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One Health for All: Advancing Human and Ecosystem Health in Cities by Integrating an Environmental Justice Lens

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Abstract

We are facing interwoven global threats to public health and ecosystem function that reveal the intrinsic connections between human and wildlife health. These challenges are especially pressing in cities, where social-ecological interactions are pronounced. The One Health concept provides an organizing framework that promotes the health and well-being of urban communities and ecosystems. However, for One Health to be successful, it must incorporate societal inequities in environmental disamenities, exposures, and policy. Such inequities affect all One Health interfaces, including the distribution of ecosystem services and disservices, the nature and frequency of human–wildlife interactions, and legacies of land use. Here, we review the current literature on One Health perspectives, pinpoint areas in which to incorporate an environmental justice lens, and close with recommendations for future work. Intensifying social, political, and environmental unrest underscores a dire need for One Health solutions informed by environmental justice principles to help build healthier, more resilient cities.

1. INTRODUCTION

We live on an urbanizing planet, which creates opportunities and challenges for the well-being of people and nature. Urban land is the fastest growing land use type on earth (Seto et al. 2012) and over two-thirds of the world's population is projected to live in urban areas by 2050 (UN Dep. Econ. Soc. Aff. 2018). Cities are complex social-ecological systems characterized by high human densities and infrastructure to support human communities (e.g., roads, buildings, vehicles, commercial activity) (Alberti et al. 2008, Grimm et al. 2008, Pickett et al. 2016). Impervious surfaces and industrial activity in cities can have elevated levels of chemical pollutants, noise, light, and heat relative to the surrounding landscape (Ouyang et al. 2018). Further, the unique habitat types, disturbance regimes, and resources available in cities typically lead to wildlife communities dominated by highly abundant, nonnative generalists (Ducatez et al. 2018, Shochat et al. 2010). The combination of these features in urban systems can create complex challenges for human and ecosystem health such as heat stress (Heaviside et al. 2017, Jesdale et al. 2013, Mitchell & Chakraborty 2015), increased exposure to air pollutants (Morello-Frosch & Jesdale 2006, Tessum et al. 2021), and novel host communities for pathogens (Murray et al. 2019). Mitigating such health challenges is imperative to protecting human, wildlife, and ecosystem health as urbanization accelerates globally.

Despite the broad significance of human, animal, and environmental health in cities, most work on urban health is siloed within fields such as wildlife disease ecology, public health, and ecotoxicology (Combs et al. 2022). Such siloed discourses limit our efforts to effectively address emerging public health threats (Zinsstag et al. 2012). Proposed solutions with narrowly focused frameworks may underestimate the complexity among the biophysical components of cities, limiting the overall reach of health solutions. Hence, modern environmental challenges and health concerns require a holistic, systems-level approach that acknowledges the interdependence of human, animal, and environmental health, a paradigm known as One Health (Cunningham et al. 2017, Daszak et al. 2000, Lebov et al. 2017). Such an approach must also acknowledge that the frequency, risks, and benefits of human–wildlife–environment interactions vary for different urban communities based on race and class.

Environmental quality is often inequitably distributed, graded along axes of race, ethnicity, wealth, and power (Cushing et al. 2015). Societal inequities in access to healthy environments, compounded with inequitable access to medical services and economic opportunities, place a substantial burden on the health of marginalized communities (Nardone et al. 2020b). For instance, more affluent neighborhoods often contain greater vegetation cover, as well as more diverse and abundant plant and animal communities (Hope et al. 2003, Leong et al. 2018). Ecosystem services provided by plants—most notably, environmental cooling, air purification, recreation, and mental health benefits—are more accessible to wealthier neighborhoods in cities (Nesbitt et al. 2019, Nowak et al. 2022). Conversely, past and present disinvestment in low-income neighborhoods and communities of color produces local environmental harms that threaten human and animal health alike (Morello-Frosch & Jesdale 2006). This environmental racism is further perpetuated in

Pathogen: an infectious agent capable of causing disease (bacteria, prions, viruses, ectoparasites, and endoparasites)

One Health: the transdisciplinary approach working across scales with the goal of achieving optimal health outcomes by recognizing the intersections among people, animals, plants, and their shared environment

Ecosystem services: any positive benefits conferred by ecosystems or organisms to humans; such benefits can be direct or indirect and include provisioning services, regulating services, cultural services, and supporting services

Environmental racism: any policy, practice, or directive that differentially affects or disadvantages (whether intended or unintended) individuals, groups, or communities based on race inequitable urban planning and design practices (e.g., residential segregation, zoning), which frequently underpin differential exposures to heat stress (Jenerette et al. 2011, Jesdale et al. 2013), reduced air quality (Tessum et al. 2021), and chemical pollutants (Masri et al. 2021). Thus, any One Health framework that does not incorporate or acknowledge environmental racism and social inequality is necessarily incomplete (Lysaght et al. 2017). Building collaborative and disciplinary bridges between the One Health and environmental justice (EJ) discourses is an especially urgent task, as income inequality is widening globally across urban development classes (Piketty & Saez 2014). Doing so can subsequently inform interventions that prioritize and support more comprehensive solutions to the emerging health threats we currently face (Cushing et al. 2015, Jennings et al. 2017, Rüegg et al. 2017).

In this review, we provide broad parallel overviews of the One Health and EJ frameworks to spotlight the synergies that exist among such discourses. In doing so, we emphasize how a One Health approach that explicitly embeds core EJ principles is more robust in addressing the confluence of health and nature disparities in urban environments. We then pinpoint how an EJ-informed One Health approach can be applied to four thematic areas: medically important arthropod communities, urban heat, air pollution, and water quality. We close by describing opportunities for fostering transdisciplinary team building, propose policy changes for the long-term benefit of all communities, and discuss future pathways to advance justice in One Health research.

Environmental justice (EJ): the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies

Zoonotic disease: an infectious disease that is transmitted between species from animals to humans or vice versa

2. INTEGRATING ENVIRONMENTAL JUSTICE INTO ONE HEALTH

Though One Health strives to be a transdisciplinary field, principles from EJ are rarely mentioned as a core consideration when planning and executing One Health projects (**Table 1**). The origins of One Health within the knowledge base of Western science partly stem from public health and the biomedical sciences, both of which have historically struggled with bias and racism (Clark & Hurd 2020, Devakumar et al. 2020). The inequities born from structural and systemic racism have hindered scientific advancements, as well as contributed to racial and ethnic health disparities (Clark & Hurd 2020). Hence, to fully integrate EJ with One Health, One Health must explicitly address the role of societal inequities in affecting human, animal, and environmental health. Doing so better facilitates diagnosing the numerous linkages among components of the One Health framework (**Figure 1**).

2.1. One Health: Origins, Challenges, and Cities

One Health is a framework rooted in highly interdisciplinary approaches to health. The framework explores the interconnectedness and interdependence of human, animal, and environmental health to prevent, manage, and mitigate disease (Cunningham et al. 2017, Daszak et al. 2000, Zinsstag et al. 2011). This nexus has been recognized for centuries (Jack et al. 2020); however, formal recognition in Western science of the need to bridge human and animal health disciplines did not occur until the mid to late twentieth century (Atlas 2012, Mi et al. 2016). The term One Health received global recognition in the mid-2000s due, in part, to the establishment of the One Health office within the US Centers for Disease Control and Prevention (Atlas 2012, Zinsstag et al. 2012). Despite the interdisciplinary scope of One Health, zoonotic diseases (i.e., diseases transmissible between humans and animals) are often the focus of One Health initiatives (Cunningham et al. 2017). However, One Health frameworks extend to a breadth of issues, including food safety and security (Garcia et al. 2020), antimicrobial resistance (Rousham et al. 2018, Walsh 2018, White & Hughes 2019), microbiome diversity (Trinh et al. 2018), and climate change (Patz & Hahn 2012, Zinsstag et al. 2018). Importantly, there is growing recognition that One Health includes

Table 1 Guiding questions for environmentally just and socially inclusive One Health research in cities

Stage	Questions
Building the research team	Who are all the actors in my system; i.e., who are the relevant human communities, wildlife species, nature spaces, vectors, pathogens, and environmental processes?
	Who is studying the relevant actors in my system? Are there local social scientists, wildlife ecologists, vector ecologists, microbiologists, virologists, hydrologists, botanists, community members and organizers, environmental scientists, political scientists, public health researchers, etc. with whom I could collaborate?
	Who is missing from the table? Who are leaders from underrepresented groups to whom I could reach out?
Designing the project	How do the actors in my system interact? Where are the natural and artificial (e.g., informational) feedbacks between human, animal, and environmental health?
	Where are the interactions between the actors most relevant? Is it possible to study the relevant processes in multiple locations? Am I studying representative human communities in terms of socioeconomic status, race, locations, etc.?
	Could some human or nonhuman communities be more at risk of health effects based on socioeconomics or other systemic processes?
	What questions are important to the human communities? How can I engage communities in the research design?
Collecting the data	Are there opportunities for participatory science and the inclusion of community scientists, especially for community members affected by environmental injustice?
	Am I creating opportunities to financially compensate participating community members?
	What are the questions of interest from the community?
	Am I being respectful and demonstrating cultural competence when working in communities outside of my own?
	Am I being cognizant of historical injustices within my research question? What communities do I need to collaborate with to ensure proper sensitivity is taken?
	Are there historical contexts that might inform sampling designs? Might certain communities be reluctant to participate in health research because of past harms?
Disseminating results	How can I reach audiences outside of academia and researchers? Can I make meetings or presentations more accessible by considering community events and times of day or by providing childcare?
	Am I disseminating results with collaborating community members and organizations that contributed to the research success?
	Am I using land acknowledgments and crediting all participating parties in presentations and publications?
	How can I make sure presentations and documents are as accessible as possible? Can infographics and closed captioning be used?

the larger definition of health as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (Zinsstag et al. 2011).

Whereas recent advances into the conceptual and theoretical underpinnings of the One Health framework have exploded, how to implement such frameworks remains the greatest challenge (Atlas 2012). This is largely because the One Health concept has manifold definitions with varying degrees of specificity, making it difficult to demarcate specific boundaries or suggest tailored applications. For instance, although One Health is frequently defined as a holistic framework that endeavors to enhance collaborative bridges, such an integration may fail due to mismatches in disciplinary scale and implementation (Cumming et al. 2006). Physicians and wildlife disease ecologists often work at different scales (i.e., individuals versus ecosystems), and variance in management responses to emerging issues may constrain efforts to mitigate disease transmission (de Garine-Wichatitsky et al. 2020). The recent global response to the coronavirus disease 2019 (COVID-19) pandemic is a quintessential example of the successes and failures of

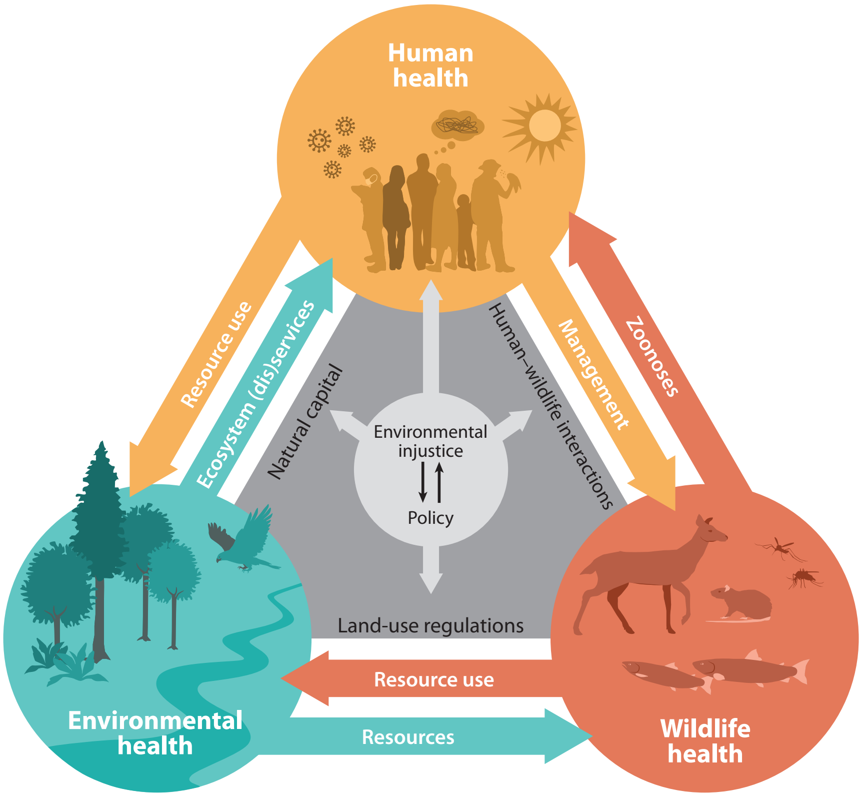


Figure 1

Conceptual framework showing the reciprocal relationships (*arrows*) between human health (*yellow*, e.g., zoonotic viruses, heat stress, and mental health), wildlife health (*orange*, e.g., zoonotic disease vectors and hosts, toxicants in wildlife tissues), and environmental health (*green*, e.g., biodiversity and the quality of air, water, and soil). These reciprocal relationships are mediated by policies that govern human exposure to ecosystem services and disservices (natural capital), potential human exposure to zoonotic pathogens (human–wildlife interactions), and ecosystem function (land-use regulations). Importantly, there are also feedbacks whereby policies relevant to One Health processes create, and are created by, environmental racism and injustices. Text labels on arrows represent examples and are not comprehensive. Illustration created by Simone Des Roches.

this One Health approach. Global coordination led to the discovery of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) virus, yet its rapid transmission facilitated by global travel and a lagging societal response led to the global spread of COVID-19 (de Garine-Wichatitsky et al. 2020). Coordination between researchers and public health officials spurred the most rapid development of vaccines in human history, yet the incomplete, lethargic, and inequitable disbursement of those vaccines may have facilitated the emergence of variants (Ahmed et al. 2020, McClymont et al. 2022). Hence, there is an urgent need to better operationalize and streamline the One Health framework to guard against future emerging infectious diseases.

Arguably, application of the One Health paradigm may be well suited for urban ecosystems. Despite the explicit design of urban areas to principally accommodate humans, land cover transformations and intensified land use can constrain ecosystem services and jeopardize human health and well-being (Pataki 2015). High rates of habitat fragmentation and landscape conversion reduce the environmental cooling and air purification services provided by plants (Jenerette et al.

Green space: an area of grasses, shrubs, and trees in an otherwise urban environment that is set apart for recreational or aesthetic reasons (e.g., community gardens, parks, green roofs)

2011). In addition, industrial activities increase air and water pollutants with myriad downstream consequences for organismal health (Cushing et al. 2015, Sepp et al. 2019). Further, noise and light pollution in cities can detrimentally impact human mental and physical health (Chepesiuk 2009, Falcón et al. 2020), with a growing body of work highlighting how such factors present challenges to wildlife health (Murray et al. 2019). The remnant urban green spaces that do survive concentrate the remaining organisms, while certain species are extirpated or go locally extinct (Sol et al. 2014). This process leads to the establishment of generalist species, often nonnative, that are well suited to living in areas with high levels of human disturbance (i.e., urban adapters), with a subset of those generalists able to optimize use of human-associated resources (i.e., urban exploiters, like human commensals) (Ducatez et al. 2018, Johnson & Munshi-South 2017). Coincidentally, many of these urban adapters and exploiters are reservoirs for zoonotic diseases (Combs et al. 2022), and the high densities of humans and wildlife in cities create novel opportunities for interspecific contact and pathogen transmission. Urban ecosystems therefore represent a unique test environment in which to advance and optimize the One Health framework. Still, (in)accessibility, location, and societal disparities are often not integrated within the application of One Health frameworks, which is problematic because socioeconomic status and policy are the very roots of health risks. EJ principles provide the necessary lens to address those roots.

2.2. Environmental Racism and Justice

Exploring the roots and history of EJ praxis highlights the synergies that exist between EJ scholarship and the emergence of the One Health framework. EJ is a rich and pluralistic organizing framework emphasizing that access to a healthy environment is a fundamental civil right (Schlosberg & Collins 2014). At the time of its inception, EJ substantially challenged the long-held belief that the environment or nature is separate from built and urban environments (Mohai et al. 2009). Rather, the environment is an all-encompassing and interdependent system in which the health and functionality of all environmental components necessarily dictates the health and well-being of all peoples. The significance of environmental quality and sustainability to public health and well-being has consistently been articulated in Black and Indigenous communities in the United States since the early to mid-1900s, but unifying consensus notes that the contemporary EJ framework emerged from the 1982 protests in Warren County, North Carolina (Anguelovski 2016, Mohai et al. 2009). Residents of Warren County, who were predominantly poor and Black, organized to resist the disposal of toxic soils and waste (Schlosberg & Collins 2014). Momentum from the protests sparked the commission of several landmark studies, which documented the palpable links between poverty, race, and environmental ills nationally. This culminated in the 1991 First National People of Color Environmental Leadership Summit, which brought together civil rights organizers and environmental groups, communities of color, and Indigenous communities to address concerns around the distributive equity of resources and environmental governance (Mohai et al. 2009). Importantly, they emphasized how societal inequities borne from oppressive policies, economic injustice, and industrialization disproportionately impacted the local environmental health of the most disenfranchised in society (Mascarenhas 2020), and they established the 17 foundational principles of EJ to reconcile and deconstruct those inequities. Further, the principles emphasized our ecological unity and interdependence with all components of the planet (Schlosberg & Collins 2014), a concept that has its roots in Indigenous thought and scholarship (Mascarenhas 2020).

Proceeding from the 1991 summit, a rich literature has repeatedly emphasized that issues of environmental racism are intrinsically social problems (Mascarenhas 2007). For example, the myriad links between environmental quality and residential segregation in the United States underscore how inequitable policy has had palpable discriminatory outcomes that are seen at present

(Nardone et al. 2021). In the 1930s the Home Owner's Loan Corporation (HOLC) established the wide-ranging policy of redlining that intentionally segregated urban neighborhoods by race, ethnicity, and income. In doing so, wealthier, White Americans had greater access to environmental amenities and resources relative to their non-White counterparts (Grove et al. 2018). In 1968, the work of civil rights leaders helped to abolish the federally sponsored program. However, the vestiges of these policies are still felt today, with contemporary policies and environmental governance in some instances exacerbating latent environmental inequities (Mohai et al. 2009). Tree canopy and vegetation cover remain relatively depauperate in previously redlined neighborhoods relative to others (Locke et al. 2021, Nardone et al. 2021, Nowak et al. 2022). Consequently, relative access to green spaces is severely limited for low-income residents and communities of color in cities (Wolch et al. 2014). The overall reduction in vegetation cover in previously redlined areas has a slew of cascading effects, including intensified urban heat islands (Jesdale et al. 2013) and air pollution (Lane et al. 2022).

Redlining: the United States' discriminatory housing practice instituted in the 1930s to 1960s to enforce racial segregation in cities using color-coded maps distinguishing highly desirable and risky neighborhoods based on racial demographics

Legacy effect: the influence of societal and land-use histories on the ecological and biological dynamics of organisms in human-dominated systems

Luxury effect: the hypothesis that a positive relationship exists between social and monetary affluence and biodiversity of organisms in urban ecosystems

Heightened exposure to environmental disamenities, linked to the legacy of redlining, still jeopardizes health outcomes for low-income residents and communities of color today (Cushing et al. 2015). Residents in historically redlined districts have a higher prevalence of cancer, asthma, and adverse mental health outcomes (Nardone et al. 2020a,b). In addition, preterm birth and mortality tend to be higher in redlined neighborhoods compared to others (Nardone et al. 2020c). Hence, the incomplete, lethargic, or piecemeal approaches of sociopolitical and medical systems to address inequitable resource allocation, paired with a lack of historical context or acknowledgment of existing problems, have perpetuated environmental harms for low-income residents and communities of color (Cushing et al. 2015). How societal legacy effects impact urban wildlife has recently gained attention (Schell et al. 2020), with initial investigations suggesting that genetic diversity is reduced in redlined neighborhoods (Schmidt & Garroway 2022).

3. DRIVERS CONNECTING ONE HEALTH AND ENVIRONMENTAL JUSTICE PRAXIS

Civil rights and EJ scholars have repeatedly emphasized the need to increase equitable access to a healthy environment for all peoples. The absence of environmental equity along economic and racial lines subsequently stratifies health outcomes. The mechanisms by which these health disparities accumulate often stem from environmental quality, with urban green space and biodiversity often at the center of discourses in both the One Health and EJ literatures (Nesbitt et al. 2019, Wolch et al. 2014). Recent studies have documented the benefits of urban nature (e.g., green spaces, biodiversity) for human physical (Hartig et al. 2014) and mental health (Bratman et al. 2019, Methorst et al. 2021, Wood et al. 2018). While parks, greenspaces, and green roofs are growing in popularity in many cities, the availability and accessibility of urban green infrastructure vary within and across cities (Wolch et al. 2014). Notably, in North America, wealthier neighborhoods that are predominantly White customarily have greater access to high-quality remnant forests and green spaces (Gerrish & Watkins 2018, Rigolon 2016, Watkins & Gerrish 2018).

Similarly, recent investigations provide palpable evidence to suggest that income inequality in cities predicts patterns of species richness and biodiversity (Chamberlain et al. 2019, Hope et al. 2003, Magle et al. 2021). This luxury effect, by which socioeconomic wealth positively predicts richness and biodiversity, often means that neighborhoods with increased economic mobility have greater access to urban biodiversity (Leong et al. 2018). Granted, the intersection of legacies of residential segregation (Schell et al. 2020), temperature and aridity gradients (Chamberlain et al. 2020), and heterogeneous patterns of urban development (Kuras et al. 2020) has the potential to dilute or negate the community-level impacts of the luxury effect. Reductions in green spaces

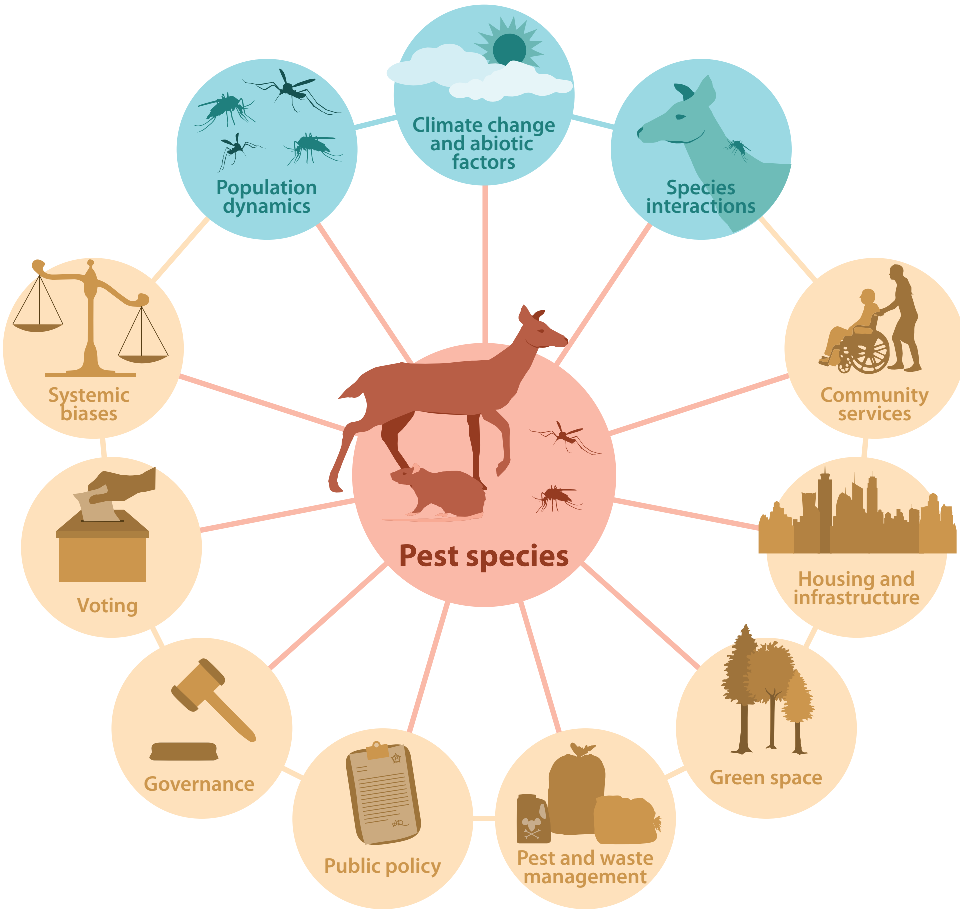


Figure 2

Conceptual diagram illustrating the complex interplay between societal factors, ecological drivers, and pest species in urban systems. To mitigate One Health issues, such as rat-associated health risks or vector-borne zoonoses, management strategies must consider how entities within the system interact. Ecological forces (*teal*) and social-ecological drivers (*yellow*) all intersect to influence the distribution, intensity, and efficacy of management strategies for pest species (*orange*). Omitting the influence of societal forces and environmental inequities on the system can hinder progress in addressing environmental and human health concerns. Illustration created by Simone Des Roches.

Brownfield sites: land previously used for industrial purposes with low levels of chemical contamination that have contemporary impacts on air and water quality, as well as human health

and biodiversity are compounded with increased industrial activity such as brownfield sites and highways, both of which can promote cancer and reduce life expectancy (Cushing et al. 2015, Nardone et al. 2020b). As a result, low-income neighborhoods and communities of color often shoulder both a pollution burden and an extinction of experience (i.e., reduced experiences with nature) that can simultaneously degrade overall health outcomes. In this way, unjust urban planning policies and natural capital can be considered a social determinant of health (Nesbitt et al. 2019). The confluence of these issues underscores the niche that the One Health framework could fill by incorporating patterns of environmental inequity to help pinpoint solutions for improving human, animal, and environmental health equitably (**Figure 2**). Doing so requires elucidation of the patterns of abiotic and biotic components that threaten health outcomes. Here, we focus on four contexts that exemplify infectious (i.e., zoonotic disease) and noninfectious (i.e., heat, air, and water quality) health risks in cities that are strongly influenced by economic and racial inequality.

3.1. Medically Important Arthropods

Vector: any organism that transmits a disease or parasite from one animal or plant to another

Vector-borne diseases remain one of the major contributors to the worldwide health burden of infectious diseases. With increasing proportions of humans living in cities, there is a need to understand the drivers and dynamics of vector-borne diseases in urban environments (LaDeau et al. 2015). A wide range of ectoparasites (e.g., fleas, lice, bed bugs) and other medically important arthropods (e.g., roaches, filth flies) are often associated with public health concerns in cities (Bradley & Altizer 2007). Here, we focus on arbovirus transmission by mosquitoes (e.g., West Nile virus, yellow fever) and the growing public health threat due to tick-borne diseases in urban and peri-urban green spaces (e.g., Lyme disease). While diversity of these arthropods is often lower in cities, the species that thrive in these conditions can attain high levels of abundance, possibly due to reduced competition and predation (Lines et al. 1994). Vector-borne disease occurrence in humans is the result of a complex interplay between reservoirs, arthropods, and the natural and built environment, all of which are affected by human behavior, decisions, and feedbacks. Arthropod-associated diseases in cities are situated at the convergence of land use, conservation, climate change, and human and animal health, meaning that they are inherently political. This is reflected through historic and contemporary choices made in urban planning and design, resulting in differences in the amounts of impervious surface and green space (and connectivity among green spaces) that are present in different parts of cities (Rigolon et al. 2018, Wolch et al. 2014), and have repercussions for heat island effects, reservoir host movement and abundance, and possibly host physiological condition.

The socioeconomic status of neighborhoods in large urban centers affects various aspects of vector-borne disease transmission potential. For instance, in some years, mosquitoes in low-income urban areas have shown a higher level of West Nile virus infection rates than mosquito populations in higher income neighborhoods in the same city (Rothman et al. 2021). The availability of containers, which can serve as habitat for the juvenile stages of mosquitoes, plays a large role in differences among parts of cities with different income levels (Katz et al. 2020). In Baltimore and Washington DC, pupae (which serve as an indication of productive mosquito habitat) of both *Culex pipiens* and *Aedes albopictus* were more likely to be found in containers in low-income areas (LaDeau et al. 2013). Little et al. (2017) subsequently showed that mosquito abundance at the block level is affected by a combination of abandonment (the prevalence of abandoned buildings in an area) and urban decay, vegetation, and precipitation. Specifically, *Ae. albopictus* occurs at higher densities in lower income areas, and while overall vegetation had a negative impact on mosquito abundance, this was not the case in areas with a high proportion of abandoned buildings, highlighting how behavioral, socioeconomic, biotic, and abiotic factors jointly affect mosquito abundance.

Along urban–rural gradients, two aspects of host-related factors can vary and affect the transmission intensity and risk of acquiring a zoonotic infection. These are (*a*) the composition, diversity, and abundance of vertebrate host communities and (*b*) human behavior (e.g., how people interact with nature in green spaces). Differences in host communities along such gradients, either due to the environmental suitability for different species or resulting from ways in which people's pets are housed (e.g., indoors or outdoors), also affect vector biting behavior and potential disease transmission. For instance, a greater presence of outdoor pets in an urban neighborhood was associated with lower mosquito feeding rates on humans compared to a suburb where pets tended to be kept indoors (Faraji et al. 2014). Similarly, in high-income neighborhoods, the proportion of blood meals from humans in *Ae. albopictus* was 50%, compared to only 6% in the low-income neighborhoods, where blood meals tended to come from other animals such as cats, dogs, deer, and rats (Goodman et al. 2018). Risk is also influenced by human preventative actions such as applying insect repellents (Bayles et al. 2013). The organization and management of green space within an urban matrix can affect vector and host species assemblages in several ways. As forest fragments become smaller, they can paradoxically sustain greater numbers of a major tick host, the white-footed mouse (*Peromyscus leucopus*), possibly due to a lack of predation or an abundance of forest-edge habitat. Because white-footed mice have a high level of competence for the Lyme disease bacterium, *Borrelia burgdorferi*, and can feed and infect large numbers of ticks, this can result in greater abundance and infection prevalence of ticks (Allan et al. 2003, Brownstein et al. 2005). The extent to which green spaces in urban settings are connected to other green spaces, allowing for movement of deer between them, has also been found to have an influence on tick-borne pathogens. For instance, nymphal *Ixodes scapularis* in New York were found to be more abundant in parks with vegetated buffer areas that had higher connectivity, and the latter also influenced the infection rate with *B. burgdorferi sensu stricto*, an agent of Lyme (VanAcker et al. 2019).

As we move to ameliorate the effects of climate change and other forms of environmental injustice on the most vulnerable populations in cities (e.g., through resilience or urban greening initiatives), it is critical that we account for the complexity of interactions that may dampen or amplify vector-borne disease transmission and recognize that both the risk of exposure and mitigating efforts, such as personal protective behaviors and municipal approaches to vector control, may be context- or situation-specific but may also be tied to differences in economics. For instance, a study in two Kenyan cities highlighted that household wealth and education levels were the main drivers affecting the likelihood of sleeping under a bed net and of using multiple mosquito-bite prevention methods (Macintyre et al. 2002). Such studies suggest that different messaging and control approaches may be required for areas of different income levels (Lines et al. 1994). The economic statuses of different parts of cities, together with political boundaries, also affect vector control capacity and funding at a local level (Moise et al. 2020, Tedesco et al. 2010), which could influence how well vector populations are suppressed in hyperlocal areas. This highlights the need to adopt or develop pest management techniques that integrate environmental and vector control approaches and are tailored to the socioeconomic and environmental variation unique to urban environments to address the diversity of needs and capacities of urban stakeholders (Lowe et al. 2019).

3.2. Urban Heat

Cities are generally hotter than the surrounding rural landscape, by as much as 10°C in some cases (Heaviside et al. 2017). This temperature difference is largely due to the extensive amount of impervious surface and building materials that are present in cities and trap and retain heat (Oke 1973). Known as the urban heat island, elevated temperatures in cities occur during the day but also persist overnight, thus providing little cooling relief to the landscape and its residents (Buyantuyev & Wu 2010, Heaviside et al. 2017). This results in more consecutive hot days, i.e. heat waves (Wang et al. 2019). Fortunately, the impacts of urban heat can be mitigated by urban greening practices, such as increasing tree canopies that provide shade and planting vegetation that absorbs heat (McDonald et al. 2020, Wang et al. 2019, 2021). However, as canopy cover and urban greening are often linked to socioeconomics (i.e., the luxury effect), the distribution of heat, and its associated health risks, are inequitably distributed (Huang & Cadenasso 2016, Mitchell & Chakraborty 2015). Lower-income neighborhoods often have less access to green spaces and parks, reduced canopy cover, and lower vegetation overall, thus limiting access to natural cooling strategies and increasing heat vulnerability for some urban residents (Jesdale et al. 2013, Mitchell & Chakraborty 2015).

High temperatures and heat waves have been linked to increased morbidity and mortality, particularly in cities, largely due to cardiovascular and respiratory illnesses caused by excessive heat (Heaviside et al. 2017). As the urban heat island is generally distributed unequally among socioeconomic groups, so too are the associated health risks. A catastrophic heat wave in Chicago, Illinois in July 1995 resulted in 692 deaths over a period of just 5 days. Victims were largely low-income elderly residents, who did not have access to air conditioning or were afraid to open their windows due to concerns about crime in their neighborhoods (Klinenberg 2015). Similarly, in 2003, an unprecedented two-week heat wave event occurred in Paris, resulting in a 140% excess mortality rate (Canouï-Poitrine et al. 2006) and largely affecting elderly residents with preexisting conditions who lived in neighborhoods that were not buffered by vegetation, among other factors (Vandentorren et al. 2006). More recently, British Columbia, Canada, experienced an unprecedented heat event in June–July 2021 wherein 569 people died from extreme heat, 79% of whom were over the age of 65 (BC Coroners Service 2021). Those who died were more likely to live in areas with less green space, be more socially isolated, and have lower income.

Climate change is predicted to cause numerous environmental changes including altered annual and seasonal precipitation, hydrological extremes, increased frequency of extreme weather events, changes to wildfire intensity and frequency, and increased temperatures and heat waves (Meehl & Tebaldi 2004, Staudinger et al. 2013). Many of these changes have already been observed. In a changing climate, the effects of the urban heat island will only be further exacerbated (Hobbie & Grimm 2020). Increased temperatures lead to increased electricity consumption through the demand for air conditioning (for those who can afford it), which in turn increases the amount of greenhouse gas emissions (McDonald et al. 2020), further intensifying climate change. These disparities will rise within and across cities, as resiliency among municipalities will vary due to geophysical factors and projected warming, as well as policies and resources (Bahadur & Tanner 2014). Furthermore, as the global population becomes more urbanized, the consequences of urban heat will be increasingly widespread (Mitchell & Chakraborty 2015).

Urban heat islands can also alter the transmission of infectious agents by arthropod vectors among animals and to people. One study found that areas within Athens-Clarke County, Georgia, with the greatest predicted potential intensity of vector-borne disease transmission had patches of trees surrounded by impervious surfaces and tended to be areas with higher human densities (Wimberly et al. 2020). Impervious surfaces have been found to have a strong positive influence on nighttime temperatures (Ziter et al. 2019), and this effect in concert with local humidity and shading from trees might lead to ideal conditions for certain mosquito species. Increasing temperatures due to climate change, paired with the existing heat islands in cities, will have complex consequences for urban biodiversity that will shape urban ecosystems. Some species may not be able to tolerate higher temperatures, either due to heat or the resulting desiccation of habitats (e.g., amphibians). Other, more heat-tolerant species may be able to expand their ranges and breeding periods, including poikilotherms such as insects (Vittoz et al. 2013) and nonnative species (Wilby & Perry 2006) or nuisance species that have high adaptive capacity. Novel or increased densities of some wildlife species could increase interactions with humans, especially in cities, causing conflict and elevated exposure to zoonotic disease. Longer frost-free periods may lead to phenological mismatches among species, such as predator and prey species and migratory birds that time migration or reproduction with available resources. Unfortunately, due to limited mobility or reduced habitat connectivity in urban areas, some species may be unable to shift their ranges to avoid the effects of urban heat, which will undoubtedly lead to species loss (Bellard et al. 2012, Staudinger et al. 2013).

3.3. Water Inequities

Water is a basic human right and a necessity for all life forms. However, in cities, access to clean water is a privilege that has historically been shown to be dependent on race and class (Schaider et al. 2019). With piped water being the most cost-effective way to deliver water into cities, water

Spillover: the transmission of a pathogen from an animal to a human that occurs when a reservoir population with high pathogen prevalence encounters novel host populations

Neglected tropical disease: diseases that have historically received little attention yet cause substantial illness and proliferate due to poor water quality and substandard access to health care and sanitation services, mostly in communities suffering extreme poverty

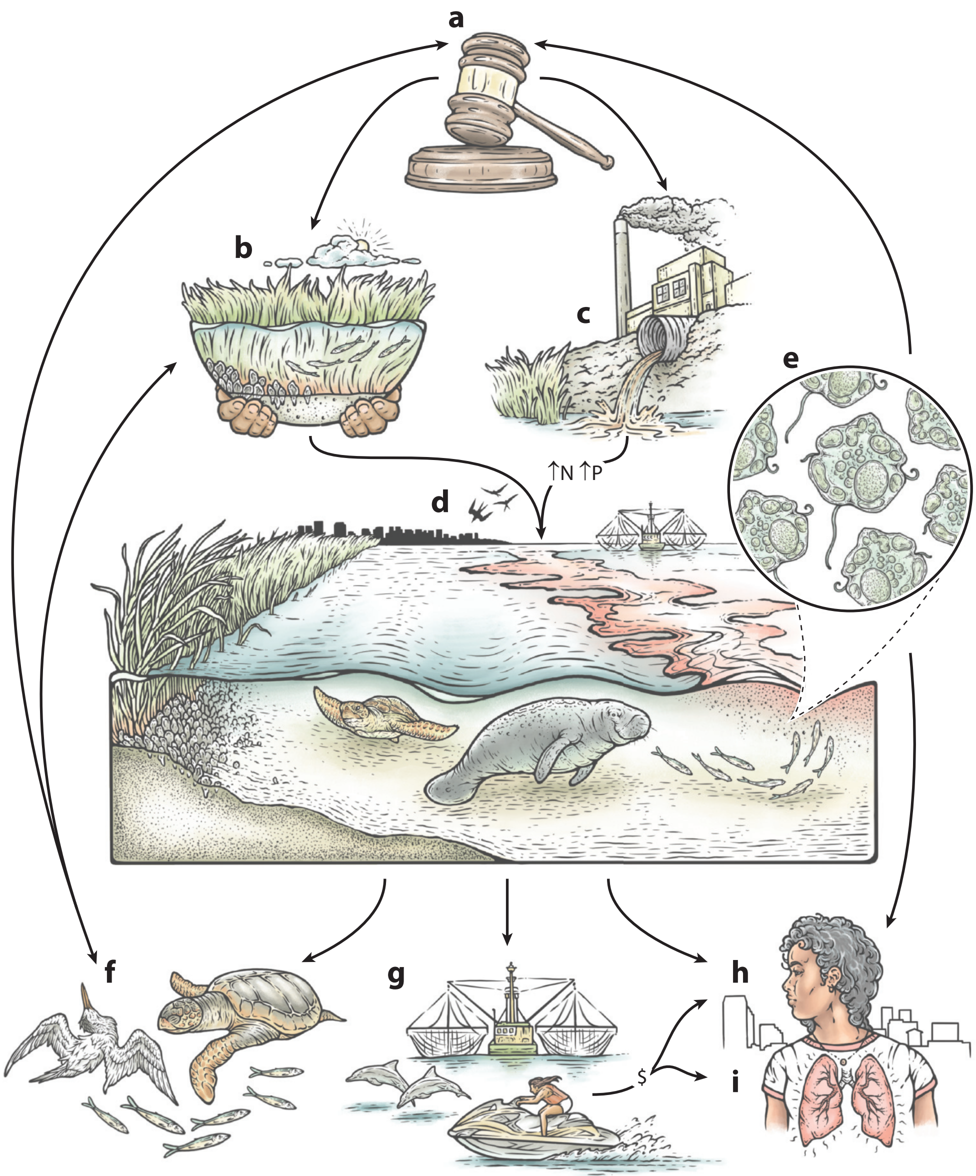
access should be accessible and affordable (Haller et al. 2007, Meehan et al. 2020). This should be true especially when more than half of the US national population lives in large metropolitan areas. Yet from 2013 to 2017, 73% of houses without piped water connections were in cities. Many unplumbed households in cities are more likely to be headed by people of color, earn lower incomes, and rent their residence (Meehan et al. 2020). The widening health and wealth gaps are only perpetuating more health disparities as the increase in unaffordable housing, medical expenses, and cost of living continues while income remains unchanged, leaving heads of (rented) houses cost burdened.

The transmission of highly contagious diseases, ingestion of metals and pesticides, and cases of dehydration can be disproportionately heightened due to the inability to wash hands and food or to have access to potable water. During a global pandemic, when the public is being advised to wash their hands for more than 20 seconds at a time, this seemingly easy task can be a difficult one to adhere to. In the United States, lack of access to clean water and the improper disposal of water waste has severely impacted the health of humans and the environment (Meehan et al. 2020). Currently, the United States and the Environmental Defense Fund are in the middle of a $50 billion bipartisan agreement to improve our nation's drinking water, wastewater, and stormwater infrastructure that includes replacing lead pipes in 9.2 million homes (Environ. Def. Fund 2022, EPA 2022). Lead service lines are the largest source of lead in water, and exposure can have severe impacts on human health, including fetal development, brain development, kidney function, and blood cell production (Jarvis & Fawell 2021). However, replacement costs are high and often the responsibility of the homeowner. Low-income residents and persons of color are more likely to be renters, at the relative mercy of landlords to remediate lead pipes (Schaider et al. 2019). The lack of policies to safeguard communities of color, environmental health, and water accessibility has deleterious effects that could be addressed using a refined One Health approach.

With expected increases in temperature, rain, and runoff, climate change threatens to displace over 150 million people due to rising sea levels by 2050 (Kulp & Strauss 2019). This impending rise in water levels will cause residents currently living in water-bordering cities to relocate and transform more green spaces for human housing developments. This is likely to bring humans closer to wildlife, creating more opportunities for human–wildlife conflict and the potential for zoonotic disease spillover and spillback events (Combs et al. 2022, König et al. 2020). As global temperatures increase and intensify urban heat island effects, temperate biomes may develop signatures of tropical environments that bolster the abundance of arthropod vectors such as mosquitoes (Caminade et al. 2019).

Unequal access to clean water can also exacerbate global inequities in disease transmission. Neglected tropical diseases (e.g., Zika, dengue, malaria) are diseases that are especially common in tropical areas where people do not have access to clean water or safe ways to dispose of human waste, most commonly occurring in Africa, Asia, and Latin America (Houweling et al. 2016). Notably, research on the control and prevention of these diseases is chronically underfunded in the regions that require them most (Franco-Paredes & Santos-Preciado 2011). Such societal inequalities further emphasize that neglected tropical diseases are diseases of neglected peoples (Ehrenberg & Ault 2005). Communities of color are disproportionately exposed to these diseases due to subpar or antagonistic policy measures that constrain their ability to access natural capital, research funding, or ecological agency. The emergence of new and deadly infectious diseases is inextricably linked to human exploitation of natural resources, like water (Franco-Paredes & Santos-Preciado 2011).

In coastal states, deep-sea fishing, water sports, waterfront hotel properties, and wildlife-sighting activities fund the tourism sector, which is the primary source for government-funded programs, such as schools and state health care; as a result, human health is both directly and indirectly dependent on the health of waterways. Water runoff from farming, factories, sewage treatment plants, and fertilizers made to keep monoculture lawns green has been dissolving into the land and into our waterways (**Figure 3**). This untreated water not only limits accessibility to potable water but also eventually flows into the ocean, creating an excess of nitrogen and phosphorus and allowing single-celled organisms like *Karenia brevis* to cause harmful algal blooms (Barile 2004). *K. brevis* produces a brevetoxin that binds to sodium channels in neurons, causing paralysis and seizures in aquatic wildlife and birds (Trainer & Baden 1999). This leads to a buildup of dead carcasses along beach fronts and putrid-smelling air, both of which can severely hinder



(Caption appears on following page)

Figure 3 (*Figure appears on preceding page*)

Illustration outlining the extended impacts of urban water contamination, algal blooms, and their effects on human and animal health. (*a*) Policy influences environmental protection and the testing of wastewater that is released into the environment. (*b*) The lack of policies and enforcement of existing policies protecting environmental spaces leave waterways vulnerable, with consequences for the health of people, wildlife, and plant life. (*c*) Testing of wastewater for contaminants such as fertilizers and sewage before being released into our oceans and water ways can be enforced and updated. (*d*) The increasing introduction of high P and N wastes, in combination with rising temperatures, creates a rich habitat for naturally occurring organisms such as *Karenia brevis* to proliferate into harmful algal blooms, also known red tide events. (*e*) *K. brevis* is a naturally occurring organism that produces brevetoxins (neurotoxins). (*f*) Marine life can be exposed to brevetoxins by consuming contaminated prey, seagrasses, and *K. brevis* itself. Brevetoxins disrupt normal neurologic processes, causing gill and fin paralysis, severe lethargy, and seizures, which result in the death of marine life, public health concerns about ingesting seafood, and disruption of marine ecosystems. (*g*) Coastal cities are heavily dependent on marine ecosystems for access to food and economic support through the tourism, fishing, service, and hospitality industries. (*h*) Revenues from the tourism industry in turn support state government funding for education, infrastructure, conservation, and health care in coastal states. (*i*) Residents of coastal cities that suffer from severe red tide events can experience intestinal issues, and exposure to harmful algal blooms can exacerbate chronic illnesses like asthma and emphysema and cause skin, eye, and throat irritations. Red tide exposure disproportionately affects working class communities that rely on marine ecosystems for their livelihood, as they typically live in coastal cities and spend a significant amount of time near or on the water. Abbreviations: N, nitrogen; P, phosphorus. Illustration created by Henry Adams, Lincoln Park Zoo.

the tourism industry (**Figure 3**). For humans, coming into contact, inhaling, and ingesting brevetoxins can exacerbate asthma and emphysema and cause coughing, severe rashes, and intestinal upsets (Kirkpatrick et al. 2004). In cities where marginalized communities are already subjected to detrimental health risks, those who work on or near the water in the service, tourism, and fishing industries are also at increased risk of losing their jobs, and thus their health insurance and state-funded health care, during repeated, extended bouts of harmful algal blooms. The lack of policies directed at protecting human health care and safeguarding natural resources will only compound human health inequities and environmental injustices as global temperatures increase.

3.4. Air Pollution

Ambient air pollution is a longstanding issue in public health with a significant global footprint (Fairburn et al. 2019). Air pollutants—including particulate matter with diameters less than 2.5 μm ($PM_{2.5}$) and 10 μm (PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), and others—have extensive deleterious effects on human health, including asthma, poor pregnancy outcomes, respiratory and cardiovascular illnesses, and mortality (Cushing et al. 2015, Nardone et al. 2020b). The deposition of these pollutants and overall air quality is generally degraded in urban systems, though there is considerable heterogeneity in the concentration of air pollutants across the urban matrix. For instance, concentrations of ambient $PM_{2.5}$ and NO_2 tend to concentrate around areas with high traffic and increased road densities (Demetillo et al. 2021, Hilker et al. 2019). Due to historical and contemporary urban planning and transportation policies, many of the drivers that detrimentally affect air quality are proximal to low-income neighborhoods, with the most severe impacts felt by communities of color (Pratt et al. 2015). For instance, interstate highways and major roads are frequently concentrated in lower-income neighborhoods (Nardone et al. 2020a). In addition, due to unjust zoning practices (Rossen & Pollack 2012), toxic waste sites are customarily located near disenfranchised communities (Anguelovski 2016), forcing persons of color to shoulder the burden of air pollution in cities.

Repeated evidence suggests that air pollution exposure is tied to environmental racism and classism. For instance, exposure to $PM_{2.5}$ tends to be greatest for Black, Latin, Asian, and Native Americans in multiple cities across the United States (Brochu et al. 2011, Gray et al. 2013, Nardone et al. 2020a, Pope et al. 2016, Tessum et al. 2021). The mechanisms driving these patterns are both historical and current. Recent evidence demonstrates that redlining has a long-lasting impact on contemporary air pollution, with $PM_{2.5}$ concentrations greatest in redlined areas (Lane et al. 2022). Reduced vegetation, amplified impervious surfaces, and the presence of more industrial sites necessarily amplify the air pollution hazards in disaffected neighborhoods (Namin et al. 2020). Further, recent work suggests that persons of color across the United States systematically experience a greater air pollution burden, even after controlling for socioeconomic wealth (Tessum et al. 2021). Moreover, communities of color are more likely to experience poor air quality indoors as well (Adamkiewicz et al. 2011), creating a double whammy of air pollution burden.

Most studies investigating the influence of ambient air pollution on animals and plants focus on how urban vegetation can help to mitigate air pollution (Setälä et al. 2013), with a few studies elucidating the associations between air pollutant loads and disease prevalence (Lovett et al. 2009). For instance, there are several studies describing the effects of air pollution on COVID-19 infections. Air pollution concentrations have been found to strongly correlate with transmission rates and severity of COVID-19 infections (Wu et al. 2020). Specifically, Black and Latin Americans living in neighborhoods with higher $PM_{2.5}$ concentrations contract the SARS-CoV-2 virus more frequently and experience higher mortality rates (Millett et al. 2020, Terrell & James 2020). Further, a recent study in Los Angeles, California, provides evidence that suggests that exposure to NO_2 increases the COVID-19 case fatality rate; this has a disproportionate effect on racial and ethnic minority groups, who live in closer proximity to roadways (Lipsitt et al. 2021). Thus, the inequality embedded in urban infrastructure, and the air pollutants generated therein, warrant a justice-oriented One Health approach.

4. RECOMMENDATIONS FOR THE FUTURE OF ONE HEALTH

Effective and sustainable One Health research must be transdisciplinary. Interdisciplinary work necessitates building collaborative relationships with researchers and practitioners from across disciplines (Lebov et al. 2017). Critically, these collaborations must meaningfully incorporate the views of those who have lived experience with their ecosystem services, integrating their knowledge and perspectives to create effective and acceptable responses (Degeling et al. 2018). In addition, One Health needs to be both plastic and resilient, as climate change and urbanization will necessarily drive health care systems to respond in a rapid and adaptive manner. Lessons from social-ecological systems and policy advocacy provide the blueprint for such an undertaking (Wilcox et al. 2019).

4.1. One Health and Social-Ecological Systems

A social-ecological systems framework (Pickett et al. 2016) is helpful for evaluating One Health problems because it recognizes the reciprocal interactions and feedbacks among human and natural systems that are already at the core of the One Health paradigm (Wilcox et al. 2019). The equal consideration of social and ecological systems makes connections among entities explicit and the interactions among them measurable, which allows for more robust evaluations of program success. Social-ecological systems frameworks also align with the complex, dynamic, and nonlinear nature of One Health systems, which involve many components, each of which may be complex (Wilcox et al. 2019). Given this complexity, management actions focused on one aspect of a system can have unanticipated and unintentional effects on other components, underscoring the importance of understanding how features of these systems intersect.

As one example, consider the management of urban rats (**Figure 2**). Commensal rats (brown and black rats) live in virtually every city on earth where abundant resources allow for increased numbers of animals (Feng & Himsworth 2014). Rats pose public health risks by hosting dozens of zoonotic bacteria and viruses (Himsworth et al. 2013), and there is a growing awareness of the mental health impacts of rat infestations (Murray et al. 2021). Socioeconomics is intimately linked to rat issues due to disinvestment in lower-income neighborhoods and provision of fewer resources for excluding rats. Many cities have policies that could alleviate infestation issues, for instance free rat abatement in response to public complaints. However, these programs rely on public engagement with municipal services, and knowledge, trust, and participation in government programs is typically lower for marginalized communities (Lee et al. 2021). While our current approach to rat management focuses solely on eradicating rats from the urban environment, a social-ecological systems framework shifts priorities to a broader understanding of rats as one component of an interconnected system that includes rats, people, sanitation, infrastructure, land-use planning, economies, politics, and other animals (**Figure 2**). Understanding feedbacks among these components can help predict the One Health consequences of rat abatement, such as poisoning nontarget wildlife (Niedringhaus et al. 2021) and increasing pathogen prevalence among rats after trapping or poisoning (Lee et al. 2018, Murray & Sánchez 2021). Importantly, understanding rats as a complex One Health system must also help address structural inequality in who is exposed to rats and who has the capacity to control rats around their dwelling.

Undertaking this systems-based and community-focused approach is challenging because of differing expertise, priorities, goals, constraints, and funding structures (Lebov et al. 2017, Wilcox et al. 2019). However, overcoming such challenges can both improve health surveillance and predict new One Health threats. For example, integration of ecological traits with machine learning has been used to identify the zoonotic capacity of mammalian hosts for SARS-CoV-2 (Fischhoff et al. 2021, Griffin et al. 2021). To improve health surveillance, management, and mitigation, it is imperative to foster real-time information sharing among sectors without overburdening any one stakeholder. Such information sharing is necessary to evaluate whether program actions have been successful and to inform ongoing and future actions so that initiatives can be responsive and adapt to changing social and ecological systems.

4.2. Policy Changes and Urban Design

A critical component of One Health systems is the policy decisions that affect the presence and distribution of health risks and benefits. Whereas the connections between One Health and some policies are obvious (e.g., government regulations on the use and disposal of environmental contaminants), other aspects of human decision-making are not typically associated with One Health systems. Decision-making processes can limit protections from health harms or access to health care, and consequently enshrine structural health inequities. Hence, including marginalized voices in environmental and health decisions is critical to eradicating health disparities (Lane et al. 2017).

Access to health care for humans and domestic animals is a central issue for One Health because it can affect the health outcomes of individuals, patterns of reportable infections, and the distribution and intensity of infection outbreaks. Among high-income countries, the United States ranks last in terms of equitable access to health care based on income (Schneider et al. 2021). However, even in countries with universal or single-payer health care systems, aspects such as dental care or prescription drugs can be dependent on private insurance. It is now well established that low socioeconomic status is negatively associated with health outcomes due to lack of preventative health care and treatment prior to hospitalization (Dubay & Lebrun 2012). This lack of information about infections prior to hospitalization may explain why predictive epidemiological models perform poorly for low-income communities (Scarpino et al. 2016), which could have important implications for zoonotic infection surveillance. Recent calls to integrate veterinarians in global health security monitoring emphasize the need to understand zoonotic infections in companion animals; however, veterinary care is largely privatized, which biases surveillance toward more affluent owners.

Along with human health outcomes, environmental health is also negatively associated with income inequality. For example, biodiversity loss is positively correlated with the Gini ratio, an indicator of income inequality among households, across 45 countries (Mikkelson et al. 2007). These relationships may arise if a relatively small group of wealthy individuals is less likely to support common goals with less affluent communities and is shielded from the negative consequences of overexploitation. Thus, addressing social inequality may positively contribute to conservation efforts (Kuras et al. 2020, Schell et al. 2020).

Explicitly quantifying the economic significance of ecosystem services in cities (e.g., shade, pest control, water filtration) may help to emphasize the importance of ecosystem health in policy making. It is crucial to acknowledge the role of human perception when conceptualizing ecosystem services and environmental health. For example, a stormwater pond in a residential neighborhood can buffer against extreme precipitation events but may be perceived as a mosquito habitat (Haas-Stapleton & Rochlin 2022). Similarly, planting trees and shrubs in vacant lots may contribute to local cooling but may increase property values, leading to gentrification and displacement (Haase et al. 2017, Wolch et al. 2014). Listening to local concerns about naturalized habitats may help promote community buy-in and coproduction of solutions that enhance intrinsic value in local environments (Bratman et al. 2019).

Ultimately, civic engagement may be the most powerful way to advance One Health goals in cities. While interdisciplinary research teams are vital for understanding host–pathogen–environment dynamics, elected officials can change discriminatory and harmful practices. Elected officials also determine the formation and funding of sanitation, rodent and insect vector abatement programs and land zoning (Rossen & Pollack 2012). Effective governance is important across spatial scales, with local elected officials (e.g., city councilors) advocating for neighborhood pest management and sanitation, while citywide policy makers (e.g., mayors) are well positioned to address land-use concerns. At larger scales, federal and state or provincial politicians can influence climate change policies, access to health care, and environmental regulations.

5. CONCLUSIONS AND FUTURE DIRECTIONS

Looking forward, the need for socially inclusive One Health work will continue to grow as the world becomes more urbanized. At its core, One Health is about interactions among human and nonhuman entities, so identifying these core interactions among humans, animals, and the environment early on will help focus research efforts. These interactions will help identify which human and nonhuman communities may be most at risk and the spatial scope of data collection. This scope can help researchers identify and connect with local experts—with various professional backgrounds and forms of knowledge—as a crucial step in understanding the study system and ensuring that any data collected are relevant, useful, and necessary. Such local leaders will ideally represent local human communities in terms of race, ethnicity, income, language, gender, and sexual orientation (Trisos et al. 2021). These connections may also present opportunities for participatory science and elevate the EJ work done by community and academic scholars.

To integrate EJ in One Health work equitably, researchers and practitioners must work to be culturally competent in order to communicate effectively with individuals from other cultures. This work includes awareness of privilege, knowledge of local history, resiliency in interrogating oppressive systems, and enhanced empathy. Developing such skills helps to embed a justice lens as the foundation of One Health research programs. More equitable and just research designs and policies will ensure that One Health work benefits all human and nonhuman communities on our urbanizing planet.

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