

Transdisciplinary research priorities for a One Health approach to human–wildlife coexistence

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Humans, domestic animals, and wildlife increasingly share space, interact, and experience conflict. These interactions shape human livelihoods, form pathways for disease transmission, and affect animal well-being. We propose that the integration of One Health and human–wildlife coexistence science provides underrealized potential to address related complex health and sustainability challenges through transdisciplinary research.

Integrating human, animal, and ecosystem well-being under One Health (OHHLEP et al. 2022) has marshaled notable recent progress in health and sustainability sciences (Aguirre et al. 2016, Miao et al. 2022). Although the links between human and domestic animal health receive disproportionate focus, the role of ecosystem health remains insufficiently recognized. Similarly, wildlife health and well-being have not been fully integrated into One Health thinking beyond the treatment of wild animals as potential pathogen reservoirs and disease vectors (Dobson et al. 2020). Such a restricted focus dampens the impacts of One Health research and limits its contribution to related fields.

In this Viewpoint, we integrate a One Health framing with the emerging global challenge of human–wildlife coexistence. Fun-

damentally, human–wildlife coexistence can be defined as co-occurrence of sustainable wildlife populations and human endeavors with minimal human–wildlife and human–human (i.e., social) conflict (Venumière-Lefebvre et al. 2022). Adopting a One Health framing broadens the coexistence approach to explicitly include the health and well-being of wildlife, humans, and domestic animals (i.e., livestock, companion animals, feral animals). In addition, ecosystem or environmental health is critical for human–wildlife coexistence, given it provides vital ecosystem services to people and habitat to wildlife in shared landscapes (figure 1; Murray et al. 2022). Placing ecosystem health as underlying the three other health components (i.e., human, domestic animal, and wildlife health.), as well as separating domestic animal and wildlife health to allow for both synergistic and antagonistic relationships, represent distinctions from more traditional One Health conceptualizations (e.g., OHHLEP et al. 2022).

With successful human–wildlife coexistence defined as a One Health challenge, we propose transdisciplinary research themes to guide a global research agenda. Our focus lies in systems where humans, wildlife, and domestic animals share space and where the complexity of coexistence demands innovative, transdisciplinary approaches. We view transdisciplinary research as

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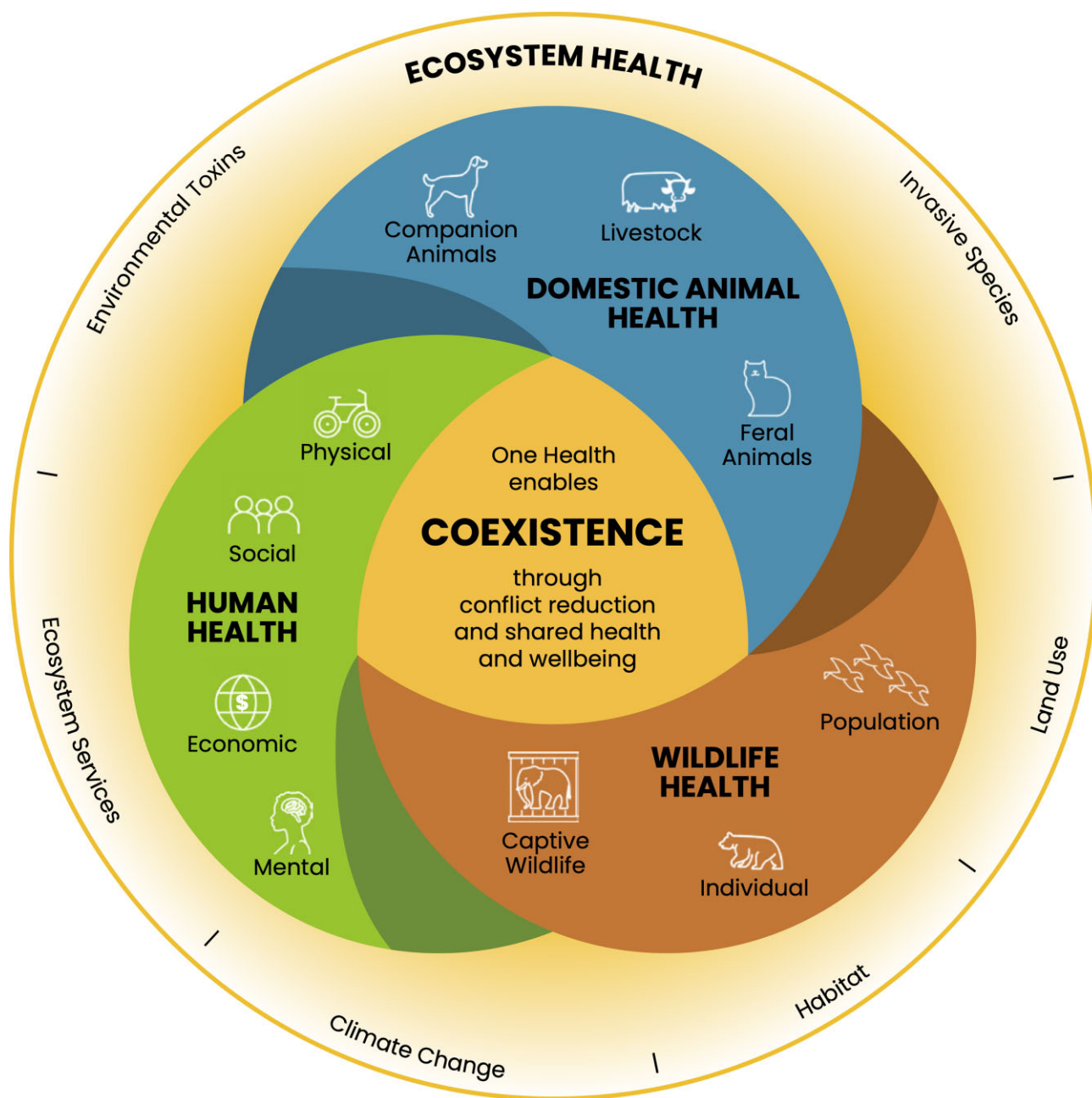


Figure 1. Human–wildlife coexistence as a One Health concept. Coexistence is conceptualized following One Health at the intersection of human health, domestic animal health, and wildlife health, all supported by ecosystem health. Pathways to coexistence should more explicitly integrate these 4 health components given that conflict arises when some but not all are considered. Coexistence requires reduction of such conflict, including direct conflict between people and animals (e.g., predation, disease transmission) as well as social conflict among people about animals (e.g., divergent values and unpopular policies). Drivers of conflict and strategies to address them are the focus of coexistence work and central to our proposed transdisciplinary research priorities. Elements shown as icons of the four health components are representative and not exhaustive. Image: Monica McQuail.

inclusive of interdisciplinary science and knowledge creation convened around a complex challenge; research coproduction including academics, other knowledge producers, practitioners, and stakeholders from diverse fields and backgrounds engaged at the stage of problem formulation; and research outcomes being fundamentally oriented toward solutions and directed toward benefits for all involved parties. We conclude by highlighting domains that crosscut the research themes, such as the need for just and equitable processes, bottom-up technology development, and open science.

Transdisciplinary research priorities

We identify 6 research priorities that should inform work at the intersection of science, policy, and practice.

Disease transmission at animal–human interfaces

Infectious disease transmission among wildlife, domestic animals, and humans is a foundational One Health challenge and a pervasive form of human–wildlife conflict worldwide. SARS,

Ebola, and the recent H5N1 highly pathogenic avian influenza outbreaks, along with the COVID-19 pandemic, have elevated focus on the risks of disease spillover between wildlife and humans as critical to global public health. Cost-benefits analyses have demonstrated that pragmatic efforts (e.g., surveillance, restricting wildlife trade) to prevent disease outbreaks may result in lower overall economic burden while decreasing comorbidities and mortality in both humans and animals (Dobson et al. 2020). This warrants precaution and preparedness for emerging zoonotic diseases and continued research to uncover causal pathways. In addition, although significant research has been focused on zoonotic spillover from wildlife to humans, less is known about spillover and spillback from humans and domestic animals to wildlife, with potential significant but uncertain implications for wildlife health and biodiversity (Thompson 2013). Disease risks at the human-animal interface will need to be collaboratively addressed by transdisciplinary teams of researchers, practitioners, policymakers, and stakeholders to develop and apply community-driven approaches to prevent and control emerging disease threats.

Wildlife predation impacts on well-being of livestock, livestock owners, and farmers

Predation of livestock and crops by wildlife is a significant source of human-wildlife conflict, leading to impacts on livestock and humans and retaliatory killing of wildlife. Carnivores can affect livestock directly through mortality or injury, as well as indirectly by causing increased stress, stress-associated sickness, and reduced weight gain and pregnancy rates. Coexisting with carnivores can also affect varied dimensions of human well-being, such as through the increased cost of managing livestock in predator-rich areas, the risk of attack on herders, and the associated chronic stress. Likewise, chronic crop predation by herbivores can cause food insecurity and associated negative health outcomes for farm families (Salerno et al. 2021). Nonetheless, the indirect costs of livestock and crop predation on the well-being of both people and livestock are understudied in human-wildlife coexistence research (IUCN 2023). Transdisciplinary efforts are needed to proactively engage livestock producers and farmers to more effectively evaluate the impacts of predation and conflict reduction approaches (Hyde et al. 2022).

The benefit of wildlife for human and domestic animal health

Although coexistence can lead to conflict, wildlife also provides benefits for both human and domestic animal health. For example, native wildlife may provide an important ecosystem service through disease regulation via a dilution effect (Keesing and Ostfeld 2021). Wildlife that causes conflict in one context may provide benefits in others, such as carnivores that sometimes consume livestock instead consume herbivores that cause crop damage. Encountering and interacting with wildlife can enhance human mental health and well-being (Yerbury and Lukey 2021), and many communities hold spiritual and kin-based relationships with wildlife. In addition, predators and scavengers can regulate zoonotic diseases by reducing the densities of pathogens, hosts, and vectors (O'Bryan et al. 2018). Despite clear benefits, the majority of coexistence research emphasizes conflict (i.e., ecosystem "disservices"), highlighting the need for further transdisciplinary research on how wildlife contribute to human and domestic animal health (Ceaşu et al. 2019).

Climate impacts on human-wildlife interactions

Anthropogenic climate change will continue to reshape human, domestic animal, and wildlife interactions, but such climate impacts remain underengaged in science, policy, and practice (Abrahms et al. 2023). Shifts in precipitation and temperature patterns alter food and water availability, with the impacts ranging from increased competition for resources among humans and animals to restrictions on adaptive movement to disease emergence and transmission to wildlife predation of crops, livestock, and humans. These climate-induced changes will be increasingly dynamic across land-use gradients, creating novel areas of conflict and associated challenges for coexistence (Salerno et al. 2021). Although early research demonstrates wide-ranging climate impacts on human-wildlife interactions, there are clear geographic and taxonomic biases (Abrahms et al. 2023). Furthermore, there is a lack of institutional adaptation to these emerging management and policy challenges, such as integrating human-wildlife coexistence science into climate vulnerability and assessment. Given widely varying climate change impacts on ecosystem health (Ceaşu et al. 2019), the need for transdisciplinary work is clear, particularly engaging communities most affected by climate-induced shifts in human-wildlife interactions (e.g., those in the Global South and those with livestock-, crop-, and foraging-based livelihoods).

Human-wildlife coexistence across land-use gradients

Global gradients of intensifying anthropogenic land use, from wildlands to rural and urban landscapes, shape human-wildlife interactions and challenge coexistence (Salerno et al. 2021, Murray et al. 2022). For example, detrimental edge effects at the boundaries of wildlands and the human-dominated matrix, including along urban and agricultural edges, intensify human-wildlife conflicts and their consequences, such as property damage, attacks on domestic animals and people, and disease transmission. Developing infrastructure such as roads and railways allows human activities and resulting conflict to further penetrate core habitat, resulting in wildlife-vehicle collisions, overexploitation of vulnerable wildlife (e.g., wild meat trade), and zoonotic spillover. Although landscape connectivity is critical for wildlife, animal movement through shared spaces can increase contact with people, exacerbating negative consequences. Such conflict may disrupt animal dispersal and impede connectivity, creating a trade-off between connectivity conservation and conflict mitigation (Vasudev et al. 2023). Attention to ensuring human, animal, and ecosystem health in shared spaces along land-use gradients sheds particular light on the diverse user groups needed within transdisciplinary approaches.

Social conflict and changing human values regarding wildlife

Human-wildlife coexistence research and practice are typically focused on direct conflicts between people and wildlife, including threats to humans (e.g., safety, property, livestock, pets) and threats to wildlife (e.g., lethal control, evolutionary shifts, population declines; Venumière-Lefebvre et al. 2022). However, a growing body of research demonstrates that conflict among people (i.e., social conflict) is a fundamental and prevalent form of conflict about wildlife coexistence (Madden and McQuinn 2014). Social conflict can affect human mental and physical health, as well as social cohesion. Moreover, social conflict can exacerbate the

frequency and intensity of direct human–wildlife conflict, such as via retaliatory killing of carnivores or unwillingness to implement nonlethal approaches to prevent livestock depredation (Venumière-Lefebvre et al. 2022). Social conflict is further exacerbated by power imbalances, identity differences, economic disparities, and value clashes. In particular, as values about wildlife shift from traditional domination to mutualism, social conflict and cultural backlash against wildlife intensify if research and policy are misaligned with public sentiment (Manfredo et al. 2017). Despite its demonstrated importance, social conflict is understudied in coexistence research (Venumière-Lefebvre et al. 2022), along with its implications for human and animal well-being. Transdisciplinary research must approach the social and ecological drivers of conflict as embedded within cultural systems, inclusive of diverse values and varying tolerance for wildlife (Lischka et al. 2018).

Cross-cutting domains in transdisciplinary coexistence research

Various cross-cutting domains are embedded in each of the above research priorities. Most prominently, we argue that a One Health framing—actively integrating the health of humans, wild and domestic animals, and ecosystems—can advance coexistence research and practice (figure 1). In turn, including coexistence science and its focus on wildlife sustainability in human-dominated landscapes can strengthen the integration of wildlife health, and more broadly environmental themes, into One Health research. Such integration is important, given that One Health has struggled to be broadly transdisciplinary and remained dominated by human and domestic animal health, and therefore medical and veterinary disciplines, with less focus on wildlife and ecosystem health (Aguirre et al. 2016, Miao et al. 2022).

The need for research coproduction cuts across priority themes as well, through leveraging a diversity of stakeholders to develop and apply practical, real-world solutions to human–animal interaction challenges. Coproduction with local communities is also necessary to help ensure just, equitable, and suitable conflict reduction approaches with prioritization across all health components (Murray et al. 2022). Particularly, greater effort is needed to elevate the role of traditionally undervalued knowledge holders (e.g., Global South versus Global North, practitioner versus academic, Indigenous versus colonizer). Likewise, researchers must prioritize open science to ensure access to and participation in knowledge creation.

In addition, technological innovation is central to addressing current and future challenges. For instance, wildlife conflict deterrents range from beehives to geofencing; transdisciplinary research incorporating innovations drawn from diverse sources ranging from traditional knowledge to artificial intelligence, while allowing community priorities to drive technology development and adoption, will promote coexistence.

Human–animal interactions and conflicts are varied, dynamic, and complex and will evolve into new forms in coming years (Dobson et al. 2020). This is especially true in the face of climate change (Salerno et al. 2021, Murray et al. 2022, Abrahms et al. 2023). However, there is reason to be encouraged. Global policy frameworks such as the recent International Union for Conservation of Nature *Guidelines on Human–Wildlife Conflict and Coexistence* (IUCN 2023) show the growing importance and intersectionality of human–animal–ecosystem health. This and broader frameworks (e.g., Intergovernmental Panel on Climate Change, Sustainable Development Goals, Intergovernmental Platform on Biodiver-

sity and Ecosystem Services) should be attentive to the priority themes highlighted above to engage with integrated One Health and coexistence goals. In addition, these goals must be reflected in funding priorities that center community, academic, and governmental partnerships supporting long-term, transdisciplinary research. A unified One Health approach integrating these transdisciplinary research priorities for human–wildlife coexistence will help advance the shared health and well-being of people, animals, and ecosystems.

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