more aggressive phenotype (Cox & Gaston, 2018; Dubois & Fraser, 2013; Kumar et al., 2019). Scrounging and kleptoparasitism (i.e., stealing of food) by wildlife is common in cities (Beisner et al., 2015; Brotcorne et al., 2017; Goumas et al., 2019) and may drive advanced cognitive abilities and innovations that enable food acquisition from manufactured structures such as bottles and garbage bins (Arbilly et al., 2014; Ducatez et al., 2017; Griffin et al., 2017; Morand-Ferron et al., 2007).

Reliable resources in cities may also alter wildlife movement patterns with important implications for conflict (Lowry et al., 2013; Wong & Candolin, 2015). Cities offer a relatively stable source of food from garbage, provisioned food, and cultivated plants and access to water (Cox & Gaston, 2018). In some instances, wildlife venture into urbanized areas to access more abundant natural resources and avoid competition or predation from other organisms deterred by higher human activity (Moll et al., 2018; Stillfried, Gras, Börner, et al., 2017; Stillfried, Gras, Busch, et al., 2017). The spatial distribution of food subsidies restructures species interactions and shapes the relative distribution of native versus non-native species (Dorresteijn et al., 2015; Fischer et al., 2012), as non-native species' ability to exploit resources and colonize urban habitats inhibits future colonization events of native species (i.e., priority effects; Lepczyk, Aronson, et al., 2017; Shochat et al., 2010; Urban & De Meester, 2009). Further, access to these stable resources helps explain why wildlife populations around the world are abandoning migration (Møller et al., 2014; Wilcove & Wikelski, 2008), often contributing to property damage in parks, aggressive encounters, and vehicular collisions (Dolbeer et al., 2014; Found & St. Clair, 2019; Hubbard & Nielsen, 2009).

Finally, direct effects of food provisioning on individuals, such as increased body mass and altered mating strategies, can have cascading effects on populations, communities, and ecosystems (Cox

& Gaston, 2018; Oro et al., 2013). Bird feeding in particular has been linked to increased survival, advancement of breeding, and increased likelihood of pathogen transmission (Robb et al., 2008). Further, intentional use of bird feeders may result in unintentional and unwanted feeding of other omnivorous species. Processed foods are typically high in sugar, salt, and fat and low in protein, leading to hyperglycemia (Schulte-Hostedde et al., 2018), and decomposing food can lead to harmful increased exposure to toxins from fungal metabolites (Murray, Hill, et al., 2016). Recent evidence linking human-associated foods to genes for metabolism of high fat and starch (Harris & Munshi-South, 2017; Ravinet et al., 2018), as well as physiological and microbiome adaptations in house sparrows (Gadau et al., 2019; Teyssier et al., 2018), provides emerging evidence that food subsidies can lead to the adaptive evolution of novel traits (Rivkin et al., 2019).

2.4 | Domestic pets and human activities

The proliferation of domestic and feral pets disrupts trophic structure through predation, disease transmission, and general wildlife disturbance (Nyhus, 2016). Outdoor domestic cats (*Felis catus*) are a significant threat to bird and rodent populations in urban areas (Cove et al., 2018; Kays et al., 2020; Lepczyk, La Sorte, et al., 2017), and also present a major driver of conflict with other urban carnivores (Gehrt et al., 2013; Kays et al., 2015). In addition, outdoor cats are often reservoirs for the spread of several diseases including leptospirosis and toxoplasmosis that are transmissible to humans and other pets (Chalkowski et al., 2019; Dabritz & Conrad, 2010; Schuller et al., 2015). Domestic dogs (*Canis lupus familiaris*) are similarly a major driver of conflict, with wild predators such as coyotes (*Canis latrans*) and leopards (*Panthera pardus*) killing domestic dogs in cities, leading to emotional and economic trauma (Butler et al., 2015; Hughes & Macdonald, 2013) or, alternatively, positive benefits such as reduced rabies risk to humans (Braczkowski et al., 2018). Domestic dogs also increase the probability of human–carnivore conflict in green spaces (Penteriani et al., 2016) and built environments across the globe (Bhatia et al., 2013; Braczkowski et al., 2018; Butler et al., 2015; Hughes & Macdonald, 2013).

Human activities and recreation also directly play a role in eliciting conflicts. Recent work suggests that human presence results in a landscape of fear, which dictates daily activity budgets and spatio-temporal use of habitat by wildlife (Clinchy et al., 2016; Nickel et al., 2020; Suraci et al., 2019). The effect of humans persists for species even on the urban–wildland boundary, suggesting that mere human presence is strong enough to drive behavioral strategies that reduce human–wildlife encounters. For mammalian carnivores in particular, human activity can dissolve spatial and temporal avoidance of heterospecific competitors as a means of avoiding human encounters (Smith et al., 2017, 2018). Successful avoidance, however, is often compromised as human recreational trails in urban areas increasingly reduce refuges by fragmenting natural remnants (Ballantyne et al., 2014).

2.5 | Health and disease

Urban living can also promote human–wildlife conflict arising from wildlife disease (Murray et al., 2019). Some wildlife pathogens such as canine distemper or rabies can directly cause changes in wildlife behavior that promote conflict. For example, raccoons (*Procyon lotor*) infected with canine distemper virus commonly exhibit abnormal behavior including lethargy, ataxia, and less wariness toward humans (Cranfield et al., 1984). Similarly, carnivores infected with the rabies virus typically exhibit increased aggression (Wang et al., 2010). Removal of infected individuals may impose a selective pressure favoring pathogen resistance. However, such infections are less likely to lead to selective removal if infected individuals cannot be readily identified based on behavior or appearance. Instead, conflict may arise due to human perception of public health risks from zoonotic pathogens transmissible to humans and consequently lower tolerance for wildlife presence. For example, urban coyote populations can have rates of tapeworm (*Echinococcus locularis*) infections as high as 65% (Luong et al., 2020), prompting public concern regarding exposure to parasites in urban green spaces (Deplazes et al., 2004).

Among the most profound examples of human–wildlife disease transmission is the current global COVID-19 pandemic that is severely affecting public health, society, and the world economy (Chakraborty & Maity, 2020; Messmer, 2020). Evidence suggests bats are a natural reservoir host for the novel coronavirus, SARS-CoV-2 (Boni et al., 2020; MacFarlane & Rocha, 2020). Continued urbanization and its resulting expansion of human activities directed at wildlife (e.g., wildlife markets) and use of urban structures by wildlife (e.g., highway underpasses, culverts, buildings) have facilitated increased human–bat urban interactions around the world (Li & Wilkins, 2014; Russo & Ancillotto, 2015). At the same time, natural roosting areas outside of urban areas (e.g., forests, caves) have been reduced due to human activity (e.g., logging, agriculture, guano harvesting, limestone quarrying), likely facilitating the increased activity and use of urban areas (Russo & Ancillotto, 2015). The contexts that promote pathogen spillover between wildlife and humans (i.e., close contact between multiple species, compounding stressors that may increase infection susceptibility) are expected to increase with urbanization unless we manage habitat to allow wildlife persistence without coming in close contact with people (Messmer, 2020; Murray et al., 2019). In addition, human–human transmission from disease spillover events versus zoonoses reliant on transmission from wildlife (e.g., leptospirosis, rabies, Lyme disease) may require different management and public health responses that mitigate the impacts of disease spread.

3 | SOCIOCULTURAL DETERMINANTS OF CONFLICT

Cost assessment of conflict is substantially modulated by how humans perceive conflict-causing species (Dickman, 2010; Soulsbury

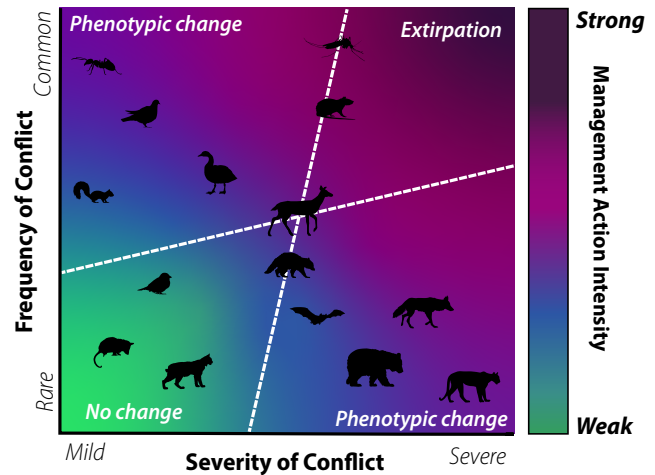


FIGURE 4 Frequency and severity of conflicts drive management action intensity and shape evolutionary trajectories of urban wildlife. The frequency and severity of conflicts dictate the strength of management action placed on wildlife, with considerable variability across taxa. Phenotypic change is predicted when frequency, severity, or both are particularly high. In instances where conflict severity and frequency are benign or mild, human–wildlife conflict is unlikely to induce evolutionary change (bottom-left quadrant). Extreme severity and conflict, however, may lead to extirpation from an urban habitat (top-right quadrant) or prevent urban colonization. In addition, conflict with larger fauna may be graded as more severe, though infrequent

& White, 2015). Human perceptions of organisms as either benign or malignant can consciously and unconsciously drive how we respond to emergent conflicts from target species (Kaplan-Hallam & Bennett, 2018). Heterogeneity in the social, cultural, economic, and personal attributes of society contributes to shaping individual human beliefs and values of wildlife (Ives & Kendal, 2014; Manfredo & Dayer, 2004), subsequently informing the type and strength of management strategies implemented (Figure 4). How conflict-causing species are managed is thus inherently social, with cascading evolutionary consequences for the target species. As organisms navigate various neighborhoods in cities, they likely encounter people across jurisdictional boundaries and municipalities with different beliefs, attitudes, and policies for managing the target species (Draheim et al., 2019; Enck et al., 2006; Manfredo et al., 2020). Reciprocally, variation in the frequency, severity, and types of conflict across taxa can inform attitudes and beliefs around each target species that principally dictates management attention (Figure 4; Box 1).

3.1 | Socioeconomic drivers of conflict

The unequal distribution of capital and income greatly contributes to the distribution of wildlife, as well as the relative proportion of native to introduced species (Leong et al., 2018; Schell et al., 2020; Warren et al., 2013). The luxury effect suggests that neighborhood wealth influences emergent patterns of urban biodiversity and

Box 1 Case studies: Coyotes versus brown rats

When considering the consequences of conflict for urban wildlife populations, perhaps no two species are more representative than coyotes and rats. These two species are unique among wildlife species because they have expanded their geographic ranges, while most others have become more restricted (Puckett et al., 2016; Thurber & Peterson, 1991). The ecological success of coyotes and rats is most likely due to their broad habitat and dietary niches (Gehrt & Riley, 2010; Guiry & Buckley, 2018), and high behavioral flexibility and tolerance for human disturbance (Breck et al., 2019; Feng & Himsworth, 2014; Murray & St. Clair, 2015; Schell et al., 2018; Young, Hammill, et al., 2019). However, the success of coyotes and rats has led to high rates of conflict in cities throughout their respective ranges. While both species come into conflict with people for various reasons, coyotes are uniquely feared for rare but alarming physical attacks on people and domestic animals (White & Gehrt, 2009) and conflicts are disproportionately caused by so-called “problem individuals,” which exhibit unusually high levels of habituation to human presence (Schmidt & Timm, 2007). Conversely, rats cause over 20 billion USD in property damage annually by chewing infrastructure and spoiling food stores (Pimentel et al., 2005) and transmit many zoonotic pathogens (Himsworth et al., 2013). Due to these differences, coyotes are often managed at the individual level by hazing or removing problem individuals (Breck et al., 2017), while the goal of rat management is to reduce densities via trapping or poisoning (Combs et al., 2019). These approaches may have important consequences for evolutionary change in cities. For coyotes, nonlethal management strategies such as hazing may select for plastic phenotypes, while the removal of problem individuals may select for less bold phenotypes. For rats, population-level culling to reduce rat densities may impose less selection than directly targeting individuals exhibiting atypical behaviors. However, intense lethal management will undoubtedly impose a selective pressure favoring neophobia and resistance to poisons, both of which have been documented in detail (Desvars-Larrive et al., 2017; Feng & Himsworth, 2014). Changing management practices toward both species will serve as natural experiments for urban evolution. For example, nonlethal management of urban coyotes is often recommended for concerned urbanites (Young, Draper, et al., 2019; Young, Hammill, et al., 2019) and rodenticides are now restricted in some jurisdictions (Quinn et al., 2019). Incorporating evolutionary concepts in such management decisions will help inform successful mitigation strategies.

community structure (Grove et al., 2014; Hope et al., 2003; Leong et al., 2018), and though wealth–biodiversity relationships are not universally positive (Gerrish & Watkins, 2018; Kuras et al., 2020; Watkins & Gerrish, 2018), repeated evidence across the globe has supported this hypothesis (Chamberlain et al., 2020). Fewer studies have investigated whether economic inequality shapes beliefs and attitudes toward wildlife in urban environments. However, recent research suggests that individuals with wealth from developed countries tend to have more favorable views of wildlife due to greater frequencies of positive interactions (Soga & Gaston, 2020). Whether these trends hold true for developing urban centers, particularly across the global south, is uncertain.

The distribution of and access to green spaces is significantly reduced for low-income communities relative to wealthier communities in cities (Rigolon et al., 2018; Wolch et al., 2014). Reductions in vegetation cover and green space, compounded with other environmental disturbances (e.g., pollutants human densities, urban heat island effects), necessarily constrain available niche space for certain wildlife in favor of non-native and pest species in low-income neighborhoods (Leong et al., 2018). For instance, reductions in vegetation cover and plant biodiversity in low-income neighborhoods (Schwarz et al., 2015) often covary with greater pest species abundances (e.g., brown rats, *Rattus norvegicus*; mosquitoes, *Aedes aegypti*) that frequently cause property damage and represent significant disease vectors, disproportionately increasing risks of zoonotic disease transmission for low-income residents (Byers et al., 2019; Mathanga et al., 2016; Murray, Fidino, et al., 2020; Peterson et al., 2020). As a result, luxury effects may indirectly determine the types of human–wildlife interactions experienced by different socioeconomic groups. Centering environmental justice in improving green space access, quality, and equity may subsequently drive positive attitudes with wildlife by providing positive interactions with nature, which can bolster overall support for wildlife-friendly policies in cities.

3.2 | Religion, culture, and media

How religious traditions view the environment and wildlife can shape how people respond to emergent conflicts from individual organisms (Dickman et al., 2013; Manfredo & Dayer, 2004). For instance, rhesus macaques (*Macaca mulatta*) in Dehradun, India, are commonly involved in property damage and injury to humans, but are also revered in Hinduism, which results in ambivalent attitudes toward conflict management by members of the public (Anand et al., 2018; Beisner et al., 2015; Saraswat et al., 2015). Ritualized feeding in Delhi, India, of black kites (*Milvus migrans*) by citizens combined with the city's inefficient waste removal is linked to higher recorded attacks and aggression on humans, yet the affected human communities demonstrate heightened empathy and tolerance for the kites (Kumar et al., 2018, 2019). Further, residents of Jodhpur, Rajasthan, India, feed urban Hanuman langurs (*Semnopithecus entellus*) in reverence to the monkey god, Hanuman (Waite et al., 2007), whereas

tourists report hostile and agonistic interactions as a residual effect of habituated monkeys (Sharma et al., 2010).

The influence of sociocultural conditions can exaggerate hostilities toward specific taxa regardless of the actual risk of conflict (Peterson et al., 2010). For example, individual attitudes and beliefs toward coyotes in urban and suburban regions of Denver strongly predict support for lethal control measures over nonlethal strategies such as hazing and education (Draheim et al., 2019). Conversely, growing interest in wildlife as pets can be influenced by popular culture trends. For instance, the global popularity of the Harry Potter movie franchise led to an increase in demand for owls as pets, with a noticeable impact on the wildlife trade (Nijman & Nekaris, 2017). In both examples, culturally informed views on specific wildlife can negatively impact wild population dynamics and lead to novel species interactions that have the potential to increase pathogen transmission risks.

How news and social media portray human-wildlife conflict can also play a substantial role in how certain species are perceived (Nyhus, 2016). For example, recent media reporting has fueled animosity toward bats due to the COVID-19 pandemic, despite repeated evidence emphasizing that human activities are the primary predictors for our current public health crisis (MacFarlane & Rocha, 2020). Similarly, negative media on urban leopards in Mumbai, India, can exacerbate negative stereotypes, which require targeted awareness campaigns, education, and multimedia approaches to alter negative beliefs (Hathaway et al., 2017). Media awareness workshops in Mumbai, India, for example, have worked to combat negative views around urban leopards as aggressors while promoting behaviors that help prevent human-leopard conflicts (Bhatia et al., 2013; Hathaway et al., 2017). Some have additionally suggested that leopards have indirect public health benefits by hunting feral dogs, which consequently reduces dog bites in the city (Braczkowski et al., 2018).

4 | MANAGEMENT-INDUCED PHENOTYPIC AND GENOTYPIC CHANGE

Management decisions to resolve conflict act as a selective agent by either (a) removing individuals from a population; (b) controlling overall growth of a population; or (c) targeting behaviors and traits that incite conflict (Box 1). The varied techniques and goals of wildlife management work at different ecological and geographic scales, and as a result, have varying consequences for organismal evolution in cities. In addition, wildlife adaptations to management decisions may produce significant feedback (Honda et al., 2018), driving coevolution between humans and wildlife in cities (Jørgensen et al., 2019; Marzluff & Angell, 2005; Mysterud, 2010). Moreover, wildlife adaptations to management decisions may produce directional, stabilizing, or disruptive selection for phenotypic traits (e.g., boldness) that drive mean-level population differences across cities (Figure 2).

Determining the proper management strategy is nontrivial, because these decisions may elicit adaptive wildlife responses that negate the long-term efficacy of the management action (Swan

et al., 2017). Understanding how differences in lethal and nonlethal management actions affect the emergence of novel traits and the strength of selection across urban taxa is essential to creating robust and dynamic management (Figure 3). What constitutes an urban area and the extraordinary variability in urban metrics across developed and developing cities (Moll et al., 2018, 2020) requires markedly distinct management solutions. Further, acknowledging how the frequency and severity of conflict—driven by social perceptions of wildlife—dictate the intensity of management action helps to predict the potential evolutionary outcomes of wildlife management efforts (Figure 4).

4.1 | Lethal management: Targeted removals

Selective removal of targeted animals is arguably the strongest and most consistent form of management-driven directional selection for urban wildlife (Hendry et al., 2017; Nyhus, 2016). Individuals with specific behavioral phenotypes that are conflict-prone are selectively removed from the population to avoid conflict escalation. As a result, we may expect that urban environments with stronger and more consistent targeted removal programs should exhibit greater selective costs for bold or aggressive individuals (Swan et al., 2017). For instance, lethal removal of conflict-prone individuals has been suggested as a strategy to manage urban deer (Honda et al., 2018); however, because boldness is a phenotype derived from genetic and environmental interactions, it is possible that culled individuals will be replaced by the next boldest individuals in a population (Found & St. Clair, 2019). Removal of individuals to control population size may also exacerbate patterns of increased genetic drift and decreased genetic diversity already experienced by urban populations (Combs et al., 2018; Edelhoff et al., 2020; Miles et al., 2019).

4.2 | Lethal management: Rodenticides

The most notable example of genetic change in response to lethal management may be evolved resistance to anticoagulant rodenticides in urban rats (Haniza et al., 2015). Integrated pest management has widely utilized anticoagulant rodenticides to control rats since the introduction of warfarin as a rodenticide in 1948 (Desvars-Larrive et al., 2017). The initial efficacy of such practices led to rodenticide products readily available for homeowners and individual residents to use at their leisure. Within a decade, individual rats expressed resistance to warfarin via genetic mutations (Boyle, 1960). In the following years, the intense use of anticoagulants created a strong selection pressure that increased the prevalence of resistant rats in many cities. To counteract this diminished effectiveness, "second-generation" anticoagulant rodenticides were developed; however, rat populations have evolved resistance to these compounds as well (Desvars-Larrive et al., 2017). Similar evolved resistance appears in mosquitos (*Culex pipiens*) and bedbugs (*Cimex lectularius*) in response to select pesticides (Asgharian

et al., 2015; Romero & Anderson, 2016). Currently, the application of rodenticides and pesticides are geographically and temporally acute, determined by need and severity of pest conflict. As a result, these toxicants create heterogeneous fitness landscapes that can result in genetic bottlenecks (nonadaptive change) and selection for toxicant resistance (adaptive) mutations.

Bioaccumulation of these rodenticides can result in unintentional secondary poisoning of nontarget species at higher trophic levels in urban systems (Elliott et al., 2016; Murray et al., 2019; Riley et al., 2007; Serieys et al., 2015, 2018). The long-term persistence of second-generation anticoagulant rodenticides (SGARs) in animal tissues increase exposure risks for secondary and tertiary predators that ingest rodent carcasses or incapacitated rodents that have ingested SGARs (López-Perea & Mateo, 2018). For example, recent evidence from urban bobcats (*Lynx rufus*) in Los Angeles suggests SGARs in blood and liver tissues increase with urban land use (Serieys et al., 2015), promote immune dysfunction (Serieys et al., 2018), and impact differential gene expression of immune-related genes (Fraser et al., 2018). Increasing exposure to rodenticides with increasing urbanization has similarly been documented for mountain lions (*Puma concolor*) and coyotes (Poessel et al., 2015; Riley et al., 2007). Hence, rodenticides have broad fitness outcomes that extend far beyond the target species.

4.3 | Nonlethal control

Developing nonlethal deterrents that are successful long-term is a major challenge due to difficulty of deployment, enhanced learning, and selection for behavioral plasticity, with the latter two leading to cognitive arms races and coevolution between humans and wildlife (Barrett et al., 2019; Marzluff & Angell, 2005). Visual, audio, taste, or scent aversion strategies yield mixed results and can be difficult to employ. For example, the use of predator scent as a repellent has shown promise in deterring unhabituated eastern gray kangaroos (*Macropus giganteus*), but implementation poses challenges for managers (Descovich et al., 2016). A variety of taxa have demonstrated habituation to nonlethal deterrents, such as effigies and frightening devices, rendering such management efforts ineffective when applied alone (VerCauteren et al., 2010). Greater exposure to humans and anthropogenic structures without selective cost also contributes to increasing urban wildlife boldness (Figure 2), as evidenced by decreased flight initiation distances when approached by humans (Breck et al., 2019; Uchida et al., 2016) and approach time toward novelty (Greggor et al., 2016; Jarjour et al., 2019). In addition, individual variation in physiology and life history traits can compound with cognition and behavioral traits to hinder the success of certain nonlethal deterrents (Barrett et al., 2019).

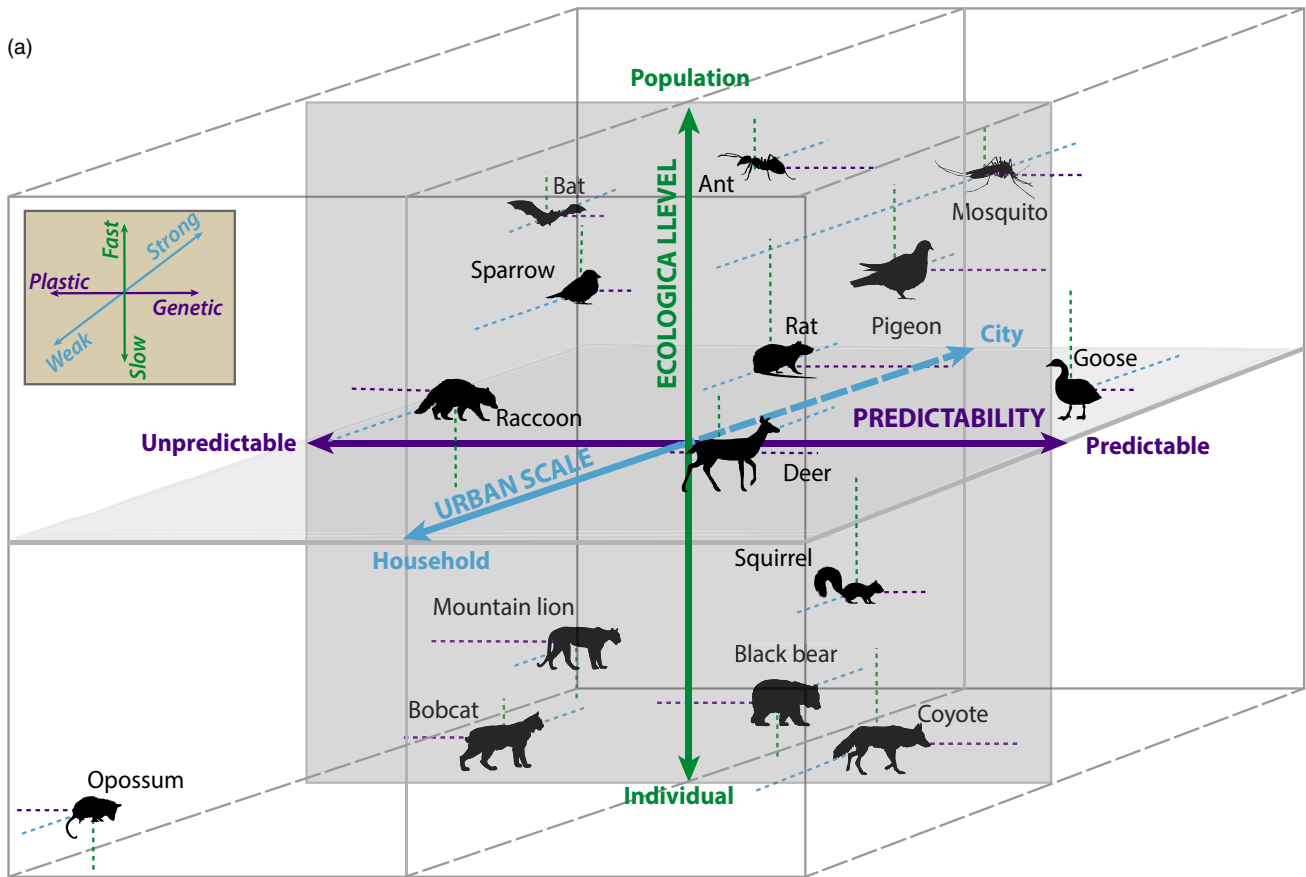
Habitat modification also serves to mitigate human-wildlife conflict. For example, physical barriers, such as fences, are employed to separate terrestrial wildlife from areas of human development. The application of spikes, coils, nets, and monofilament wires to surfaces

is usually successful in deterring undesired feeding and roosting by birds when applied correctly (VerCauteren et al., 2010). Managers may also remove water sources, secure food subsidies, or alter vegetative composition to make particular conflict zones less appealing to wildlife (VerCauteren et al., 2010), which further reduces potential ecological and evolutionary traps that jeopardize wildlife fitness (Greggor et al., 2019; Lamb et al., 2017). Although fences present some benefits for wildlife conservation, they often result in unintended, negative consequences (Woodroffe et al., 2014). Fences have been shown to cause injury and reduce landscape connectivity, disrupting daily activity and migration of terrestrial mammals (Jakes et al., 2018). In addition, fencing and other anthropogenic barriers constrain wildlife access to essential habitats, reduce animal movement, and contribute to moderate losses in genetic diversity (Osipova et al., 2018).

Translocation is a popular nonlethal management strategy that has recently increased in implementation (Germano et al., 2015). This may be due to public views and beliefs that this strategy is a humane alternative to targeted removal or pesticides and is less intensive than repeated behavioral deterrents. However, the efficacy of this strategy is seldom clear and postrelease survival is generally poor (Fontúrbel & Simonetti, 2011; Germano et al., 2015; Lehrer et al., 2016; Massei et al., 2010). Human-related mortality (e.g., vehicle collisions, hunting) accounts for approximately 80% of carnivore deaths after a translocation event (Fontúrbel & Simonetti, 2011). It is common for problem individuals to widely disperse or return to their point of origin after translocation (i.e., “homing”), making their initial removal ineffective (Fontúrbel & Simonetti, 2011). Urban individuals that survive and do not return to their original location may be susceptible to predation (Lehrer et al., 2016) or exhibit problem behaviors in their relocated environment (Athreya et al., 2011). In the few cases where urban translocation has been successful (Nelson & Theimer, 2012), the sweeping removal of entire family groups creates genetic bottlenecks that fundamentally shape urban population genetic structure (Weeks et al., 2011).

5 | APPLICATIONS FOR ADAPTIVE WILDLIFE MANAGEMENT

Wildlife managers and practitioners inherently value evolutionary principles and their relevance to wildlife management efforts (Cook & Sgrò, 2018). Time and budget constraints paired with the near-immediate call for management action from the public, however, place a distinct burden on managers to quickly develop effective strategies. Clearly articulating the links between urban evolution and wildlife management, with succinct recommendations and potential outcomes, is necessary for effective communication across these disciplines. The spatial extent, ecological level, and predictability of wildlife management implementation are intrinsically linked to the strength and rate of evolutionary



MANAGEMENT ACTION

	Targeted removal	Rodenticide/ Pesticide	Translocation	Habitat modification	Behavioral deterrents	Sterilization
Frequency of management action	Moderate	Common	Rare	Common	Common	Rare
Ecological level	Individual	Population	Individual	Population	Population, Individual	Population, Individual
Evolutionary mechanism(s)	Selection	Drift, selection	Drift, selection	Gene flow, drift	Selection**	Selection
Species targeted*						

FIGURE 5 A conceptual model and heuristic model predicting the strength, rate, and type of phenotypic change (i.e., plastic or genetic) due to management action scale, predictability, and ecological level. (a) The scale of management application, how consistent management actions are, and the overarching goal (i.e., individual problem animal removal vs. broad-scale population control) differentially affect evolutionary change across urban taxa. (b) Specific management actions have varying levels of implementation, operate at different ecological levels, and influence different adaptive (i.e., selection) and nonadaptive (i.e., drift, gene flow) evolutionary mechanisms. The species targeted also vary with respect to the management action taken. **Behavioral deterrents are a special case of selection, as aversive conditioning may lead to social learning or transgenerational plasticity that ultimately leads to variance in selection but is inherently not targeting specific gene frequencies

change (Figure 5). Further, phenotypic signatures of urbanization are trophic- and scale-dependent (Strubbe et al., 2020), and scalar differences within and across cities are fundamentally driven by

social determinants of urban landscapes (Liu et al., 2007; Zipperer et al., 2011), making it difficult to implement broad management recommendations.

Discerning whether observed changes in urban traits are plastic or genetic is not only an essential question in urban evolutionary ecology (Alberti et al., 2017; Donihue & Lambert, 2014; Ouyang et al., 2018; Rivkin et al., 2019; Schell, 2018), but also informs the most effective management and conservation strategy (Lambert & Donihue, 2020). For instance, if expressions of boldness are predominantly plastic or learned, deterrents could effectively be used to instill fear dynamics and promote cautionary behavior without lethal removal (Clucas & Marzluff, 2012). Associative learning through aversive conditioning could also bolster population-level fear, even if certain individuals have never encountered negative anthropogenic stimuli (Barrett et al., 2019). If the trait is principally genetic, then improved identification and targeted removal of repeat problem animals may functionally reduce problem-associated alleles in the population (Swan et al., 2017).

Strategies to mitigate human-wildlife conflict would ideally be implemented early in the development of urban areas and would accommodate changes in patterns of conflict that may arise during development. For example, Khan et al. (2018) documented increased conflicts with leopards in developing areas of Pakistan; such knowledge of how species respond to developing areas could be used in urban planning. Understanding species responses to urbanization (Moll et al., 2020; Santini et al., 2019), subsequent potential conflict patterns (Goswami et al., 2015), and the evolutionary impacts (Rivkin et al., 2019) could prevent the development of maladaptive behavior in wildlife species and help urban landscape planners minimize conflicts during development (Nilon et al., 2017). In fact, there is a growing interest in smart growth to lessen environmental impacts of urban development (Theobald et al., 2005). Studies of wildlife behavior and human-wildlife conflicts along the urban-rural interface, combined with modeled projections of future human development (Yovovich et al., 2020), may provide insight into how or whether management strategies should shift with urbanization; for example, cougars expand their niche along with urban expansion (Moss et al., 2016), alter prey selection (Smith et al., 2016), and shift habitat use (Maletzke et al., 2017; Yovovich et al., 2020) based on human development characteristics.

Understanding how natural and built structures coalesce to form heterogeneous fitness landscapes is critical to diagnosing conflict zones, informing which habitat modifications may yield the most positive results for conflict mitigation (Nyhus, 2016). For instance, the spatiotemporal concentration of natural or artificial food subsidies may create ecological and evolutionary traps for wildlife (Lamb et al., 2017; Lewis et al., 2015). Deterring maladaptive resource use in human-dominated environments may require several nonlethal strategies that appropriate cognitive mechanisms (Greggor et al., 2019). Involving urban planning and policymakers can also help to develop built structures that promote connectivity and increase gene flow, combating against urban-driven loss in genetic diversity and human damages arising from collisions on roads (Schmidt et al., 2020). Green infrastructure in cities, including green roofs, wetlands, and wildlife corridors, provides valuable passages, stepping stones, and refuges for wildlife to avoid several types of

conflicts with people (Lundholm, 2015). Comprehensive implementation of green infrastructure is an effective tool in mitigating human-wildlife conflict (Ravenelle & Nyhus, 2017), and examples such as smooth-coated otter (*Lutrogale perspicillata*) conservation in the nation city of Singapore provide a blueprint. Sustained urban greening and public communication created refugia for otters while simultaneously bolstered social views on the value of the species (Theng & Sivasothi, 2016). Hence, striking a balance between wildlife tolerance of cities while reducing potential conflict will require a similar nuanced and targeted approach.

6 | CONCLUSION

Our world is becoming increasingly urbanized, compelling organisms to adjust under rapid timescales. Such adjustments are exacerbating levels of conflict globally, with the recent global COVID-19 pandemic a significant case study. The convergence of human and wildlife populations in urban areas has substantial feedbacks on regional and international economies, conservation efforts, and public health initiatives. Our changing relationships with urban wildlife are affecting how we view, conserve, and manage wildlife, all of which will dictate our success in promoting coexistence. Hence, diagnosing how conflicts arise and change over time is a priority for public health, the environment, and society. It is imperative that evolutionary biologists work with urban planners, wildlife practitioners, social scientists, and policymakers create holistic efforts leveraging the strengths of our communities to benefit all organisms in an increasingly urbanizing world.

ACKNOWLEDGEMENTS

We thank the University of Washington Tacoma Faculty of the School of Interdisciplinary Arts and Sciences for their support. We also thank Animal Behavior and Cognition Lab at the University of Wyoming for their review and helpful feedback on figures and content. This research was supported by the intramural research program of the U.S. Department of Agriculture, National Wildlife Research Center. This material is based upon work supported by the National Science Foundation under Grant no. 1923882. The findings and conclusions in this publication have not been formally disseminated by the U.S. Department of Agriculture and should not be construed to represent any agency determination or policy.

CONFLICT OF INTEREST


None declared.

DATA AVAILABILITY STATEMENT

There are no data associated with this article.

ORCID

Christopher J. Schell  <https://orcid.org/0000-0002-2073-9852>

Lauren A. Stanton  <https://orcid.org/0000-0002-8171-4034>

Julie K. Young  <https://orcid.org/0000-0003-4522-0157>

Lisa M. Angeloni  <https://orcid.org/0000-0002-2385-0599>
 Joanna E. Lambert  <https://orcid.org/0000-0002-2849-3930>
 Stewart W. Breck  <https://orcid.org/0000-0003-3138-1929>
 Maureen H. Murray  <https://orcid.org/0000-0002-2591-0794>

REFERENCES

- Adducci, A., Jasperse, J., Riley, S., Brown, J., Honeycutt, R., & Monzón, J. (2020). Urban coyotes are genetically distinct from coyotes in natural habitats. *Journal of Urban Ecology*, 6(1), 1–11. <https://doi.org/10.1093/jue/juaa010>
- Alberti, M. (2015). Eco-evolutionary dynamics in an urbanizing planet. *Trends in Ecology and Evolution*, 30(2), 114–126. <https://doi.org/10.1016/j.tree.2014.11.007>
- Alberti, M., Correa, C., Marzluff, J. M., Hendry, A. P., Palkovacs, E. P., Gotanda, K. M., Hunt, V. M., Apgar, T. M., & Zhou, Y. (2017). Global urban signatures of phenotypic change in animal and plant populations. *Proceedings of the National Academy of Sciences of the United States of America*, 114(34), 8951–8956. <https://doi.org/10.1073/pnas.1606034114>
- Anand, S., Binoy, V. V., & Radhakrishna, S. (2018). The monkey is not always a God: Attitudinal differences toward crop-raiding macaques and why it matters for conflict mitigation. *Ambio*, 47(6), 711–720. <https://doi.org/10.1007/s13280-017-1008-5>
- Arbilly, M., Weissman, D. B., Feldman, M. W., & Grodzinski, U. (2014). An arms race between producers and scroungers can drive the evolution of social cognition. *Behavioral Ecology*, 25(3), 487–495. <https://doi.org/10.1093/beheco/aru002>
- Asgharian, H., Chang, P. L., Lysenkov, S., Scobeyeva, V. A., Reisen, W. K., & Nuzhdin, S. V. (2015). Evolutionary genomics of *Culex pipiens*: Global and local adaptations associated with climate, life-history traits and anthropogenic factors. *Proceedings of the Royal Society B: Biological Sciences*, 282(1810), 20150728. <https://doi.org/10.1098/rspb.2015.0728>
- Athreya, V., Odden, M., Linnell, J. D. C., & Karanth, K. U. (2011). Translocation as a tool for mitigating conflict with leopards in human-dominated landscapes of India. *Conservation Biology*, 25(1), 133–141. <https://doi.org/10.1111/j.1523-1739.2010.01599.x>
- Audet, J. N., Ducatez, S., & Lefebvre, L. (2016). The town bird and the country bird: Problem solving and immunocompetence vary with urbanization. *Behavioral Ecology*, 27(2), 637–644. <https://doi.org/10.1093/beheco/arv201>
- Baker, P. J., Dowding, C. V., Molony, S. E., White, P. C. L., & Harris, S. (2007). Activity patterns of urban red foxes (*Vulpes vulpes*) reduce the risk of traffic-induced mortality. *Behavioral Ecology*, 18(4), 716–724. <https://doi.org/10.1093/beheco/arm035>
- Balkenhol, N., & Waits, L. P. (2009). Molecular road ecology: Exploring the potential of genetics for investigating transportation impacts on wildlife. *Molecular Ecology*, 18(20), 4151–4164. <https://doi.org/10.1111/j.1365-294X.2009.04322.x>
- Ballantyne, M., Gudes, O., & Pickering, C. M. (2014). Recreational trails are an important cause of fragmentation in endangered urban forests: A case-study from Australia. *Landscape and Urban Planning*, 130(1), 112–124. <https://doi.org/10.1016/j.landurbplan.2014.07.004>
- Barrett, L. P., Stanton, L. A., & Benson-Amram, S. (2019). The cognition of 'nuisance' species. *Animal Behaviour*, 147, 167–177. <https://doi.org/10.1016/j.anbehav.2018.05.005>
- Beisner, B. A., Heagerty, A., Seil, S. K., Balasubramaniam, K. N., Atwill, E. R., Gupta, B. K., Tyagi, P. C., Chauhan, N. P. S., Bonal, B. S., Sinha, P. R., & McCowan, B. (2015). Human-wildlife conflict: Proximate predictors of aggression between humans and rhesus macaques in India. *American Journal of Physical Anthropology*, 156(2), 286–294. <https://doi.org/10.1002/ajpa.22649>
- Bhatia, S., Athreya, V., Grenyer, R., & Macdonald, D. W. (2013). Understanding the role of representations of human-leopard conflict in Mumbai through media-content analysis. *Conservation Biology*, 27(3), 588–594. <https://doi.org/10.1111/cobi.12037>
- Boni, M. F., Lemey, P., Jiang, X., Lam, T.-Y., Perry, B. W., Castoe, T. A., Rambaut, A., & Robertson, D. L. (2020). Evolutionary origins of the SARS-CoV-2 sarbecovirus lineage responsible for the COVID-19 pandemic. *Nature Microbiology*. <https://doi.org/10.1038/s41564-020-0771-4>
- Boyle, C. M. (1960). Case of apparent resistance of *Rattus norvegicus* berkenhout to anticoagulant poisons. *Nature*, 188(4749), 517. <https://doi.org/10.1038/188517a0>
- Braczkowski, A. R., O'Bryan, C. J., Stringer, M. J., Watson, J. E. M., Possingham, H. P., & Beyer, H. L. (2018). Leopards provide public health benefits in Mumbai, India. *Frontiers in Ecology and the Environment*, 16(3), 176–182. <https://doi.org/10.1002/fee.1776>
- Brady, S. P., & Richardson, J. L. (2017). Road ecology: Shifting gears toward evolutionary perspectives. *Frontiers in Ecology and the Environment*, 15(2), 91–98. <https://doi.org/10.1002/fee.1458>
- Breck, S. W., Poessel, S. A., & Bonnell, M. A. (2017). Evaluating lethal and nonlethal management options for urban coyotes. *Human-Wildlife Interactions*, 11(2), 133–145. <https://doi.org/10.5070/v427110686>
- Breck, S. W., Poessel, S. A., Mahoney, P., & Young, J. K. (2019). The intrepid urban coyote: A comparison of bold and exploratory behavior in coyotes from urban and rural environments. *Scientific Reports*, 9(1), 2104. <https://doi.org/10.1038/s41598-019-38543-5>
- Brotcorne, F., Giraud, G., Gunst, N., Fuentes, A., Wandia, I. N., Beudels-Jamar, R. C., Poncin, P., Huynen, M.-C., & Leca, J.-B. (2017). Intergroup variation in robbing and bartering by long-tailed macaques at Uluwatu Temple (Bali, Indonesia). *Primates*, 58(4), 505–516. <https://doi.org/10.1007/s10329-017-0611-1>
- Brown, C. R., & Bomberger Brown, M. (2013). Where has all the road kill gone? *Current Biology*, 23(6), R233–R234. <https://doi.org/10.1016/j.cub.2013.02.023>
- Butler, J. R. A. A., Linnell, J. D. C. C., Marrant, D., Athreya, V., Lescureux, N., & McKeown, A. S. (2015). Dog eat dog, cat eat dog: Social-ecological dimensions of dog predation by wild carnivores. In *Free-ranging dogs and wildlife conservation* (27 pp). <https://doi.org/10.1093/acprof:oso/9780199663217.003.0005>
- Byers, K. A., Lee, M. J., Patrick, D. M., & Himsforth, C. G. (2019). Rats about town: A systematic review of rat movement in urban ecosystems. *Frontiers in Ecology and Evolution*, 7(JAN), 1–12. <https://doi.org/10.3389/fevo.2019.00013>
- Chakraborty, I., & Maity, P. (2020). COVID-19 outbreak: Migration, effects on society, global environment and prevention. *Science of the Total Environment*, 728, 138882. <https://doi.org/10.1016/j.scitotenv.2020.138882>
- Chalkowski, K., Wilson, A. E., Lepczyk, C. A., & Zohdy, S. (2019). Who let the cats out? A global meta-analysis on risk of parasitic infection in indoor versus outdoor domestic cats (*Felis catus*). *Biology Letters*, 15(4). <https://doi.org/10.1098/rsbl.2018.0840>
- Chamberlain, D., Reynolds, C., Amar, A., Henry, D., Caprio, E., & Batáry, P. (2020). Wealth, water and wildlife: Landscape aridity intensifies the urban luxury effect. *Global Ecology and Biogeography*, 29(9), 1595–1605. <https://doi.org/10.1111/geb.13122>
- Clinchy, M., Zanette, L. Y., Roberts, D., Suraci, J. P., Buesching, C. D., Newman, C., & Macdonald, D. W. (2016). Fear of the human "super predator" far exceeds the fear of large carnivores in a model mesocarnivore. *Behavioral Ecology*, 284(August), arw117. <https://doi.org/10.1093/beheco/arw117>
- Clucas, B., & Marzluff, J. M. (2011). Coupled Relationships between Humans and other Organisms in Urban Areas. In J. Niemela (Ed.), *Urban ecology* (pp. 135–147). <https://doi.org/10.1093/acprof:oso/9780199563562.003.0017>

- Clucas, B., & Marzluff, J. M. (2012). Attitudes and actions toward birds in urban areas: Human cultural differences influence bird behavior. *The Auk*, 129(1), 8–16. <https://doi.org/10.1525/auk.2011.11121>
- Combs, M., Byers, K. A., Ghersi, B. M., Blum, M. J., Cacccone, A., Costa, F., & Munshi-South, J. (2018). Urban rat races: Spatial population genomics of brown rats (*Rattus norvegicus*) compared across multiple cities. *Proceedings of the Royal Society B: Biological Sciences*, 285(1880), 20180245. <https://doi.org/10.1098/rspb.2018.0245>
- Combs, M., Byers, K., Himsforth, C., & Munshi-South, J. (2019). Harnessing population genetics for pest management: Theory and application for urban rats. *Human-Wildlife Interactions*, 13(2), 250–263. <https://doi.org/10.5070/v42811003>
- Cook, C. N., & Sgrò, C. M. (2018). Understanding managers' and scientists' perspectives on opportunities to achieve more evolutionarily enlightened management in conservation. *Evolutionary Applications*, 11(8), 1371–1388. <https://doi.org/10.1111/eva.12631>
- Cove, M. V., Gardner, B., Simons, T. R., Kays, R., & O'Connell, A. F. (2018). Free-ranging domestic cats (*Felis catus*) on public lands: Estimating density, activity, and diet in the Florida Keys. *Biological Invasions*, 20(2), 333–344. <https://doi.org/10.1007/s10530-017-1534-x>
- Cox, D. T. C., & Gaston, K. J. (2018). Human–nature interactions and the consequences and drivers of provisioning wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373(1745), 20170092. <https://doi.org/10.1098/rstb.2017.0092>
- Cranfield, M. R., Barker, I. K., Mehren, K. G., & Rapley, W. A. (1984). Canine distemper in wild raccoons (*Procyon lotor*) at the metropolitan Toronto zoo. *The Canadian Veterinary Journal*, 25(2), 63–66.
- Dabritz, H. A., & Conrad, P. A. (2010). Cats and toxoplasma: Implications for public health. *Zoonoses and Public Health*, 57(1), 34–52. <https://doi.org/10.1111/j.1863-2378.2009.01273.x>
- DeCandia, A. L., Henger, C. S., Krause, A., Gormezano, L. J., Weckel, M., Nagy, C., & vonHoldt, B. M. (2019). Genetics of urban colonization: Neutral and adaptive variation in coyotes (*Canis latrans*) inhabiting the New York metropolitan area. *Journal of Urban Ecology*, 5(1), 1–12. <https://doi.org/10.1093/jue/juz002>
- Deplazes, P., Hegglin, D., Gloor, S., & Romig, T. (2004). Wilderness in the city: The urbanization of *Echinococcus multilocularis*. *Trends in Parasitology*, 20(2), 77–84. <https://doi.org/10.1016/j.pt.2003.11.011>
- Derry, A. M., Fraser, D. J., Brady, S. P., Astorg, L., Lawrence, E. R., Martin, G. K., Matte, J.-M., Negrín Dastis, J. O., Paccard, A., Barrett, R. D. H., Chapman, L. J., Lane, J. E., Ballas, C. G., Close, M., & Crispo, E. (2019). Conservation through the lens of (mal)adaptation: Concepts and meta-analysis. *Evolutionary Applications*, 12(7), 1287–1304. <https://doi.org/10.1111/eva.12791>
- Descovich, K., Tribe, A., McDonald, I. J., & Phillips, C. J. C. (2016). The eastern grey kangaroo: Current management and future directions. *Wildlife Research*, 43(7), 576. <https://doi.org/10.1071/WR16027>
- Desvars-Larrive, A., Pascal, M., Gasqui, P., Cosson, J.-F., Benoît, E., Lattard, V., Crespin, L., Lorvelec, O., Pisanu, B., Teynié, A., Vayssier-Taussat, M., Bonnet, S., Marianneau, P., Lacôte, S., Bourhy, P., Berny, P., Pavio, N., Le Poder, S., Gilot-Fromont, E., ... Vourc'h, G. (2017). Population genetics, community of parasites, and resistance to rodenticides in an urban brown rat (*Rattus norvegicus*) population. *PLoS ONE*, 12(9), e0184015. <https://doi.org/10.1371/journal.pone.0184015>
- Dickman, A. J. (2010). Complexities of conflict: The importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation*, 13(5), 458–466. <https://doi.org/10.1111/j.1469-1795.2010.00368.x>
- Dickman, A. J., Marchini, S., & Manfredi, M. (2013). The human dimension in addressing conflict with large carnivores. In *Key topics in conservation biology 2* (pp. 110–126). <https://doi.org/10.1002/978118520178.ch7>
- Ditchkoff, S. S., Saalfeld, S. T., & Gibson, C. J. (2006). Animal behavior in urban ecosystems: Modifications due to human-induced stress. *Urban Ecosystems*, 9(1), 5–12. <https://doi.org/10.1007/s11252-006-3262-3>
- Dolbeer, R. A., Seubert, J. L., & Begier, M. J. (2014). Population trends of resident and migratory Canada geese in relation to strikes with civil aircraft. *Human-Wildlife Interactions*, 8(1), 88–99. <https://doi.org/10.26077/ea1k-ch43>
- Donihue, C. M., & Lambert, M. R. (2014). Adaptive evolution in urban ecosystems. *Ambio*, 44(3), 194–203. <https://doi.org/10.1007/s13280-014-0547-2>
- Dorresteijn, I., Schultner, J., Nimmo, D. G., Fischer, J., Hanspach, J., Kuemmerle, T., Kehoe, L., & Ritchie, E. G. (2015). Incorporating anthropogenic effects into trophic ecology: Predator – Prey interactions in a human-dominated landscape. *Proceedings of the Royal Society B: Biological Sciences*, 282(1814), 20151602. <https://doi.org/10.1098/rspb.2015.1602>
- Draheim, M. M., Parsons, E. C. M., Crate, S. A., & Rockwood, L. L. (2019). Public perspectives on the management of urban coyotes. *Journal of Urban Ecology*, 5(1), 1–13. <https://doi.org/10.1093/jue/juz003>
- Dubois, S., & Fraser, D. (2013). A framework to evaluate wildlife feeding in research, wildlife management, tourism and recreation. *Animals*, 3(4), 978–994. <https://doi.org/10.3390/ani3040978>
- Ducatez, S., Audet, J. N., Rodriguez, J. R., Kayello, L., & Lefebvre, L. (2017). Innovativeness and the effects of urbanization on risk-taking behaviors in wild Barbados birds. *Animal Cognition*, 20(1), 33–42. <https://doi.org/10.1007/s10071-016-1007-0>
- Edelhoff, H., Zachos, F. E., Fickel, J., Epps, C. W., & Balkenhol, N. (2020). Genetic analysis of red deer (*Cervus elaphus*) administrative management units in a human-dominated landscape. *Conservation Genetics*, 21(2), 261–276. <https://doi.org/10.1007/s10592-020-01248-8>
- Elliott, J. E., Rattner, B. A., Shore, R. F., & Van Den Brink, N. W. (2016). Paying the pipers: Mitigating the impact of anticoagulant rodenticides on predators and scavengers. *BioScience*, 66(5), 401–407. <https://doi.org/10.1093/biosci/biw028>
- Ellwanger, A. L., & Lambert, J. E. (2018). Investigating niche construction in dynamic human-animal landscapes: Bridging ecological and evolutionary timescales. *International Journal of Primatology*, 39(5), 797–816. <https://doi.org/10.1007/s10764-018-0033-y>
- Enck, J. W., Decker, D. J., Riley, S. J., Organ, J. F., Carpenter, L. H., & Siemer, W. F. (2006). Integrating ecological and human dimensions in adaptive management of wildlife-related impacts. *Wildlife Society Bulletin*, 34(3), 698–705. [https://doi.org/10.2193/0091-7648\(2006\)34\[698:ieahdi\]2.0.co;2](https://doi.org/10.2193/0091-7648(2006)34[698:ieahdi]2.0.co;2)
- Erlandson, J. M., & Rick, T. C. (2010). Archaeology meets marine ecology: The antiquity of maritime cultures and human impacts on marine fisheries and ecosystems. *Annual Review of Marine Science*, 2(1), 231–251. <https://doi.org/10.1146/annurev.marine.010908.163749>
- Feng, A. Y. T., & Himsforth, C. G. (2014). The secret life of the city rat: A review of the ecology of urban Norway and black rats (*Rattus norvegicus* and *Rattus rattus*). *Urban Ecosystems*, 17(1), 149–162. <https://doi.org/10.1007/s11252-013-0305-4>
- Fischer, J. D., Cleeton, S. H., Lyons, T. P., & Miller, J. R. (2012). Urbanization and the predation paradox: The role of trophic dynamics in structuring vertebrate communities. *BioScience*, 62(9), 809–818. <https://doi.org/10.1525/bio.2012.62.9.6>
- Fontúrbel, F. E., & Simonetti, J. A. (2011). Translocations and human-carnivore conflicts: Problem solving or problem creating? *Wildlife Biology*, 17(2), 217–224. <https://doi.org/10.2981/10-091>
- Found, Robert, & St. Clair, C. C. (2019). Influences of personality on ungulate migration and management. *Frontiers in Ecology and Evolution*, 7(November), 1–11. <https://doi.org/10.3389/fevo.2019.00438>
- Fraser, D., Mouton, A., Serieys, L. E. K., Cole, S., Carver, S., Vandewoude, S., & Wayne, R. (2018). Genome-wide expression reveals multiple systemic effects associated with detection of anticoagulant poisons in bobcats (*Lynx rufus*). *Molecular Ecology*, 27(5), 1170–1187. <https://doi.org/10.1111/mec.14531>

- Gadau, A., Crawford, M. S., Mayek, R., Giraudeau, M., McGraw, K. J., Whisner, C. M., Kondrat-Smith, C., & Sweazea, K. L. (2019). A comparison of the nutritional physiology and gut microbiome of urban and rural house sparrows (*Passer domesticus*). *Comparative Biochemistry and Physiology Part - B: Biochemistry and Molecular Biology*, 237(August), 110332. <https://doi.org/10.1016/j.cbpb.2019.110332>
- Gaynor, K. M., Hohnjowski, C. E., Carter, N. H., & Brashares, J. S. (2018). The influence of human disturbance on wildlife nocturnality. *Science*, 360(6394), 1232–1235. <https://doi.org/10.1126/science.aar7121>
- Geffroy, B., Samia, D. S. M., Bessa, E., & Blumstein, D. T. (2015). How nature-based tourism might increase prey vulnerability to predators. *Trends in Ecology & Evolution*, 30(12), 755–765. <https://doi.org/10.1016/j.tree.2015.09.010>
- Gehrt, S. D., & Riley, S. P. D. (2010). Coyotes (*Canis latrans*). In S. D. Gehrt, S. P. D. Riley, & B. L. Cypher (Eds.), *Urban carnivores: Ecology, conflict, and conservation* (pp. 79–95). JHU Press.
- Gehrt, S. D., Wilson, E. C., Brown, J. L., & Anchor, C. (2013). Population ecology of free-roaming cats and interference competition by coyotes in urban parks. *PLoS ONE*, 8(9), 1–11. <https://doi.org/10.1371/journal.pone.0075718>
- Germano, J. M., Field, K. J., Griffiths, R. A., Clulow, S., Foster, J., Harding, G., & Swaisgood, R. R. (2015). Mitigation-driven translocations: Are we moving wildlife in the right direction? *Frontiers in Ecology and the Environment*, 13(2), 100–105. <https://doi.org/10.1890/140137>
- Gerrish, E., & Watkins, S. L. (2018). The relationship between urban forests and income: A meta-analysis. *Landscape and Urban Planning*, 170(September 2017), 293–308. <https://doi.org/10.1016/j.landurbplan.2017.09.005>
- Goswami, V. R., Medhi, K., Nichols, J. D., & Oli, M. K. (2015). Mechanistic understanding of human-wildlife conflict through a novel application of dynamic occupancy models. *Conservation Biology*, 29(4), 1100–1110. <https://doi.org/10.1111/cobi.12475>
- Goumas, M., Burns, I., Kelley, L. A., & Boogert, N. J. (2019). Herring gulls respond to human gaze direction. *Biology Letters*, 15(8), 20190405. <https://doi.org/10.1098/rsbl.2019.0405>
- Greggor, A. L., Clayton, N. S., Fulford, A. J. C., & Thornton, A. (2016). Street smart: Faster approach towards litter in urban areas by highly neophobic corvids and less fearful birds. *Animal Behaviour*, 117, 123–133. <https://doi.org/10.1016/j.anbehav.2016.03.029>
- Greggor, A. L., Trimmer, P. C., Barrett, B. J., & Sih, A. (2019). Challenges of learning to escape evolutionary traps. *Frontiers in Ecology and Evolution*, 7(October). <https://doi.org/10.3389/fevo.2019.00408>
- Gregory, R., Ohlson, D., & Arvai, J. (2006). Deconstructing adaptive management: Criteria for applications to environmental management. *Ecological Applications*, 16(6), 2411–2425. [https://doi.org/10.1890/1051-0761\(2006\)016\[2411:DAMCFA\]2.0.CO;2](https://doi.org/10.1890/1051-0761(2006)016[2411:DAMCFA]2.0.CO;2)
- Griffin, A. S., Tebbich, S., & Bugnyar, T. (2017). Animal cognition in a human-dominated world. *Animal Cognition*, 20(1), 1–6. <https://doi.org/10.1007/s10071-016-1051-9>
- Grove, J. M., Locke, D. H., O'Neil-Dunne, J. P. M., & O'Neil-Dunne, J. P. M. (2014). An ecology of prestige in New York City: Examining the relationships among population density, socio-economic status, group identity, and residential canopy cover. *Environmental Management*, 54(3), 402–419. <https://doi.org/10.1007/s00267-014-0310-2>
- Guiry, E., & Buckley, M. (2018). Urban rats have less variable, higher protein diets. *Proceedings of the Royal Society B: Biological Sciences*, 285(1889), 20181441. <https://doi.org/10.1098/rspb.2018.1441>
- Hager, S. B., Cosentino, B. J., McKay, K. J., Monson, C., Zuurdeeg, W., & Blevins, B. (2013). Window area and development drive spatial variation in bird-window collisions in an urban landscape. *PLoS ONE*, 8(1), e53371. <https://doi.org/10.1371/journal.pone.0053371>
- Haniza, M. Z. H., Adams, S., Jones, E. P., MacNicoll, A., Mallon, E. B., Smith, R. H., & Lambert, M. S. (2015). Large-scale structure of brown rat (*Rattus norvegicus*) populations in England: Effects on rodenticide resistance. *PeerJ*, 3, e1458. <https://doi.org/10.7717/peerj.1458>
- Harris, S. E., & Munshi-South, J. (2017). Signatures of positive selection and local adaptation to urbanization in white-footed mice (*Peromyscus leucopus*). *Molecular Ecology*, 26(22), 6336–6350. <https://doi.org/10.1111/mec.14369>
- Hathaway, R. S., Bryant, A. E. M., Draheim, M. M., Vinod, P., Limaye, S., & Athreya, V. (2017). From fear to understanding: Changes in media representations of leopard incidences after media awareness workshops in Mumbai, India. *Journal of Urban Ecology*, 3(1), 1–7. <https://doi.org/10.1093/jue/jux009>
- Hendry, A. P., Gotanda, K. M., & Svensson, E. I. (2017). Human influences on evolution, and the ecological and societal consequences. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372(1712), 20160028. <https://doi.org/10.1098/rstb.2016.0028>
- Himsworth, C. G., Parsons, K. L., Jardine, C., & Patrick, D. M. (2013). Rats, cities, people, and pathogens: A systematic review and narrative synthesis of literature regarding the ecology of rat-associated zoonoses in urban centers. *Vector-Borne and Zoonotic Diseases*, 13(6), 349–359. <https://doi.org/10.1089/vbz.2012.1195>
- Honda, T., Iijima, H., Tsuboi, J., & Uchida, K. (2018). A review of urban wildlife management from the animal personality perspective: The case of urban deer. *Science of the Total Environment*, 644, 576–582. <https://doi.org/10.1016/j.scitotenv.2018.06.335>
- Hope, D., Gries, C., Zhu, W., Fagan, W. F., Redman, C. L., Grimm, N. B., Nelson, A. L., Martin, C., & Kinzig, A. (2003). Socioeconomics drive urban plant diversity. *Proceedings of the National Academy of Sciences of the United States of America*, 100(15), 8788–8792. <https://doi.org/10.1073/pnas.1537557100>
- Hubbard, R. D., & Nielsen, C. K. (2009). White-tailed deer attacking humans during the fawning season: A unique human – Wildlife conflict on a university campus. *Human-Wildlife Conflicts*, 3(1), 129–135.
- Hughes, J., & Macdonald, D. W. (2013). A review of the interactions between free-roaming domestic dogs and wildlife. *Biological Conservation*, 157, 341–351. <https://doi.org/10.1016/j.biocon.2012.07.005>
- Hulme-Beaman, A., Dobney, K., Cucchi, T., & Searle, J. B. (2016). An ecological and evolutionary framework for commensalism in anthropogenic environments. *Trends in Ecology and Evolution*, 31(8), 633–645. <https://doi.org/10.1016/j.tree.2016.05.001>
- Ives, C. D., & Kendal, D. (2014). The role of social values in the management of ecological systems. *Journal of Environmental Management*, 144, 67–72. <https://doi.org/10.1016/j.jenvman.2014.05.013>
- Jakes, A. F., Jones, P. F., Paige, L. C., Seidler, R. G., & Huijser, M. P. (2018). A fence runs through it: A call for greater attention to the influence of fences on wildlife and ecosystems. *Biological Conservation*, 227, 310–318. <https://doi.org/10.1016/j.biocon.2018.09.026>
- Jarjour, C., Evans, J. C., Routh, M., & Morand-Ferron, J. (2019). Does city life reduce neophobia? A study on wild black-capped chickadees. *Behavioral Ecology*. <https://doi.org/10.1093/beheco/arz167>
- Johnson, H. E., Lewis, D. L., & Breck, S. W. (2020). Individual and population fitness consequences associated with large carnivore use of residential development. *Ecosphere*, 11(5). <https://doi.org/10.1002/ecs2.3098>
- Johnson, M. T. J., & Munshi-South, J. (2017). Evolution of life in urban environments. *Science*, 358(6363), eaam8327. <https://doi.org/10.1126/science.aam8327>
- Jørgensen, P. S., Folke, C., & Carroll, S. P. (2019). Evolution in the anthropocene: Informing governance and policy. *Annual Review of Ecology, Evolution, and Systematics*, 50(1), 527–546. <https://doi.org/10.1146/annurev-ecolsys-110218-024621>
- Kahle, L. Q., Flannery, M. E., & Dumbacher, J. P. (2016). Bird-window collisions at a west-coast urban park museum: Analyses of bird biology and window attributes from Golden Gate Park, San Francisco.

- PLoS ONE, 11(1), e0144600. <https://doi.org/10.1371/journal.pone.0144600>
- Kaplan-Hallam, M., & Bennett, N. J. (2018). Adaptive social impact management for conservation and environmental management. *Conservation Biology*, 32(2), 304–314. <https://doi.org/10.1111/cobi.12985>
- Kays, R., Costello, R., Forrester, T., Baker, M. C., Parsons, A. W., Kalies, E. L., Hess, G., Millspaugh, J. J., & McShea, W. (2015). Cats are rare where coyotes roam. *Journal of Mammalogy*, 96(5), 981–987. <https://doi.org/10.1093/jmammal/gyv100>
- Kays, R., Dunn, R. R., Parsons, A. W., McDonald, B., Perkins, T., Powers, S. A., Shell, L., McDonald, J. L., Cole, H., Kikillus, H., Woods, L., Tindle, H., & Roetman, P. (2020). The small home ranges and large local ecological impacts of pet cats. *Animal Conservation*, 2–9. <https://doi.org/10.1111/acv.12563>
- Kemp, M. E., Mychajliw, A. M., Wadman, J., & Goldberg, A. (2020). 7000 years of turnover: Historical contingency and human niche construction shape the Caribbean's Anthropocene biota. *Proceedings of the Royal Society B: Biological Sciences*, 287(1927), 20200447. <https://doi.org/10.1098/rspb.2020.0447>
- Khan, U., Lovari, S., Ali Shah, S., & Ferretti, F. (2018). Predator, prey and humans in a mountainous area: Loss of biological diversity leads to trouble. *Biodiversity and Conservation*, 27(11), 2795–2813. <https://doi.org/10.1007/s10531-018-1570-6>
- Kozakiewicz, C. P., Burrridge, C. P., Funk, W. C., Salerno, P. E., Trumbo, D. R., Gagne, R. B., & Carver, S. (2019). Urbanization reduces genetic connectivity in bobcats (*Lynx rufus*) at both intra- and interpopulation spatial scales. *Molecular Ecology*, 28(23), 5068–5085. <https://doi.org/10.1111/mec.15274>
- Kumar, N., Gupta, U., Jhala, Y. V., Qureshi, Q., Gosler, A. G., & Sergio, F. (2018). Habitat selection by an avian top predator in the tropical megacity of Delhi: Human activities and socio-religious practices as prey-facilitating tools. *Urban Ecosystems*, 21(2), 339–349. <https://doi.org/10.1007/s11252-017-0716-8>
- Kumar, N., Jhala, Y. V., Qureshi, Q., Gosler, A. G., & Sergio, F. (2019). Human-attacks by an urban raptor are tied to human subsidies and religious practices. *Scientific Reports*, 9(1), 2545. <https://doi.org/10.1038/s41598-019-38662-z>
- Kuras, E. R., Warren, P. S., Zinda, J. A., Aronson, M. F. J., Cilliers, S., Goddard, M. A., Nilon, C. H., & Winkler, R. (2020). Urban socioeconomic inequality and biodiversity often converge, but not always: A global meta-analysis. *Landscape and Urban Planning*, 198(March), 103799. <https://doi.org/10.1016/j.landurbplan.2020.103799>
- Lamb, C. T., Mowat, G., McLellan, B. N., Nielsen, S. E., & Boutin, S. (2017). Forbidden fruit: Human settlement and abundant fruit create an ecological trap for an apex omnivore. *Journal of Animal Ecology*, 86(1), 55–65. <https://doi.org/10.1111/1365-2656.12589>
- Lambert, M. R., & Donihue, C. M. (2020). Urban biodiversity management using evolutionary tools. *Nature Ecology & Evolution*, 4(7), 903–910. <https://doi.org/10.1038/s41559-020-1193-7>
- LaPoint, S., Balkenhol, N., Hale, J., Sadler, J., & van der Ree, R. (2015). Ecological connectivity research in urban areas. *Functional Ecology*, 29(7), 868–878. <https://doi.org/10.1111/1365-2435.12489>
- Lehrer, E. W., Schooley, R. L., Nevis, J. M., Kilgour, R. J., Wolff, P. J., & Magle, S. B. (2016). Happily ever after? Fates of translocated nuisance woodchucks in the Chicago metropolitan area. *Urban Ecosystems*, 19(3), 1389–1403. <https://doi.org/10.1007/s11252-016-0560-2>
- Leong, M., Dunn, R. R., & Trautwein, M. D. (2018). Biodiversity and socio-economics in the city: A review of the luxury effect. *Biology Letters*, 14(5), 20180082. <https://doi.org/10.1098/rsbl.2018.0082>
- Lepczyk, C. A., Aronson, M. F. J., Evans, K. L., Goddard, M. A., Lerman, S. B., & Macivor, J. S. (2017). Biodiversity in the City: Fundamental questions for understanding the ecology of urban green spaces for biodiversity conservation. *BioScience*, 67(9), 799–807. <https://doi.org/10.1093/biosci/bix079>
- Lepczyk, C. A., La Sorte, F. A., Aronson, M. F. J., Goddard, M. A., MacGregor-Fors, I., Nilon, C. H., & Warren, P. S. (2017). Global patterns and drivers of urban bird diversity. In *Ecology and conservation of birds in urban environments* (pp. 13–33). https://doi.org/10.1007/978-3-319-43314-1_2
- Lewis, D. L., Baruch-Mordo, S., Wilson, K. R., Breck, S. W., Mao, J. S., & Broderick, J. (2015). Foraging ecology of black bears in urban environments: Guidance for human-bear conflict mitigation. *Ecosphere*, 6(8), art141. <https://doi.org/10.1890/ES15-00137.1>
- Li, H., & Wilkins, K. T. (2014). Patch or mosaic: Bat activity responds to fine-scale urban heterogeneity in a medium-sized city in the United States. *Urban Ecosystems*, 17(4), 1013–1031. <https://doi.org/10.1007/s11252-014-0369-9>
- Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., Pell, A. N., Deadman, P., Kratz, T., Lubchenco, J., Ostrom, E., Ouyang, Z., Provencher, W., Redman, C. L., Schneider, S. H., & Taylor, W. W. (2007). Complexity of coupled human and natural systems. *Science*, 317(5844), 1513–1516. <https://doi.org/10.1126/science.1144004>
- López-Perea, J. J., & Mateo, R. (2018). Secondary exposure to anticoagulant rodenticides and effects on predators. In *Anticoagulant rodenticides and wildlife* (pp. 159–193). https://doi.org/10.1007/978-3-319-64377-9_7
- Loss, S. R. S. S., Will, T., Loss, S. R. S. S., & Marra, P. P. (2014). Bird-building collisions in the United States: Estimates of annual mortality and species vulnerability. *The Condor*, 116(1), 8–23. <https://doi.org/10.1650/CONDOR-13-090.1>
- Lowry, H., Lill, A., & Wong, B. B. M. (2013). Behavioural responses of wildlife to urban environments. *Biological Reviews*, 88(3), 537–549. <https://doi.org/10.1111/brv.12012>
- Lundholm, J. T. (2015). The ecology and evolution of constructed ecosystems as green infrastructure. *Frontiers in Ecology and Evolution*, 3(SEP), 1–7. <https://doi.org/10.3389/fevo.2015.00106>
- Luong, L. T., Chambers, J. L., Moizis, A., Stock, T. M., & St. Clair, C. C. (2020). Helminth parasites and zoonotic risk associated with urban coyotes (*Canis latrans*) in Alberta, Canada. *Journal of Helminthology*, 94, e25. <https://doi.org/10.1017/S0022149X1800113X>
- MacFarlane, D., & Rocha, R. (2020). Guidelines for communicating about bats to prevent persecution in the time of COVID-19. *Biological Conservation*, 248(May), 108650. <https://doi.org/10.1016/j.biocon.2020.108650>
- Maletzke, B., Kertson, B., Swanson, M., Koehler, G., Beausoleil, R., Wielgus, R., & Cooley, H. (2017). Cougar response to a gradient of human development. *Ecosphere*, 8(7), 1–14. <https://doi.org/10.1002/ecs2.1828>
- Manfredo, M. J., & Dayer, A. A. (2004). Concepts for exploring the social aspects of Human-Wildlife conflict in a global context. *Human Dimensions of Wildlife*, 9(4), 1–20. <https://doi.org/10.1080/10871200490505765>
- Manfredo, M. J., Urquiza-Haas, E. G., Don Carlos, A. W., Bruskotter, J. T., & Dietsch, A. M. (2020). How anthropomorphism is changing the social context of modern wildlife conservation. *Biological Conservation*, 241(October), 108297. <https://doi.org/10.1016/j.biocon.2019.108297>
- Marzluff, J., & Angell, T. (2005). Cultural coevolution: How the human bond with crows and ravens extends theory and raises new questions. *Journal of Ecological Anthropology*, 9(1), 69–75. <https://doi.org/10.5038/2162-4593.9.1.5>
- Massei, G., Quy, R. J., Gurney, J., & Cowan, D. P. (2010). Can translocations be used to mitigate human – Wildlife conflicts? *Wildlife Research*, 37(5), 428. <https://doi.org/10.1071/WR08179>
- Mathanga, D. P., Tembo, A. K., Mzilahowa, T., Bauleni, A., Mtimaukenena, K., Taylor, T. E., Valim, C., Walker, E. D., & Wilson, M. L. (2016). Patterns and determinants of malaria risk in urban and peri-urban areas of Blantyre, Malawi. *Malaria Journal*, 15(1), 590. <https://doi.org/10.1186/s12936-016-1623-9>

- McCleery, R. A., Moorman, C. E., & Peterson, M. N. (2014). Urban wildlife conservation: Theory and practice. In R. A. McCleery, C. E. Moorman, & M. N. Peterson (Eds.), *Urban wildlife conservation: Theory and practice*. <https://doi.org/10.1007/978-1-4899-7500-3>
- Messmer, T. A. (2020). Humans, wildlife, and our environment: One Health is the common link. *Human-Wildlife Conflicts*, 14(1). <https://doi.org/10.1108/01604951111105069>
- Miles, L. S., Rivkin, L. R., Johnson, M. T. J., Munshi-South, J., & Verrelli, B. C. (2019). Gene flow and genetic drift in urban environments. *Molecular Ecology*, 28(18), 4138–4151. <https://doi.org/10.1111/mec.15221>
- Moll, R. J., Cepek, J. D., Lorch, P. D., Dennis, P. M., Robison, T., Millsbaugh, J. J., & Montgomery, R. A. (2018). Humans and urban development mediate the sympatry of competing carnivores. *Urban Ecosystems*, 21(4), 765–778. <https://doi.org/10.1007/s11252-018-0758-6>
- Moll, R. J., Cepek, J. D., Lorch, P. D., Dennis, P. M., Robison, T., & Montgomery, R. A. (2020). At what spatial scale(s) do mammals respond to urbanization? *Ecography*, 43(2), 171–183. <https://doi.org/10.1111/ecog.04762>
- Moll, R. J., Cepek, J. D., Lorch, P. D., Dennis, P. M., Tans, E., Robison, T., Millsbaugh, J. J., & Montgomery, R. A. (2019). What does urbanization actually mean? A framework for urban metrics in wildlife research. *Journal of Applied Ecology*, 56(5), 1289–1300. <https://doi.org/10.1111/1365-2664.13358>
- Møller, A. P., Jokimäki, J., Skorka, P., & Tryjanowski, P. (2014). Loss of migration and urbanization in birds: A case study of the blackbird (*Turdus merula*). *Oecologia*, 175(3), 1019–1027. <https://doi.org/10.1007/s00442-014-2953-3>
- Morand-Ferron, J., Sol, D., & Lefebvre, L. (2007). Food stealing in birds: Brain or brawn? *Animal Behaviour*, 74(6), 1725–1734. <https://doi.org/10.1016/j.anbehav.2007.04.031>
- Moss, W. E., Alldredge, M. W., Logan, K. A., & Pauli, J. N. (2016). Human expansion precipitates niche expansion for an opportunistic apex predator (*Puma concolor*). *Scientific Reports*, 6(November), 2–6. <https://doi.org/10.1038/srep39639>
- Murray, M. H., Becker, D. J., Hall, R. J., & Hernandez, S. M. (2016). Wildlife health and supplemental feeding: A review and management recommendations. *Biological Conservation*, 204, 163–174. <https://doi.org/10.1016/j.biocon.2016.10.034>
- Murray, M. H., Fidino, M., Fyffe, R., Byers, K. A., Pettengill, J. B., Sondgeroth, K. S., Killion, H., Magle, S. B., Rios, M. J., Ortinau, N., & Santymire, R. M. (2020). City sanitation and socioeconomics predict rat zoonotic infection across diverse neighbourhoods. *Zoonoses and Public Health*, 67(6), 673–683. <https://doi.org/10.1111/zph.12748>
- Murray, M. H., Fyffe, R., Fidino, M., Byers, K. A., Jazmin Rios, M., Mulligan, M. P., & Magle, S. B. (2018). Public complaints reflect rat relative abundance across diverse urban neighborhoods. *Frontiers in Ecology and Evolution*, 6(NOV), 1–10. <https://doi.org/10.3389/fevo.2018.00189>
- Murray, M. H., Hill, J., Whyte, P., & St. Clair, C. C. (2016). Urban compost attracts coyotes, contains toxins, and may promote disease in urban-adapted wildlife. *EcoHealth*, 13(2), 285–292. <https://doi.org/10.1007/s10393-016-1105-0>
- Murray, M. H., Lankau, E. W., Kidd, A. D., Welch, C. N., Ellison, T., Adams, H. C., Lipp, E. K., & Hernandez, S. M. (2020). Gut microbiome shifts with urbanization and potentially facilitates a zoonotic pathogen in a wading bird. *PLoS ONE*, 15(3), e0220926. <https://doi.org/10.1371/journal.pone.0220926>
- Murray, M. H., Sánchez, C. A., Becker, D. J., Byers, K. A., Worsley-Tonks, K. E. L., & Craft, M. E. (2019). City sicker? A meta-analysis of wildlife health and urbanization. *Frontiers in Ecology and the Environment*, 17(10), 575–583. <https://doi.org/10.1002/fee.2126>
- Murray, M. H., & St. Clair, C. C. (2015). Individual flexibility in nocturnal activity reduces risk of road mortality for an urban carnivore. *Behavioral Ecology*, 26(6), 1520–1527. <https://doi.org/10.1093/behec/0/arv102>
- Mysterud, A. (2010). Still walking on the wild side? Management actions as steps towards “semi-domestication” of hunted ungulates. *Journal of Applied Ecology*, 47(4), 920–925. <https://doi.org/10.1111/j.1365-2664.2010.01836.x>
- Nelson, E. J., & Theimer, T. C. (2012). Translocation of Gunnison's prairie dogs from an urban and suburban colony to abandoned wildland colonies. *Journal of Wildlife Management*, 76(1), 95–101. <https://doi.org/10.1002/jwmg.281>
- Neumann, W., Ericsson, G., Dettki, H., Bunnefeld, N., Keuler, N. S., Helmers, D. P., & Radeloff, V. C. (2012). Difference in spatiotemporal patterns of wildlife road-crossings and wildlife-vehicle collisions. *Biological Conservation*, 145(1), 70–78. <https://doi.org/10.1016/j.biocon.2011.10.011>
- Newsome, S. D., Garbe, H. M., Wilson, E. C., & Gehrt, S. D. (2015). Individual variation in anthropogenic resource use in an urban carnivore. *Oecologia*, 178(1), 115–128. <https://doi.org/10.1007/s00442-014-3205-2>
- Nickel, B. A., Suraci, J. P., Allen, M. L., & Wilmers, C. C. (2020). Human presence and human footprint have non-equivalent effects on wildlife spatiotemporal habitat use. *Biological Conservation*, 241(August 2019), 108383. <https://doi.org/10.1016/j.biocon.2019.108383>
- Nijman, V., & Nekaris, K. A. I. (2017). The Harry Potter effect: The rise in trade of owls as pets in Java and Bali, Indonesia. *Global Ecology and Conservation*, 11, 84–94. <https://doi.org/10.1016/j.gecco.2017.04.004>
- Nilon, C. H., Aronson, M. F. J., Cilliers, S. S., Dobbs, C., Frazee, L. J., Goddard, M. A., O'Neill, K. M., Roberts, D., Stander, E. K., Werner, P., Winter, M., & Yocom, K. P. (2017). Planning for the future of urban biodiversity: A global review of city-scale initiatives. *BioScience*, 67(4), 332–342. <https://doi.org/10.1093/biosci/bix012>
- Nyhus, P. J. (2016). Human-Wildlife Conflict And Coexistence. In *Annual review of environment and resources* (Vol. 41). <https://doi.org/10.1146/annurev-environ-110615-085634>
- Oro, D., Genovart, M., Tavecchia, G., Fowler, M. S., & Martínez-Abraín, A. (2013). Ecological and evolutionary implications of food subsidies from humans. *Ecology Letters*, 16(12), 1501–1514. <https://doi.org/10.1111/ele.12187>
- Osipova, L., Okello, M. M., Njumbi, S. J., Ngene, S., Western, D., Hayward, M. W., & Balkenhol, N. (2018). Fencing solves human-wildlife conflict locally but shifts problems elsewhere: A case study using functional connectivity modelling of the African elephant. *Journal of Applied Ecology*, 55(6), 2673–2684. <https://doi.org/10.1111/1365-2664.13246>
- Ouyang, J. Q., Isaksson, C., Schmidt, C., Hutton, P., Bonier, F., & Dominoni, D. (2018). A new framework for urban ecology: An integration of proximate and ultimate responses to anthropogenic change. *Integrative and Comparative Biology*, 58(5), 915–928. <https://doi.org/10.1093/icb/icy110>
- Pagani-Núñez, E., Liang, D., He, C., Zhou, X., Luo, X., Liu, Y., & Goodale, E. (2019). Niches in the anthropocene: Passerine assemblages show niche expansion from natural to urban habitats. *Ecography*, 42(8), 1360–1369. <https://doi.org/10.1111/ecog.04203>
- Pataki, D. E. (2015). Grand challenges in urban ecology. *Frontiers in Ecology and Evolution*, 3(JUN), 1–6. <https://doi.org/10.3389/fevo.2015.00057>
- Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I.-C., Clark, T. D., Colwell, R. K., Danielsen, F., Evengård, B., Falconi, L., Ferrier, S., Frusher, S., Garcia, R. A., Griffis, R. B., Hobday, A. J., Janion-Scheepers, C., Jarzyna, M. A., Jennings, S., ... Williams, S. E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, 355(6332), eaai9214. <https://doi.org/10.1126/science.aai9214>

- Penteriani, V., Delgado, M. D. M., Pinchera, F., Naves, J., Fernández-Gil, A., Kojola, I., Härkönen, S., Norberg, H., Frank, J., Fedriani, J. M., Sahlén, V., Støen, O.-G., Swenson, J. E., Wabakken, P., Pellegrini, M., Herrero, S., & López-Bao, J. V. (2016). Human behaviour can trigger large carnivore attacks in developed countries. *Scientific Reports*, 6(1432), 20552. <https://doi.org/10.1038/srep20552>
- Peterson, A. C., Ghersi, B. M., Campanella, R., Riegel, C., Lewis, J. A., & Blum, M. J. (2020). Rodent assemblage structure reflects socioecological mosaics of counter-urbanization across post-Hurricane Katrina New Orleans. *Landscape and Urban Planning*, 195(November 2018), 103710. <https://doi.org/10.1016/j.landurbplan.2019.103710>
- Peterson, M. N., Birckhead, J. L., Leong, K., Peterson, M. J., & Peterson, T. R. (2010). Rearticulating the myth of human-wildlife conflict. *Conservation Letters*, 3(2), 74–82. <https://doi.org/10.1111/j.1755-263X.2010.00099.x>
- Pickett, S. T. A., Cadenasso, M. L., Childers, D. L., McDonnell, M. J., & Zhou, W. (2016). Evolution and future of urban ecological science: Ecology in, of, and for the city. *Ecosystem Health and Sustainability*, 2(7), e01229. <https://doi.org/10.1002/ehs2.1229>
- Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics*, 52(3), 273–288. <https://doi.org/10.1016/j.ecolecon.2004.10.002>
- Poessel, S. A., Breck, S. W., Fox, K. A., & Gese, E. M. (2015). Anticoagulant rodenticide exposure and toxicosis in coyotes (*Canis latrans*) in the Denver Metropolitan Area. *Journal of Wildlife Diseases*, 51(1), 265–268. <https://doi.org/10.7589/2014-04-116>
- Proctor, M. F., Kasworm, W. F., Teisberg, J. E., Servheen, C., Radandt, T. G., Lamb, C. T., Kendall, K. C., Mace, R. D., Paetkau, D., & Boyce, M. S. (2020). American black bear population fragmentation detected with pedigrees in the transborder Canada-United States region. *Ursus*, 2020(31e1), 1. <https://doi.org/10.2192/ursus-d-18-00003r2>
- Proppe, D. S., McMillan, N., Congdon, J. V., & Sturdy, C. B. (2017). Mitigating road impacts on animals through learning principles. *Animal Cognition*, 20(1), 19–31. <https://doi.org/10.1007/s10071-016-0989-y>
- Puckett, E. E., Park, J., Combs, M., Blum, M. J., Bryant, J. E., Caccone, A., & Munshi-South, J. (2016). Global population divergence and admixture of the brown rat (*Rattus norvegicus*). *Proceedings of the Royal Society B: Biological Sciences*, 283(1841), 20161762. <https://doi.org/10.1098/rspb.2016.1762>
- Quinn, N., Kenmuir, S., & Krueger, L. (2019). A California without rodenticides: Challenges for commensal rodent management in the future. *Human-Wildlife Interactions*, 13(2), 212–225. <https://doi.org/10.5070/v42811007>
- Ravenelle, J., & Nyhus, P. J. (2017). Global patterns and trends in human-wildlife conflict compensation. *Conservation Biology*, 31(6), 1247–1256. <https://doi.org/10.1111/cobi.12948>
- Ravinet, M., Elgvin, T. O., Trier, C., Aliabadian, M., Gavrillov, A., & Sætre, G. P. (2018). Signatures of human-commensalism in the house sparrow genome. *Proceedings of the Royal Society B: Biological Sciences*, 285(1884), <https://doi.org/10.1098/rspb.2018.1246>
- Richardson, J. L., Urban, M. C., Bolnick, D. I., & Skelly, D. K. (2014). Microgeographic adaptation and the spatial scale of evolution. *Trends in Ecology and Evolution*, 29(3), 165–176. <https://doi.org/10.1016/j.tree.2014.01.002>
- Richardson, S., Mill, A. C., Davis, D., Jam, D., & Ward, A. I. (2020). A systematic review of adaptive wildlife management for the control of invasive, non-native mammals, and other human-wildlife conflicts. *Mammal Review*, 50(2), 147–156. <https://doi.org/10.1111/mam.12182>
- Rigolon, A., Browning, M., & Jennings, V. (2018). Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States. *Landscape and Urban Planning*, 178(June), 156–169. <https://doi.org/10.1016/j.landurbplan.2018.05.026>
- Riley, S. P. D., Bromley, C., Poppenga, R. H., Uzal, F. A., Whited, L., & Sauvajot, R. M. (2007). Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California. *Journal of Wildlife Management*, 71(6), 1874–1884. <https://doi.org/10.2193/2005-615>
- Riley, S. P. D., Pollinger, J. P., Sauvajot, R. M., York, E. C., Bromley, C., Fuller, T. K., & Wayne, R. K. (2006). A southern California freeway is a physical and social barrier to gene flow in carnivores. *Molecular Ecology*, 15(7), 1733–1741. <https://doi.org/10.1111/j.1365-294X.2006.02907.x>
- Riley, S. P. D., Serieys, L. E. K., Pollinger, J. P., Sikich, J. A., Dalbeck, L., Wayne, R. K., & Ernest, H. B. (2014). Individual behaviors dominate the dynamics of an urban mountain lion population isolated by roads. *Current Biology*, 24(17), 1989–1994. <https://doi.org/10.1016/j.cub.2014.07.029>
- Rivkin, L. R., Santangelo, J. S., Alberti, M., Aronson, M. F. J., de Keyser, C. W., Diamond, S. E., Fortin, M.-J., Frazee, L. J., Gorton, A. J., Hendry, A. P., Liu, Y., Losos, J. B., Maclvor, J. S., Martin, R. A., McDonnell, M. J., Miles, L. S., Munshi-South, J., Ness, R. W., Newman, A. E. M., ... Johnson, M. T. J. (2019). A roadmap for urban evolutionary ecology. *Evolutionary Applications*, 12(3), 384–398. <https://doi.org/10.1111/eva.12734>
- Robb, G. N., McDonald, R. A., Chamberlain, D. E., & Bearhop, S. (2008). Food for thought: Supplementary feeding as a driver of ecological change in avian populations. *Frontiers in Ecology and the Environment*, 6(9), 476–484. <https://doi.org/10.1890/060152>
- Romero, A., & Anderson, T. D. (2016). High levels of resistance in the Common Bed Bug, *Cimex lectularius* (Hemiptera: Cimicidae), to neonicotinoid insecticides. *Journal of Medical Entomology*, 53(3), 727–731. <https://doi.org/10.1093/jme/tjv253>
- Russo, D., & Ancillotto, L. (2015). Sensitivity of bats to urbanization: A review. *Mammalian Biology*, 80(3), 205–212. <https://doi.org/10.1016/j.mambio.2014.10.003>
- Santini, L., González-Suárez, M., Russo, D., Gonzalez-Voyer, A., von Hardenberg, A., & Ancillotto, L. (2019). One strategy does not fit all: Determinants of urban adaptation in mammals. *Ecology Letters*, 22(2), 365–376. <https://doi.org/10.1111/ele.13199>
- Santos, S. M., Mira, A., Salgueiro, P. A., Costa, P., Medinas, D., & Beja, P. (2016). Avian trait-mediated vulnerability to road traffic collisions. *Biological Conservation*, 200, 122–130. <https://doi.org/10.1016/j.biocon.2016.06.004>
- Saraswat, R., Sinha, A., & Radhakrishna, S. (2015). A god becomes a pest? Human-rhesus macaque interactions in Himachal Pradesh, northern India. *European Journal of Wildlife Research*, 61(3), 435–443. <https://doi.org/10.1007/s10344-015-0913-9>
- Schell, C. J. (2018). Urban evolutionary ecology and the potential benefits of implementing genomics. *Journal of Heredity*, 109(2), 138–151. <https://doi.org/10.1093/jhered/esy001>
- Schell, C. J., Dyson, K., Fuentes, T. L., Des Roches, S., Harris, N. C., Miller, D. S., Woelfle-Erskine, C. A., & Lambert, M. R. (2020). The ecological and evolutionary consequences of systemic racism in urban environments. *Science*, eaay4497. <https://doi.org/10.1126/science.aay4497>
- Schell, C. J., Young, J. K., Lonsdorf, E. V., Santymire, R. M., & Mateo, J. M. (2018). Parental habituation to human disturbance over time reduces fear of humans in coyote offspring. *Ecology and Evolution*, 8(24), 12965–12980. <https://doi.org/10.1002/ece3.4741>
- Schmidt, C., Domaratzki, M., Kinnunen, R. P., Bowman, J., & Garroway, C. J. (2020). Continent-wide effects of urbanization on bird and mammal genetic diversity. *Proceedings of the Royal Society B: Biological Sciences*, 287(1920), 20192497. <https://doi.org/10.1098/rspb.2019.2497>
- Schmidt, R. H., & Timm, R. M. (2007). Bad dogs: Why do coyotes and other canids become unruly? *Proceedings of the 12th Wildlife Damage Management Conference*, 287–302.

- Schuller, S., Francey, T., Hartmann, K., Hugonnard, M., Kohn, B., Nally, J. E., & Sykes, J. (2015). European consensus statement on leptospirosis in dogs and cats. *Journal of Small Animal Practice*, 56(3), 159–179. <https://doi.org/10.1111/jsap.12328>
- Schulte-Hostedde, A. I., Mazal, Z., Jardine, C. M., & Gagnon, J. (2018). Enhanced access to anthropogenic food waste is related to hyperglycemia in raccoons (*Procyon lotor*). *Conservation Physiology*, 6(1), 1–6. <https://doi.org/10.1093/conphys/coy026>
- Schwarz, K., Fragkias, M., Boone, C. G., Zhou, W., McHale, M., Grove, J. M., O'Neil-Dunne, J., McFadden, J. P., Buckley, G. L., Childers, D., Ogden, L., Pincetl, S., Pataki, D., Whitmer, A., & Cadenasso, M. L. (2015). Trees grow on money: Urban tree canopy cover and environmental justice. *PLoS ONE*, 10(4), e0122051. <https://doi.org/10.1371/journal.pone.0122051>
- Serieys, L. E. K., Armenta, T. C., Moriarty, J. G., Boydston, E. E., Lyren, L. M., Poppenga, R. H., Crooks, K. R., Wayne, R. K., & Riley, S. P. D. (2015). Anticoagulant rodenticides in urban bobcats: Exposure, risk factors and potential effects based on a 16-year study. *Ecotoxicology*, 24(4), 844–862. <https://doi.org/10.1007/s10646-015-1429-5>
- 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. *Proceedings of the Royal Society B: Biological Sciences*, 285(1871), 20172533. <https://doi.org/10.1098/rspb.2017.2533>
- Serieys, L. E. K., Lea, A., Pollinger, J. P., Riley, S. P. D., & Wayne, R. K. (2015). Disease and freeways drive genetic change in urban bobcat populations. *Evolutionary Applications*, 8(1), 75–92. <https://doi.org/10.1111/eva.12226>
- Sharma, G., Vijay, P., Devilal, D., Ram, C., & Rajpurohit, L. S. (2010). Study of the impact of tourists and local visitors/feeders on free-ranging Hanuman langur population in and around Jodhpur, Rajasthan (India). *Journal of Applied and Natural Science*, 2(2), 225–229. <https://doi.org/10.31018/jans.v2i2.124>
- Shochat, E., Lerman, S. B., Anderies, J. M., Warren, P. S., Faeth, S. H., & Nilon, C. H. (2010). Invasion, competition, and biodiversity loss in urban ecosystems. *BioScience*, 60(3), 199–208. <https://doi.org/10.1525/bio.2010.60.3.6>
- Smith, J. A., Suraci, J. P., Clinchy, M., Crawford, A., Roberts, D., Zanette, L. Y., & Wilmers, C. C. (2017). Fear of the human 'super predator' reduces feeding time in large carnivores. *Proceedings of the Royal Society B: Biological Sciences*, 284(1857), 20170433. <https://doi.org/10.1098/rspb.2017.0433>
- Smith, J. A., Thomas, A. C., Levi, T., Wang, Y., & Wilmers, C. C. (2018). Human activity reduces niche partitioning among three widespread mesocarnivores. *Oikos*, 127(6), 890–901. <https://doi.org/10.1111/oik.04592>
- Smith, J. A., Wang, Y., & Wilmers, C. C. (2016). Spatial characteristics of residential development shift large carnivore prey habits. *The Journal of Wildlife Management*, 80(6), 1040–1048. <https://doi.org/10.1002/jwmg.21098>
- Snell-Rood, E. C., & Wick, N. (2013). Anthropogenic environments exert variable selection on cranial capacity in mammals. *Proceedings of the Royal Society B: Biological Sciences*, 280(1769), 20131384. <https://doi.org/10.1098/rspb.2013.1384>
- Soga, M., & Gaston, K. J. (2020). The ecology of human–nature interactions. *Proceedings of the Royal Society B: Biological Sciences*, 287(1918), 20191882. <https://doi.org/10.1098/rspb.2019.1882>
- Sol, D., Lapedra, O., & González-Lagos, C. (2013). Behavioural adjustments for a life in the city. *Animal Behaviour*, 85(5), 1101–1112. <https://doi.org/10.1016/j.anbehav.2013.01.023>
- Sorensen, A., van Beest, F. M., & Brook, R. K. (2014). Impacts of wildlife baiting and supplemental feeding on infectious disease transmission risk: A synthesis of knowledge. *Preventive Veterinary Medicine*, 113(4), 356–363. <https://doi.org/10.1016/j.prevetmed.2013.11.010>
- Soulsbury, C. D., & White, P. C. L. (2015). Human-wildlife interactions in urban areas: A review of conflicts, benefits and opportunities. *Wildlife Research*, 42(7), 541–553. <https://doi.org/10.1071/WR14229>
- St. Clair, C. C., Backs, J., Friesen, A., Gangadharan, A., Gilhooly, P., Murray, M., & Pollock, S. (2019). Animal learning may contribute to both problems and solutions for wildlife-train collisions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 374(1781), 20180050. <https://doi.org/10.1098/rstb.2018.0050>
- Stillfried, M., Fickel, J., Börner, K., Wittstatt, U., Heddergott, M., Ortman, S., Kramer-Schadt, S., & Frantz, A. C. (2017). Do cities represent sources, sinks or isolated islands for urban wild boar population structure? *Journal of Applied Ecology*, 54(1), 272–281. <https://doi.org/10.1111/1365-2664.12756>
- Stillfried, M., Gras, P., Börner, K., Göritz, F., Painer, J., Röllig, K., Wenzler, M., Hofer, H., Ortman, S., & Kramer-Schadt, S. (2017). Secrets of success in a landscape of fear: Urban wild boar adjust risk perception and tolerate disturbance. *Frontiers in Ecology and Evolution*, 5(DEC), 1–12. <https://doi.org/10.3389/fevo.2017.00157>
- Stillfried, M., Gras, P., Busch, M., Börner, K., Kramer-Schadt, S., & Ortman, S. (2017). Wild inside: Urban wild boar select natural, not anthropogenic food resources. *PLoS ONE*, 12(4), 1–20. <https://doi.org/10.1371/journal.pone.0175127>
- Strandin, T., Babayan, S. A., & Forbes, K. M. (2018). Reviewing the effects of food provisioning on wildlife immunity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373(1745), 20170088. <https://doi.org/10.1098/rstb.2017.0088>
- Strubbe, D., Salleh Hudin, N., Teyssier, A., Vantieghe, P., Aerts, J., & Lens, L. (2020). Phenotypic signatures of urbanization are scale-dependent: A multi-trait study on a classic urban exploiter. *Landscape and Urban Planning*, 197(January), 103767. <https://doi.org/10.1016/j.landurbplan.2020.103767>
- Sullivan, A. P., Bird, D. W., & Perry, G. H. (2017). Human behaviour as a long-term ecological driver of non-human evolution. *Nature Ecology and Evolution*, 1(3), 1–11. <https://doi.org/10.1038/s41559-016-0065>
- Suraci, J. P., Clinchy, M., Zanette, L. Y., & Wilmers, C. C. (2019). Fear of humans as apex predators has landscape-scale impacts from mountain lions to mice. *Ecology Letters*, 22(10), 1578–1586. <https://doi.org/10.1111/ele.13344>
- Swan, G. J. F., Redpath, S. M., Bearhop, S., & McDonald, R. A. (2017). Ecology of problem individuals and the efficacy of selective wildlife management. *Trends in Ecology and Evolution*, 32(7), 518–530. <https://doi.org/10.1016/j.tree.2017.03.011>
- Teyssier, A., Rouffaer, L. O., Salleh Hudin, N., Strubbe, D., Matthysen, E., Lens, L., & White, J. (2018). Inside the guts of the city: Urban-induced alterations of the gut microbiota in a wild passerine. *Science of the Total Environment*, 612, 1276–1286. <https://doi.org/10.1016/j.scitotenv.2017.09.035>
- Theng, M., & Sivasothi, N. (2016). The smooth-coated otter *Lutrogale perspicillata* (Mammalia: Mustelidae) in Singapore: Establishment and expansion in natural and semi-urban environments. *IUCN Otter Specialist Group Bulletin*, 33(1), 37–49.
- Theobald, D. M., Spies, T., Kline, J., Maxwell, B., Hobbs, N. T., & Dale, V. H. (2005). Ecological support for rural land-use planning. *Ecological Applications*, 15(6), 1906–1914. <https://doi.org/10.1890/03-5331>
- Thurber, J. M., & Peterson, R. O. (1991). Changes in body size associated with range expansion in the coyote (*Canis latrans*). *Journal of Mammalogy*, 72(4), 750–755. <https://doi.org/10.2307/1381838>
- Treves, A., Wallace, R. B., Naughton-Treves, L., & Morales, A. (2006). Co-managing human–wildlife conflicts: A review. *Human Dimensions of Wildlife*, 11(6), 383–396. <https://doi.org/10.1080/10871200600984265>
- Trumbo, D. R., Salerno, P. E., Logan, K. A., Alldredge, M. W., Gagne, R. B., Kozakiewicz, C. P., Kraberger, S., Fountain-Jones, N. M., Craft, M. E., Carver, S., Ernest, H. B., Crooks, K. R., VandeWoude, S., & Funk, W. C. (2019). Urbanization impacts apex predator gene flow but not

- genetic diversity across an urban-rural divide. *Molecular Ecology*, 28(22), 4926–4940. <https://doi.org/10.1111/mec.15261>
- Tuomainen, U., & Candolin, U. (2011). Behavioural responses to human-induced environmental change. *Biological Reviews*, 86(3), 640–657. <https://doi.org/10.1111/j.1469-185X.2010.00164.x>
- Turner, K. G., Schell, C. J., & Moyers, B. T. (2018). Genomics of adaptation to human contexts. *Journal of Heredity*, 109(2), 101–102. <https://doi.org/10.1093/jhered/esx113>
- Uchida, K., Suzuki, K., Shimamoto, T., Yanagawa, H., & Koizumi, I. (2016). Seasonal variation of flight initiation distance in Eurasian red squirrels in urban versus rural habitat. *Journal of Zoology*, 298(3), 225–231. <https://doi.org/10.1111/jzo.12306>
- Urban, M. C., & De Meester, L. (2009). Community monopolization: Local adaptation enhances priority effects in an evolving metacommunity. *Proceedings of the Royal Society B: Biological Sciences*, 276(1676), 4129–4138. <https://doi.org/10.1098/rspb.2009.1382>
- VerCauteren, K. C., Dolbeer, R. A., & Gese, E. M. (2010). *Identification and management of wildlife damage*.
- Waite, T. A., Chhangani, A. K., Campbell, L. G., Rajpurohit, L. S., & Mohnot, S. M. (2007). Sanctuary in the city: Urban monkeys buffered against catastrophic die-off during ENSO-related drought. *EcoHealth*, 4(3), 278–286. <https://doi.org/10.1007/s10393-007-0112-6>
- Wang, X., Brown, C. M., Smole, S., Werner, B. G., Han, L., Farris, M., & DeMaria, A. (2010). Aggression and Rabid Coyotes, Massachusetts, USA. *Emerging Infectious Diseases*, 16(2), 357–359. <https://doi.org/10.3201/eid1602.090731>
- Warren, P. S., Harlan, S. L., Boone, C., Lerman, S. B., Shochat, E., & Kinzig, A. P. (2013). Urban ecology and human social organisation. *Urban Ecology*. <https://doi.org/10.1017/cbo9780511778483.009>
- Watkins, S. L., & Gerrish, E. (2018). The relationship between urban forests and race: A meta-analysis. *Journal of Environmental Management*, 209, 152–168. <https://doi.org/10.1016/j.jenvman.2017.12.021>
- Weeks, A. R., Sgro, C. M., Young, A. G., Frankham, R., Mitchell, N. J., Miller, K. A., Byrne, M., Coates, D. J., Eldridge, M. D. B., Sunnucks, P., Breed, M. F., James, E. A., & Hoffmann, A. A. (2011). Assessing the benefits and risks of translocations in changing environments: A genetic perspective. *Evolutionary Applications*, 4(6), 709–725. <https://doi.org/10.1111/j.1752-4571.2011.00192.x>
- White, L. A., & Gehrt, S. D. (2009). Coyote attacks on humans in the United States and Canada. *Human Dimensions of Wildlife*, 14(6), 419–432. <https://doi.org/10.1080/10871200903055326>
- Wilcove, D. S., & Wikelski, M. (2008). Going, going, gone: Is animal migration disappearing. *PLoS Biology*, 6(7), e188. <https://doi.org/10.1371/journal.pbio.0060188>
- Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: The challenge of making cities “just green enough”. *Landscape and Urban Planning*, 125, 234–244. <https://doi.org/10.1016/j.landurbplan.2014.01.017>
- Wong, B. B. M., & Candolin, U. (2015). Behavioral responses to changing environments. *Behavioral Ecology*, 26(3), 665–673. <https://doi.org/10.1093/beheco/aru183>
- Woodroffe, R., Hedges, S., & Durant, S. M. (2014). To fence or not to fence. *Science*, 344(6179), 46–48. <https://doi.org/10.1126/science.1246251>
- Wynn-Grant, R., Ginsberg, J. R., Lackey, C. W., Sterling, E. J., & Beckmann, J. P. (2018). Risky business: Modeling mortality risk near the urban-wildland interface for a large carnivore. *Global Ecology and Conservation*, 16, e00443. <https://doi.org/10.1016/j.gecco.2018.e00443>
- Young, J. K., Draper, J., & Breck, S. (2019). Mind the gap: Experimental tests to improve efficacy of fladry for nonlethal management of coyotes. *Wildlife Society Bulletin*, 43(2), 265–271. <https://doi.org/10.1002/wsb.970>
- Young, J. K., Hammill, E., & Breck, S. W. (2019). Interactions with humans shape coyote responses to hazing. *Scientific Reports*, 9(1), 20046. <https://doi.org/10.1038/s41598-019-56524-6>
- Yovovich, V., Allen, M. L., Macaulay, L. T., & Wilmers, C. C. (2020). Using spatial characteristics of apex carnivore communication and reproductive behaviors to predict responses to future human development. *Biodiversity and Conservation*, 29(8), 2589–2603. <https://doi.org/10.1007/s10531-020-01990-y>
- Zipperer, W. C., Morse, W. F., & Gaither, C. J. (2011). Linking social and ecological systems. In J. Niemela (Ed.), *Urban ecology* (pp. 298–308). <https://doi.org/10.1093/acprof:oso/9780199563562.003.0035>

How to cite this article: Schell CJ, Stanton LA, Young JK, et al. The evolutionary consequences of human-wildlife conflict in cities. *Evol. Appl.* 2021;14:178–197. <https://doi.org/10.1111/eva.13131>