Human–Wildlife Conflict and Coexistence

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Abstract

Human interactions with wildlife are a defining experience of human existence. These interactions can be positive or negative. People compete with wildlife for food and resources, and have eradicated dangerous species; co-opted and domesticated valuable species; and applied a wide range of social, behavioral, and technical approaches to reduce negative interactions with wildlife. This conflict has led to the extinction and reduction of numerous species and uncountable human deaths and economic losses. Recent advances in our understanding of conflict have led to a growing number of positive conservation and coexistence outcomes. I summarize and synthesize factors that contribute to conflict, approaches that mitigate conflict and encourage coexistence, and emerging trends and debates. Fertile areas for scholarship include scale and complexity, models and scenarios, understanding generalizable patterns, expanding boundaries of what is considered conflict, using new tools and technologies, information sharing and collaboration, and the implications of global change. The time may be ripe to identify a new field, anthrotherology, that brings together scholars and practitioners from different disciplinary perspectives to address human–wildlife conflict and coexistence.

Contents

1. INTRODUCTION

Human interactions with wildlife are a defining experience of human existence. These interactions can be positive or negative. *Homo sapiens* have competed with other species for habitat and resources and have innovated and adapted to become the dominant ecological force on the planet (1). This conflict has contributed to the extinction of numerous species (2); changes in ecosystem structure and function (3); and immeasurable loss of human life, crops, livestock, and property (2, 4). The amelioration and mitigation of this conflict is central to the conservation and restoration of many species, and debates over how and whether to coexist with other animals drive social, economic, and political conflict within and among human communities (2, 5).

The challenges of human–wildlife conflict are older than recorded history but an interdisciplinary field of study focused on human–wildlife conflict and coexistence, although still relatively

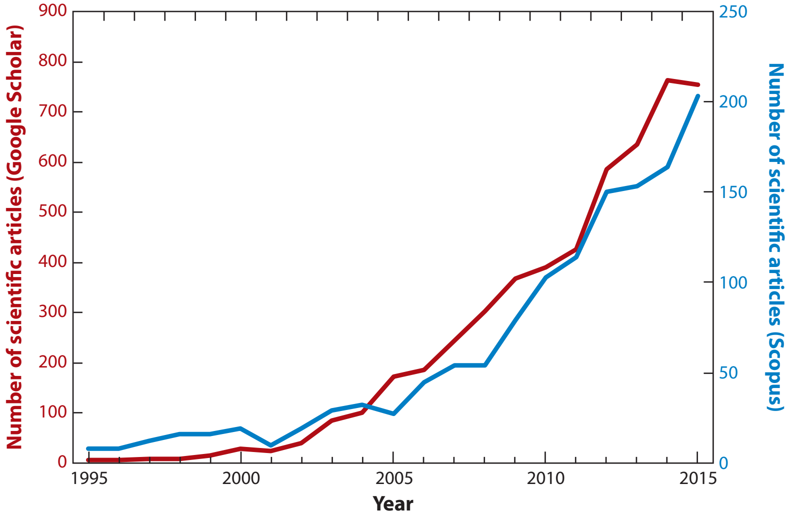

Figure 1

Growth in scientific papers referencing human–wildlife conflict between 1995 and 2015 as measured by (*red*) citations that use the exact words human–wildlife conflict or human wildlife conflict in Google Scholar, and (*blue*) any combination of the terms human and wildlife with conflict in the scientific database *Scopus*.

new, is growing rapidly. Over the past 20 years, the number of scientific publications addressing human–wildlife conflict and coexistence has increased almost exponentially (**Figure 1**).

In this review, I synthesize the current state of scholarship on human–wildlife conflict and coexistence. I define key concepts, describe the importance of conflict, place it in evolutionary and historical context, examine broad categories of conflict, characterize factors influencing conflict and responses to conflict, and identify future research needs. This topic is too large to cover all aspects of conflict in depth, so I focus particular attention on large vertebrates and human–wildlife conflict in the context of wildlife conservation.

1.1. Defining Human–Wildlife Conflict and Coexistence

Human–wildlife conflict is commonly described as conflict that occurs between people and wildlife (2); actions by humans or wildlife that have an adverse effect on the other (4); threats posed by wildlife to human life, economic security, or recreation (6); or the perception that wildlife threatens human safety, health, food, and property (7). The term wildlife is defined broadly as nondomesticated plants and animals (8), although domesticated and feral animals are sometimes included in the human–wildlife conflict literature. Wildlife damage management is defined as the science and art of diminishing the negative consequences of wildlife while maintaining or enhancing their positive aspects (8), and is often synonymous with human–wildlife conflict mitigation (2, 8).

Numerous scholars point out that the notion of human–wildlife conflict is complicated by underlying tensions from human–human conflicts over conservation and resource use (2, 7, 9, 10). Another complication is that human interactions with wildlife are often framed negatively even if important positive benefits—recreational, educational, psychological, and ecosystem services—exist (11). As a result, there is a growing convergence around the phrase human–wildlife conflict and coexistence to connote the recognition of both problems and solutions (2, 10, 12), although some authors question whether coexistence is more precisely co-occurrence (13).

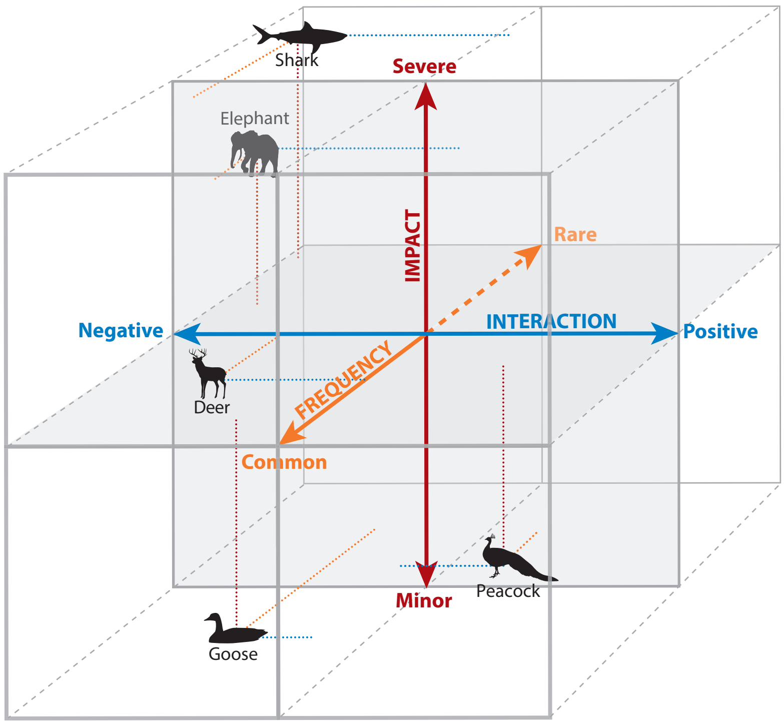

Figure 2

A model for conceptualizing different types of human–wildlife conflict. The *x*-axis represents a range of interactions or outcomes from negative (e.g., crop damage) to positive (e.g., income from tourism or cultural or religious benefits). The *y*-axis represents impact on a continuum from minor (e.g., nuisance interactions between people and birds in an urban park) to severe (e.g., loss of life or severe injuries). The *z*-axis represents frequency of occurrence from common to rare. Model based in part on Reference 11. Different individuals or groups of people may perceive similar interactions in different ways. Other dimensions could be added, such as whether few or many people are impacted, or whether conflict is localized or ubiquitous.

1.2. Importance of Conflict

Human–wildlife conflict has significant consequences for human health, safety, and welfare, as well as biodiversity and ecosystem health. Impacts on humans can be direct or indirect. Human injury and death can result when animals bite, claw, gore, or otherwise directly attack people; during collisions between animals and automobiles, trains, planes, boats and ships, and other vehicles; and from the transmission of a zoonotic disease or parasite (4). Conflict with wildlife can cause direct material and economic damage to crops, livestock, game species, and property (2, 14–16). Indirect impacts of conflict, more difficult to measure, include opportunity costs to farmers and rangers associated with guarding crops or livestock, diminished psychosocial wellbeing, disruption of livelihoods, and food insecurity (2, 12, 14, 15, 17, 18).

Human–wildlife interactions vary on a continuum from positive to negative, in intensity from minor to severe, and in frequency from rare to common (11; see also **Figure 2**). Attacks on people by apex predators such as tigers, lions, and sharks are now relatively infrequent but the attacks can be lethal and lead to strong public reactions (2). Conversely, conflict between people and common garden pests or birds such as geese may be more common but provoke less concern. Conflict frequency can also be highly variable within and among geographic regions. Some households or farms within a community may suffer little damage whereas neighbors may experience a surplus killing event in which a predator may kill many animals in one attack (12), or some properties may be better protected than others.

The most extreme biological impact is extinction. Hundreds of terrestrial and marine vertebrate species have become extinct in recorded history, and populations of many remaining species have declined in abundance (19). The decline of large, predatory animals in particular has resulted in cascading ecological consequences for other species and ecosystem services (20), and many of these declines are linked to conflict with humans.

2. CONFLICT IN EVOLUTIONARY AND HISTORICAL PERSPECTIVE

Human evolution is fundamentally a story of human interactions with other wildlife. Our ability to survive in the face of competition from other species fueled the early stages of our eventual global domination as a "superpredator" (21). Early hominids may have experienced selection for predator avoidance such as effective vigilance, social adaptations such as formation of small groups for protection, and intelligence to eventually develop technologies such as weapons to reduce the threat of predation (22, 23). Modern vertebrates represent those that survived environmental changes and competition with early hominids (22).

Expansion of early human populations coincided with major changes in large vertebrate abundance. There is growing evidence that humans contributed to the extinction of large mammals (terrestrial taxa with adults >45 kg) during the late Pleistocene glacial period (~110,000 to 11,650 years ago) (24), although the relative contributions of climate changes and human hunting to megafaunal extinctions continue to be debated (24).

Our earliest historical records document close interactions with wildlife. Early cave paintings on multiple continents show people interacting with wildlife (25). Efforts to protect crops and fellow humans from wildlife are known from the earliest records in ancient civilizations of Egypt, the Indus River Valley, China, Greece, and in the Christian Bible (4). Records exist of elephant (*Elephas maximus*) crop raiding in Asia as early as 300 BC (26). The spread of agriculture led to new technologies such as poisons, repellents, and traps to reduce wildlife damage (4).

In modern times, governments developed laws and policies to address wildlife conflict. Laws were established as early as 1424 in Scotland to control bird damage, and some of the earliest laws passed in the new American colonies were bounties to eradicate wolves (*Canis lupus*), foxes (*Vulpes vulpes*), and birds (4). Kingdoms and colonial empires often supported predator eradication efforts because of the danger posed by wild animals. Tens of thousands of people have been reported killed and injured by tigers in Asia and countless tigers have been killed in retaliation (27). Entire species have been vilified because of conflict with humans. In China, two millennia of tiger–human conflict resulted in an estimated 10,000 people killed or injured in four provinces of southern China, eventually leading to a "war on nature" by China's Chairman Mao Zedong and the eradication of almost all of China's tigers (28).

Government support for control and eradication programs continued in many areas well into the twentieth century (16, 29, 30). Real and perceived conflict with wolves led to their eradication from large areas of Europe and the continental US (31). The "success" of eradication programs contributed to the extinction of three tiger subspecies and the near elimination of two others (27), as well as the extinction of canid species such as the Falklands wolf (*Dusicyon australis*) (29). Other species such as coyotes (*Canis latrans*) and red foxes were more resilient, adapted better to human persecution, and expanded in spite of these control efforts (29).

Thus, a common theme from prehistory to modern history is that human populations evolved and expanded by competing effectively with wildlife for space and resources, eradicating or diminishing individual wildlife populations or entire species that posed the most serious threats, and trying to minimize threats and damage from those species that survived. In recent decades, this pattern has shifted as growing awareness about the value of biological diversity and the emergence of better information, tools, laws and institutions, and new values encouraged more creative ways to manage wildlife using a coexistence model and encouraging conservation of wildlife populations (2, 6).

3. COMMON CONFLICT TYPES AND LOCATIONS

Human–wildlife conflict and coexistence occurs with species that are rare and protected, abundant and considered pests, heavily managed or even domesticated, and occur in diverse ecosystems. Not surprisingly, much scholarship in the human–wildlife conflict literature has focused on species of conservation concern (2, 29, 30). A major challenge of modern conservation is how to balance the protection of endangered species with the needs of local communities so resolution of conflict is an important element of many conservation strategies (2). The following examples illustrate the broad spectrum of taxa, locations, and impacts for common types of human–wildlife conflict.

3.1. Large Terrestrial and Amphibious Species

Animal size is often a good predictor of conflict because large predators and herbivores can injure and kill people and livestock. Many human–wildlife conflict studies have focused on terrestrial species or amphibious species such as crocodilians that use terrestrial, aquatic, and sometimes brackish habitats.

3.1.1. Carnivores. People around the world have expressed deep hostility toward large carnivores because of real and perceived impacts on human health and livelihoods (6, 32). Felids and canids are particularly at risk for conflict with people because of their large home ranges, large physical size, and dietary requirements (29, 30). Their abundance is often determined by factors such as prey availability (33), so artificially enhancing "prey" density by increasing livestock can potentially lead to increased conflict. Globally, at least two dozen species of terrestrial carnivores commonly prey on nine common species of livestock (34). More than 75% of the world's felid species are somehow affected by human–wildlife conflict (35), and the severity of conflict generally increases with increasing body mass (35). Humans have persecuted, extirpated, and caused severe range reduction of wolves in Asia, North America, and Europe, jaguars (*Panthera onca*) in the Americas, lions (*Panthera leo*) and wild dogs (*Lycaon pictus*) in Africa, and tigers (*Panthera tigris*) in Asia (15).

3.1.2. Herbivores and omnivores. A wide variety of animals, including species in the order Proboscidea (elephants) and Artiodactyla (e.g., swine, deer, hippopotami), commonly come into conflict with people. Approximately 60% of the world's 74 largest terrestrial herbivore species (body mass $\geq$ 100 kg) are threatened with extinction, with important implications for other species and ecosystem processes (36). Large vertebrate herbivores can cause conflict with people by trampling, directly consuming, and otherwise damaging vegetation of ecological and socioeconomic importance (3). Elephants in particular cause significant damage to crops and vegetation across Asia and Africa (17, 26).

Conflicts between humans and ursids are widespread (32). Brown bears (*Ursus arctos*) are one of the world's most widely distributed terrestrial mammals. Brown bears occupy a wide range of habitats and are generalist feeders that consume human-related foods, such as livestock, crops, and beehives (37). All species of bears, particularly large ones such as polar bears (*Ursus maritimus*), are known to come into conflict with people, but bear–human conflict in regions such as Asia has received relatively less scholarly attention than felid– and canid–human conflict (37). Conflict is not restricted to the largest or most dangerous animals: numerous smaller vertebrates compete with humans for food and space (4). Agricultural damage from wild boar (*Sus scrofa*) in Europe reaches millions of US dollars annually (38).

3.1.3. Reptiles. Numerous reptile species, including hundreds of snake species, come into conflict with humans (8). Crocodilians, including alligators, crocodiles, and caimans, are nonvenomous reptiles capable of causing serious or fatal injuries in humans (4). From 1928 through 2008, 567 reports of adverse encounters with alligators and 24 deaths were reported in the United States, and nuisance complaints are increasing as the alligator population increases (39). In Australia, 62 unprovoked attacks by wild saltwater crocodiles between 1971 and 2004 were reported (40).

3.2. Abundant Agricultural Pests

Although charismatic species such as tigers and wolves receive considerable attention, many abundant species are among the most economically important sources of conflict. Agricultural pests, biological organisms that are considered harmful to crops or livestock (41), are leading causes of agricultural damage. A common pest management approach is to eradicate as many individuals of a species as possible (42). Another common approach is to disperse animals considered pests. In 2014, the US Department of Agriculture's Wildlife Service dispersed or harassed approximately 28 million animals and "took" (i.e., killed) 2.7 million animals. Of those taken, 57% were non-native European starlings, house sparrows, and pigeons or blackbirds (43). An estimated 200 million European starlings eat cattle feed and increase the risk of disease transmission by contaminating feed and water troughs (43). Many agricultural pests are invasive species, including starlings, and hundreds of species, including 92 birds and 32 mammals, are considered exotic in North America alone (8).

3.3. Feral Animals

Domestic and feral cats and dogs are widely recognized as important predators, and the world's human-dominated landscapes provide a home for more than 700 million domestic dogs and millions of domesticated cats (44, 45). Dogs and cats can cause conflict through predation on other wildlife, disease transmission, wildlife disturbance, hybridization, and direct attacks on livestock and people. Dogs are responsible for 99% of the reported 55,000 annual human fatalities due to rabies (46). In the United States, free-ranging domestic cats kill an estimated 1.3–4 billion birds and 6.3–22.3 billion mammals annually (45). Wild predators in turn also kill domesticated pets. Wolves are known to kill hunting dogs in North America and Europe, resulting in emotional and sometimes economic trauma for dog owners (47, 48). An estimated 87% of leopard prey biomass in one study in India came from domestic animals, including 39% from domestic dogs (49).

A wide variety of other feral animals are also important sources of conflict. For example, Australia has the world's largest population of feral horses, estimated at more than 400,000 individuals, which results in excessive trampling and grazing, impacts on native habitats and species, and conflict with rural populations (50).

3.4. Marine Species

Human–wildlife conflict is also common and important in the world's oceans. Marine conflict can take many forms, including direct attacks, bites, stings, and collisions, as well as impacts related to pollution, removal and modification of natural habitat, resource extraction, tourism and recreation, entanglement with fishing gear, and other harvesting activities (51, 52). Large marine vertebrates are well represented in the marine human–wildlife conflict literature. Shark attacks on humans are relatively rare but elicit considerable public media attention. Documented unprovoked shark attacks globally have grown steadily, with each decade having more attacks than the previous decade since 1900, reaching 658 recorded attacks between 2000 and 2009 (51). A record 98 confirmed unprovoked attacks were reported worldwide in 2015 (51). North America is typically home to the most shark attacks, and the state of Florida typically is responsible for approximately half of the unprovoked attacks in the United States (51). In Australian waters over the past 218 years, there have been 178 documented fatalities and 322 injuries from sharks (53).

Fin whales, right whales, humpback whales, and sperm whales are the mostly common of 11 whale species involved in collisions with ships (54). In an analysis of four decades of human-caused whale mortality in the Northwest Atlantic, Van Der Hoop et al. (52) documented 1,762 cases of human-caused mortality and serious injury involving eight species of whales. Mortality from harvesting led to historic global whale population declines, but deaths from collisions constitute a continuing threat (54).

3.5. Disease Transmission

A unique but important subset of human–wildlife conflict is the transmission of disease from wildlife to humans and from humans to wildlife (11). Many wildlife species are reservoirs for pathogens, and zoonotic and vector-borne diseases pose considerable risks to livestock, human, and wildlife health (55).

Zoonotic diseases have been important throughout history and remain one of the world's most important public health challenges (56, 57). During the 400-year span of the Black Death, the plague (*Yersinia pestis*) killed an estimated 50% of the human population in China, 33% in Europe, and 17% in Africa (57). Approximately 60% of all globally emerging infectious diseases are zoonotic diseases that infect both humans and animals (57), and 72% originate in wildlife (56). Common zoonoses of interest include bacterial diseases such as plague, brucellosis, tularemia, anthrax, salmonellosis, and *Escherichia coli*; viral diseases such as rabies, West Nile virus, encephalitis, influenza, and hantavirus; and transmissible spongiform encephalopathies (prion diseases) such as Creutzfeldt-Jakob disease, chronic wasting disease, mad cow, and scrapie (57). Examples of important zoonotic disease outbreaks include Ebola, avian influenza viruses A(H5N6) and A(H7N9), Middle East respiratory syndrome coronavirus, and cholera (see **http://www.who.int/csr/en**).

Disease can also influence how animals behave, contributing to additional conflict. An estimated 350 pathogens, including rabies virus, canine distemper virus, and canine parvovirus, can infect dog populations and threaten both wolf and wild dog populations (44, 47). The majority of documented cases of wolf attacks on people in twentieth-century Europe were attributed to rabid wolves (58).

4. FACTORS INFLUENCING CONFLICT

Many social and ecological factors influence conflict risk at various scales. Some of the most important underlying drivers of conflict include growing human populations and associated increases in agriculture, land and resource use, technology, transportation, and energy. Proximate drivers include a range of biological, ecological, and behavioral factors that increase the probability of wildlife conflict with people. Human–wildlife conflict typically does not occur at random (11), but patterns of conflict can be difficult to identify because of the complexity inherent in wildlife behavior and ecology, human behavior, and changes in seasonality, cropping and husbandry behavior, and resource availability.

4.1. Global Trends

Human population growth and associated economic activities are fundamentally altering the planet (1). Urbanization is a major anthropogenic force (59), and for the first time in human history the Earth's population is now more urban that rural (**http://www.unpopulation.org**). At local and regional levels, the relationship between human population size and wildlife conflict is less clear. Woodroffe (60) hypothesized there may be associations between high human population densities and loss of carnivore populations at local scales, but others have argued that favorable laws and effective management regimes are likely more important factors than human population size or density alone (32, 61). In some regions, smaller rural populations may actually increase conflict because carnivores may be better able to recolonize landscapes with more prey and fewer humans (62).

The global intensification of agriculture has had a major impact on the world's natural ecosystems (63). Agricultural growth is expected to accelerate, with farmlands occupying an additional 200–300 million hectares by 2050 (64), which will further reduce wildlife habitat. Livestock populations are a dominant ecological and economic force on the planet, and the global growth in livestock production is a major driver of human–wildlife conflict in some regions. Livestock systems occupy approximately 30% of the planet's ice-free terrestrial surface area, contribute in excess of US $1.4 trillion to the world's economy (representing one-third of global agricultural GDP), employ an estimated 1.3 billion people, and directly support the livelihoods of 600 million poor smallholder farmers in the developing world (65). Livestock is one of the fastest growing agricultural subsectors in developing countries (65). Habitat loss and degradation resulting from agricultural expansion and retaliation for livestock predation are key factors driving the decline of predators such as lions (2).

Global human population growth has fueled a massive increase in transportation networks. Transportation-related collisions with wildlife are one of the most widespread and persistent forms of human–wildlife conflict (4). Deer–vehicle collisions are common wildlife management and human safety challenges in Europe and North America, with an estimated 30,000 people injured and more than 200 killed annually in approximately 0.5 million collisions in Europe and 1–1.5 million collisions in the United States (66, 67). These collisions result in yearly damage in excess of US$ 1 billion in North America and represent the largest cause of deer mortality after hunting (68). Factors that can influence the location and frequency of collisions with animals like deer and moose include species-specific behaviors, traffic density and speed, and land cover and land use (69). Traffic on roads cause an estimated 89–340 million bird deaths each year in the United States (70), and wildlife strikes in aviation have claimed more than 250 human lives and more than 229 aircraft since 1988 (71). In the United States, 97% of the 131,096 wildlife-related aircraft collisions between 1990 and 2012 were caused by birds and resulted in an estimated $957 million annual direct and indirect losses (71).

World energy consumption is increasing rapidly, and growing energy production, including from the emerging renewable energy sector, poses a major risk for wildlife conflict and conservation (72). Oil exploration and exploitation directly and indirectly threaten wildlife populations virtually everywhere oil and natural gas drilling occur (73). Collisions with monopole turbines kill an estimated 140,000–328,000 birds annually in the contiguous United States (74), and the number of turbines and industrial solar installations is growing nearly exponentially (**http://www.awea.org**).

Increased conflict resulting from growing human populations, expanded cultivation and livestock husbandry, higher density transportation, and increased energy production have been balanced in part in some regions by stronger conservation laws, policies, institutions, and more organizations focused on human–wildlife conflict and coexistence. In the United States, populations of wolves increased rapidly after they were listed under the Endangered Species Act (75). Populations of some species that declined because of conflict, such as several of Europe's largest carnivores, have increased because of effective conservation practices, including improved laws and policies and more supportive public opinion (32). Increased habitat protection has also contributed to positive conservation outcomes. The world's protected areas network, particularly in less economically developed countries, has been growing nearly exponentially (76). By 2014, 15.4% of the world's terrestrial and inland water areas and 3.4% of the world's oceans were protected (77). Although protected areas alone do little to reduce conflict, and in some cases may exacerbate conflict, they do provide protected habitat and legal protection for some species.

4.2. Biological and Ecological Factors Influencing Conflict and Coexistence

There is often considerable variation among individual animals or groups in the frequency of crop raiding or livestock depredation. Some individuals within populations may never or rarely be involved with conflict, some occasionally involved, and others habitually involved (17). Life stage is one factor that may influence conflict probability. Old, injured, or sick animals may be more likely to engage in livestock depredation, crop raiding, or other risky endeavors because they can no longer compete for wild prey or have been displaced to suboptimal habitat by younger competitors (78, 79), although there is debate over how common this really is (30). In other situations, young animals may be more likely to engage in high-risk behavior. Increased conflicts between cougars (*Puma concolor*) and humans in the western United States may be the result of a young age structure of the population due to heavy hunting, which selectively targets older individuals, in addition to intrusion into cougar habitat by humans and habituation of cougars to humans (79, 80). These young animals may engage in high-risk behavior because of limited experience or be influenced by group social structure and networks (79).

Sex is another factor. Male Asian elephants and male African elephants (*Loxodonta africana*) are disproportionately involved in crop raiding behavior (26, 81). Male felids are more likely to kill livestock than females (16), and subadult male bears frequently encroach into human areas (82). This may be because in many species males have larger home ranges and are thus more likely to occur near human settlements (16). Females with cubs are also frequently involved in conflict (82).

There is growing evidence that social learning may have a major influence on the acquisition of raiding behavior among some species. In Kenya, approximately 30% of male elephants studied in Amboseli National Park were crop raiders, and a subset of 10 animals was responsible for more than 50% of the recorded crop raids (83). Male elephants may have an increased likelihood of raiding if they have older close associates who are raiders (78).

The distribution of food and water as well as other ecological factors are hypothesized to influence the distribution and abundance of conflict (17, 84). Wild prey availability can significantly affect the potential for and location of conflict. Felid attacks on people and livestock in many areas are higher with lower prey abundance (35, 85) or when native prey populations are more difficult to find (86). However, attacks may also occur in areas of high prey density. For example, depredation by Eurasian lynx (*Lynx lynx*) on domestic sheep in Norway and France may occur in areas where prey are abundant because lynx find these areas appealing, leading to higher rates of chance encounters with sheep (87, 88). Temporally, livestock depredation may decrease when natural prey populations are more readily available because of seasonal prey migration patterns or climatic changes, such as drought, leading to weaker prey populations (16). There is some evidence for thresholds above or below which conflict is more or less likely to occur. For example, Chartier et al. (89) suggest that elephant conflict in India was associated with a decrease in forest cover below 30–40%.

Temporal patterns of conflict are extremely varied among species and even differ between populations of the same species (35). In some situations, carnivore behavior may change as a result of persecution. Ethiopian wolves (*Canis simensis*) shift to more nocturnal behaviors when persecuted (90), gray wolves have adopted more secretive habits in parts of Europe where people are common, and red foxes are more diurnal where undisturbed (16).

The spatial distribution of wildlife and people can influence patterns of conflict. Conflict between wide-ranging predators and people near protected area borders is a major cause of mortality (16, 91), and numerous studies have found that decreasing distance from protected area boundaries and households is often a strong predictor of crop damage (62, 84). Depredation rates tend to increase with increasing proximity to natural habitat types that provide suitable cover for felids but decrease with increasing proximity to human habitation (35). In urban landscapes, conflict may occur on a gradient of development, with more occurring at intermediate levels of development (e.g., ex-urban and suburban landscapes) (11), particularly near natural areas, parks, agricultural areas, and other greenspaces (92). In the marine realm, variables that increase conflict risk include frequency of interaction, such as the density of whales within a shipping route, volume of shipping traffic, ship size and speed, and whale behavior (93). Factors that influence shark–human interactions include number of people at sea, shark population size, and a diversity of local economic, social, and biophysical conditions; people involved in board sports and swimmers are the most common victims (51).

4.3. Human Behavior Factors Influencing Conflict and Coexistence

Human relationships with wildlife are shaped by a wide range of social and psychological considerations, including diverse cultural and emotional experiences, economics, governance, and stakeholder engagement (94, 95). Human–wildlife conflict may also involve human–human conflicts among different stakeholder groups and include variations in perceived threats to lifestyles, values, and worldviews (6, 10, 12, 14).

Risk perception is one important ingredient in wildlife conflict, and there is often a mismatch between perceptions of risk, actual degree of risk, and proportional response to risk (96). Factors that influence perception of conflict risk include cultural values, histories and ideologies, intrinsic dread, and novelty of risk (96). For example, large, visible, and potentially dangerous species such as elephants may generate disproportionate concern even if species such as rodents or invertebrates cause more damage (2). A study of tiger killing behavior in the Sundarbans found that retaliatory killing for attacks on people or livestock or previous negative experiences with tigers may be less important than diverse sociopsychological factors, including risk perceptions, beliefs, attitudes, perceived failings of local authorities, perceived personal rewards, and contextual factors (e.g., the severity and location of tiger incidents) (97). How conflicts are framed by the media can shape public opinion (98), and education may encourage behaviors that reduce risks of conflict. Enforcement may keep people outside of protected areas, but both education programs and enforcement are challenging and require long-term commitments (27).

Other factors limit opportunities for communities to work together to reduce conflict. Some people may be unwilling to overcome distrust and different values to engage in meaningful dialogue, there may be a mismatch in the scale of the problem and parties involved, and legislation and enforcement tools may not be sufficiently flexible (5). Mitigation may be more difficult in regions where education levels are more limited or there are specific historical or cultural attributes (such as herding or hunting) that predispose communities to conflict. Gender is important because women and men use and interact with the environment in gender-specific ways and approach conflict differently. For example, women in Uttarakhand, India, disproportionately experienced decreased food security, changes to workload, decreased physical and psychological wellbeing, and economic hardship because of crop-raiding by elephants (99).

The historical context of any given conflict is also important (100). In Europe, many communities have had a long history of coexisting with carnivores and have developed livestock husbandry techniques, such as shepherding and night corrals, and policies, such as stable land tenure and strong legal protection, that promote coexistence (32, 61). Conversely, in the American West, after a century without large carnivores following widespread eradication, local communities may perceive the return of large carnivores as contradicting recalled historical values, recollections, and actions (100, 101).

In rural areas, increased agricultural activities have been attributed to increased conflict, but poor livestock husbandry and management practices in particular often contribute to high levels of livestock depredation (2, 35). Seasonal changes in livestock husbandry, such as lambing and calving periods or movement of livestock into vulnerable locations, can increase risk, whereas daily peaks in human activity can reduce risk (16). In and around urban areas, human–wildlife conflict is responsible for billions of dollars of damage and costs associated with mitigation and prevention (4), including lethal conflicts and nonlethal nuisance conflicts such as damage to landscaping and gardens, fouling of public spaces and noise, and raiding of garbage bins (11). Urban environments are notorious sources of urban mortality for wildlife, including from roads (102), collisions with buildings and other structures (70), depredation, and disease (57). Animals that move into human-dominated landscapes may show different behaviors than those in more natural landscapes (e.g., if they perceive humans as top predators), and may have more access to human-provided food, potentially increasing opportunities for conflict (103).

5. MANAGING CONFLICT: WILDLIFE

A wide range of responses have emerged, broadly categorized as lethal and nonlethal approaches, to prevent conflict from occurring or to reduce the frequency or severity of conflict. These can include activities that are regulated or unregulated and range from methods that require expensive infrastructure or government involvement to methods that can be carried out with low-cost tools by individuals.

5.1. Lethal Control

Throughout history, lethal control has been a common if sometimes controversial method to manage animal damage. At its most extreme, this has included a strategy of eradication of entire populations or even entire species (6). Bounties were once widely used to reduce and eliminate predator populations. For example, wolves and cougars were nearly eradicated in the western United States in the twentieth century as a result of predator control programs (31, 104). Lethal control is now more common to control abundant species, such as coyotes, or to selectively remove aggressive animals that have been unambiguously identified as directly threatening human life (17). Common methods used to kill animals include firearms, poison, and traps, such as neck snares and rotating-jaw traps (34).

Regulated harvest of animals combines monitoring and lethal control to achieve management objectives (6). Sanctioned lethal control (e.g., sport hunting) is widely used as a preventive or remedial measure (105, 106). In the United States, state management plans were developed to reduce cougar populations through sport hunting in part to decrease cougar–human interactions (106). Unregulated or illegal harvesting is a serious conservation concern for many species. In Sweden, approximately one-half of wolf deaths between 1998 and 2009 were attributed to illegal poaching (107), and in the western United States, slightly more than 12% of 711 radio-collared gray wolves were illegally killed between 1982 and 2004 (108).

Hunting can contribute to increased infanticide (109), increased hybridization, disrupted social structure and dispersal patterns, and reduced juvenile survival and recruitment (108, 110); it can also reduce gene transfer among populations (111). In some situations, selective removal of targeted animals results in less conflict. In a 10-year study of tiger conflict in Russia, Goodrich et al. (112) noted that removal of injured or unhealthy tigers resulted in fewer human deaths. Selective lethal control may also have no impact, or may even increase the likelihood of conflict. Among African elephants, individual crop raiders are often replaced by new recruits (83).

Efforts to reduce conflict using lethal control can have additional unintended consequences. In the US state of Washington, increased harvest of cougars was found to increase cougar interactions with livestock, prey, and people (106). In Australia, control efforts resulted in fewer dingoes (*Canis lupus dingo*), but in a case of mesopredator release, a greater number of feral cats (113). Retaliatory killing may also impact wildlife populations differently than other forms of hunting. In a study of leopards (*Panthera pardus*) in South Africa, retaliatory killing resulted in higher levels of leopard mortality compared to recreational sport hunting, especially at low leopard abundance, leading to more dramatic demographic consequences and thus risks to leopard population viability (114).

5.2. Nonlethal Control

Numerous nonlethal approaches are available to reduce conflict, and these approaches are often preferable for species of conservation concern. These include methods to move wildlife; separate wild animals from people and livestock; and use guard animals, mechanical tools, and chemicals to deter wildlife.

5.2.1. Translocation. Wildlife managers may selectively move wildlife away from locations where conflict is occurring or likely to occur. Numerous species have been translocated to address conflict, including bears, elephants, large felids, wolves, wolverines (*Gulo gulo*) and other mustelids, and even raptors (115). The success rate of translocations has been typically low and frequently expensive (16, 116). In a literature review of cases of translocation used to manage carnivore–human conflicts, less than one-half were successful and human-caused mortality accounted for 83% of deaths after translocations (116). Problems associated with translocations include the death of target animals or animals returning to their original capture site or continuing their conflict behaviors in new locations (115, 117).

5.2.2. Barriers and exclusionary devices. Barriers and exclusionary devices are widely used to reduce wildlife damage and can include constructed barriers (e.g., fences) or natural barriers (e.g., planted vegetation). Fencing restricts wildlife to specific areas, restricts movement of unwanted or invasive species, inhibits disease transmission, and protects small, valuable, or highly endangered species (118). Barriers range from those that are large enough to separate countries and protected areas to those that protect a single community, field, or house, or even smaller areas (8). Fences can be reinforced with electricity or other cues, such as fladry barriers consisting of flags hanging from ropes to discourage wolves (119).

Some regions have developed traditional barriers, such as bomas used in parts of Africa (constructed structures to separate livestock and wildlife) or hybrid "living walls" that combine fast-growing trees and traditional fencing (120). Habitat can be manipulated by creating plant barriers or by growing buffer crops to prevent crop raiding. In Asia and Africa, efforts to encourage chili cultivation by farmers have resulted in some limited success against elephants in small-scale trials (17, 121). Wildlife managers may modify habitats to discourage animals, such as by draining ponds or removing certain types of vegetation (8). Farmers sometimes provide alternative food sources to divert attention away from more valuable crops, such as planting additional grain fields to divert birds away from primary crop fields (4). Barriers can even include other animals. In Kenya, African honey bees (*Apis mellifera*) have been placed in fences, known as beehive fences, to try to reduce elephant crop raiding (122). Bears and other generalists may habituate to human environments in part because they can access high-quality food waste; as such, securing these food sources is a commonly used method to reduce incentives for bears to use human-dominated areas (82, 123).

Large-scale barriers such as fencing can have potentially serious conservation costs, however, including bisecting wildlife populations, restricting gene flow, changing vegetation, reducing carrying capacity, and increasing local hostility if traditional human movement patterns are also restricted (118). Large animals such as elephants can damage fences or walk long distances to circumvent barriers, and fence construction and maintenance can be expensive (17).

5.2.3. Guarding, restraints, and repellents. One of the oldest and most successful methods for reducing conflict is for people to watch over their livestock or crops. The costs of labor and the need for constant vigilance are the key drawbacks of this approach. Some predators, such as lions and tigers, may not be deterred by people, particularly at night or when people venture into carnivore habitat or are tending domestic animals or crops (35, 117). Throughout history people have modified livestock husbandry practices to protect their livestock. Common strategies (in addition to protective barriers) include changing of planting and harvesting schedules and modification of buildings such as grain storage facilities and barns (4). People may discourage free roaming of livestock or shift to keeping livestock protected within enclosures at night (2, 16).

Farmers in many areas train guard animals, particularly dogs, to protect livestock from predator attacks. Domestication of dogs is at least 9,000 years old and possibly as old as 30,000 years (44). The resurgence of carnivore populations, such as wolves in Europe and North America, and the banning of lethal control tools, such as poisons, has resulted in a return to the use of livestock guarding dogs (44). Dogs are used to protect livestock from cheetah in Namibia (*Acinonyx jubatus*) (124); coyotes, cougars, wolves, and black bears (*Ursus americanus*) in North America; wolves and bears in Europe (125); and dingoes in Australia (113). Llamas (*Lama glama*) have been used to protect livestock by acting as guard animals that are capable of counterattacking carnivores (6). Problems with guard dogs include the need for extensive training, control of behavioral problems such as inattentiveness, and prevention of premature death (e.g., from snake bites) (126). Dogs can also trigger conflict. The killing of trained hunting dogs and pets by wild carnivores may trigger retaliation and resentment (113). Wild dogs are also known to prey on livestock. In northern Spain, sheep remains were found in 3% of wolf scat and 36% of dog scat, even though wolves are often blamed for livestock losses in this area (113).

A wide variety of technologies are used to capture or repel unwanted wildlife. Restraining traps, such as foothold traps, snares, nets and cages, and other devices, enable capture and release of animals (4, 8). Animals can be repelled with fear-provoking stimuli, chemicals, or tools that startle or divert animals (4, 8). Common categories of fear-provoking stimuli include visual, auditory, olfactory, or habitat modification stimulants (4). For example, in Asia people use firecrackers, torches, or bang pans to deter elephants. Carnivores attacking livestock, or animals such as elephants raiding crops, can be discouraged from repeating these activities using aversive conditioning, the application of negative stimuli to change behavior such as using chemicals that taste bad or induce vomiting, electric shock collars, rubber bullets, loud noise or lights, guard dogs, and plants (4, 117).

A growing number of newly emerging technologies show promise for managing conflict. Radio telemetry is widely used in wildlife research but can also be used to understand and reduce human–wildlife conflict (34). For example, signals can be sent when livestock are motionless for extended periods to enable managers to more quickly evaluate the cause of death (117) or to determine whether predator movements are associated with temporal variation in depredation behavior (127). A variety of medical approaches are also being used to reduce conflict. Sterilization programs attempt to reduce conflict by reducing reproduction and fertility (8). Fertility control can be done through mechanical and surgical techniques, endocrine disruption, and immunocontraception (4). In some situations, particularly with abundant species like deer or wild horses, contraceptives have been used to reduce sexual activities of target animals instead of culling (71).

6. MANAGING CONFLICT: HUMANS

In addition to managing wildlife or building barriers, there is growing recognition that efforts to change human behavior can be as or more important than simply reducing damage caused by wildlife (94, 96). Common methods used to study the human dimensions of conflict and coexistence include surveys and interviews, direct field observations, ethnographic approaches, community participation and focus groups (including participatory rural appraisal), and other forms of direct engagement with communities and stakeholder groups (2, 5, 8, 34, 94). A full description of all these approaches is beyond the scope of this review but two important approaches widely addressed in the human–wildlife conflict literature include leveraging public policy and applying economic tools (**Figure 3**).

6.1. Governance and Policy

Public policy is one important ingredient in strategies to promote coexistence of people and wildlife (95), and a diverse suite of policy responses has been used to address human–wildlife conflict. Some of the most notable, particularly in Europe and North America, include stable political institutions, national laws and international agreements, effective law enforcement, and wildlife-friendly economic and agricultural policies (32). In the United States, the Fish and Wildlife Service, Congress, individual states, and state and federal courts have played a role in efforts to retain or remove federal protection under the US Endangered Species Act for many species, including wolves and grizzly bears (95). One major problem is that large animals such as wolves can cross state, province, or country boundaries, and different regions have different legal requirements. Another problem is that policy outcomes may differ from the original intent. For example, policies intended to encourage proconservation behavior may have unintended consequences. A program that allowed up to 43 wolves implicated in livestock attacks in the US state of Wisconsin to be culled with the intent to foster greater social tolerance for wolves actually failed to increase tolerance (128).

A wide range of approaches encourage people to work together to resolve wildlife and conservation conflicts in a proactive way, including education and information sharing, comanagement, collaborative and participatory planning, risk assessment, strategies to change perceptions, poverty

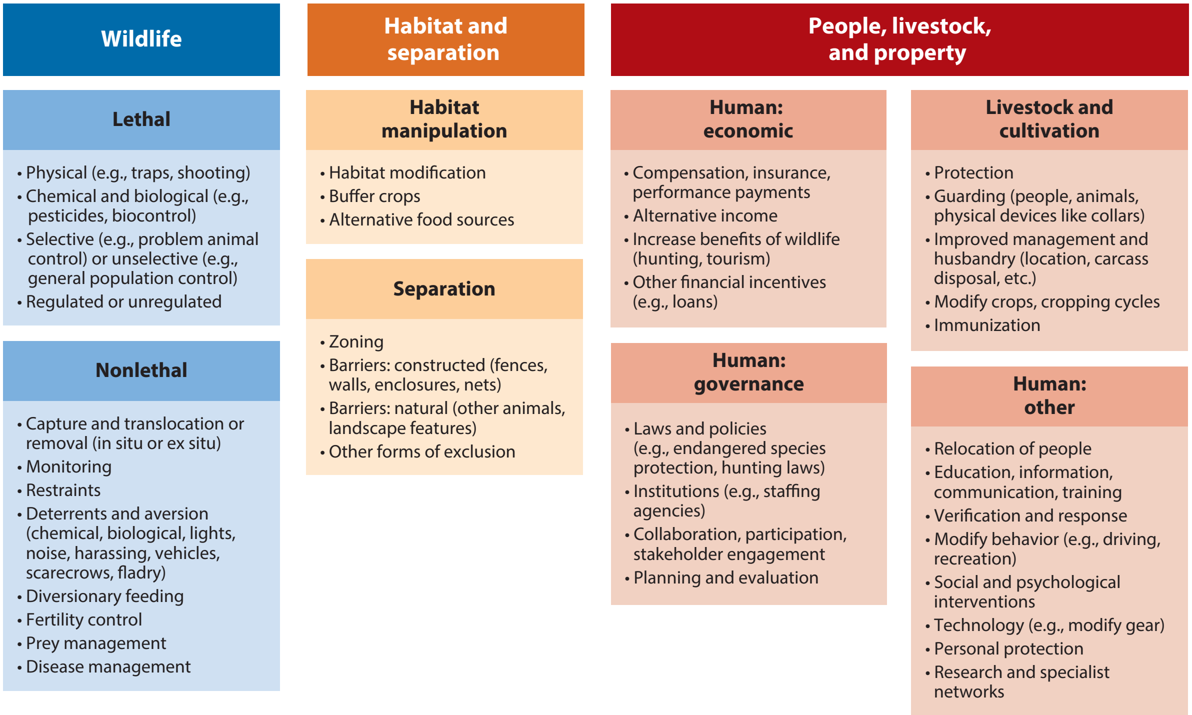

Figure 3

Summary of selected common approaches used to mitigate human–wildlife conflict and promote human–wildlife coexistence organized by broad categories of intervention (8, 24, 26, 136, 146). The categories are not mutually exclusive (e.g., almost all interventions are influenced by laws and policies). Some interventions, such as fences, could be more focused on wildlife (e.g., electric fences to restrict elephant movement) or people and livestock (e.g., pens to restrict livestock movement).

alleviation programs, community-based natural resource management, and other forms of stakeholder engagement and processes (2, 5, 10, 95, 129, 130). Some approaches may work at the landscape scale. For example, spatial zoning is widely used as a land use conservation tool but has been understudied as a conflict mitigation tool (2). At the simplest level, zoning can be used to delineate wildlife areas (e.g., protected areas where hunting is forbidden) and people areas (e.g., where hunting is legal). These zones can regulate management objectives, restrict access, control responses, and help to prioritize economic outlays, such as subsidies or compensation (117). In the marine realm, spatial planning is a form of zoning that is gaining acceptance as a tool for preventing whale-ship conflict (93).

6.2. Economic Responses

Economic incentives are widely applied to increase tolerance for predators and other wildlife (75). Four common economic tools include compensation, insurance, performance payments, and incentives.

Compensation typically involves reimbursing with cash or in-kind payments people who have experienced wildlife damage to crops or livestock, or who have experienced personal injury or threats from wildlife. The idea behind these payments is to increase tolerance for wildlife (131). Common challenges associated with compensation schemes include the difficulty of verifying the cause of damage; slow, cumbersome, or insufficient payment; moral hazard (e.g., farmers may have little incentive to protect livestock if they can obtain economic compensation for depredation); high transaction costs; and problems of trust and transparency (117, 131, 132). In Norway, for example, Sámi reindeer herders must prove that dead reindeer were killed by lynx or wolverine to receive compensation, but herders find remains of only 5% to 10% of the reindeer that they lose (133). Many compensation programs only compensate direct effects of livestock losses, but carnivores can also cause indirect losses such as insufficient weight gain in livestock from stress, which can impact animal health and reproduction. Knowing how to adequately price these damages is difficult (134). To address the criticism that compensation may reduce incentives of participants to take efforts to prevent conflict, many programs now require proof of improved livestock husbandry to receive payments (117).

Insurance schemes are similar to compensation programs but typically require participants to pay a premium (12). Insurance can promote fair payments by better incorporating the risk into the price of premiums and payments (135). Insurance schemes are also challenged by the risk of fraudulent claims and adverse selection (e.g., difficulties differentiating between low-risk and high-risk clients) (131). The challenges of small pools of participants and high premiums have been addressed in some areas by supplementing funds with government or nongovernmental support, community financing (e.g., through ecotourism), or better risk evaluation (131, 135).

Performance payments compensate people on the condition of wildlife abundance. These payments establish a direct link between monetary payments and the production of desired conservation objectives (12, 131) but differ from traditional subsidies, which are not typically linked to conservation outcomes (136). In Sweden, Sámi reindeer herders were paid for wolverine reproductions, resulting in reduced female mortality and an increase in wolverine populations of almost 120% within a decade (137).

A variety of other economic incentives and benefits may offset the cost of conflict. Photographic tourism and other forms of ecotourism in which tourists pay local communities to see wildlife may reduce incentives to eliminate wildlife that cause conflict (98). Trophy hunting can enable hunters who kill carnivores to pay fees that can be returned to local communities (98, 138). In countries such as Namibia, conservancies enable communities and collaborating landholders to share costs and benefits of carnivore presence (98).

7. CONCLUSION AND FUTURE RESEARCH NEEDS

Tremendous progress has been made in our understanding of the importance of human–wildlife conflict, biological and social factors that influence conflict, and strategies to reduce conflict and promote coexistence, but the field is in its infancy and there are abundant opportunities for further research. The following observations identify gaps and emerging opportunities for future scholarship related to human–wildlife conflict and coexistence.

7.1. Engaging Different Disciplines

Studies in the human–wildlife conflict literature draw on many different disciplines, including anthropology, biology (including animal behavior, conservation biology, ecology, genetics, wildlife ecology, zoology), economics, environmental studies, geography, history, natural resource management, political science, and psychology, among others. This disciplinary diversity has already yielded a rich mix of interesting studies and is likely to continue to be an incubator for novel ideas in the future. Potentially interesting avenues for further scholarship include the following:

- Further work on the role of evolution in understanding human and wildlife behavior in the context of human–wildlife conflict could help to inform both human and wildlife responses to conflict.
- The explosion of recent scholarship exploring the role of apex consumers in regulating top-down forcing in ecosystems and associated trophic cascades (3) offers abundant opportunities to improve our understanding of how human–wildlife conflicts impact the process, function, and resilience of local, regional, and global ecosystems (3).
- Innovations in economics and political science in managing common property resources may provide interesting avenues for scholarship related to managing human–wildlife conflict (95).
- Efforts to link conflict scholarship to other conservation priorities and emerging areas of study, such as large landscape conservation, conservation genetics, and conservation psychology, may produce fertile opportunities for novel collaborations. Expanding beyond the more obvious links to conservation, there is a need to better understand how land use planning and infrastructure development—from energy production to agriculture to transportation—may increase or decrease human–wildlife conflict.
- Understanding how conflict is related to environmental justice and human rights should be further explored. The role of gender is another area of human–wildlife conflict that has not been adequately addressed (99), including hidden costs that are uncompensated, temporally delayed, or psychological or social in nature (99).

7.2. Crossing Boundaries

The wildlife conflict literature has understandably focused on distinct categories of animals (e.g., carnivores and herbivores), families (e.g., felids, canids), species (e.g., tigers, wild dogs), or other biological or taxonomic groupings, as well as specific regions. These studies commonly focus on quantifying conflict or identifying common spatial or temporal patterns of conflict. Abundant opportunities exist for a fuller understanding of generalizable patterns across broad taxonomic groupings and geographic regions.

Similarly, most human–wildlife conflict scholarship addresses just one ecosystem (e.g., terrestrial or marine). There may be opportunities to understand novel patterns of conflict and explore novel solutions by looking at conflict comparatively across diverse ecosystems, including the atmosphere (e.g., conflict resulting from air transportation).

7.3. Scale and Complexity

The study and practice of human–wildlife conflict and coexistence is fascinating because of the diverse scales involved. Conflict may occur at the scale of households and farms but wildlife populations may reside at the scale of regions, and laws and institutions protecting species or promoting coexistence may cover states, countries, or multiple countries (e.g., the European Union).

- A growing number of studies have sought to synthesize data across continents and regions, notably in Europe and North America, or even globally, but abundant opportunities remain to carry out comparative studies and to mine the growing global data on wildlife conflict to better understand the role of scale in the causes of and solutions to conflict.
- Some regions (e.g., Europe and North America) and taxa (e.g., bears, lions, tigers, and wolves) have been studied more than others. There is a need to encourage scholarship in underrepresented geographic regions and scholarship focused on underrepresented taxa, such as smaller felids.

- The emergence of research on coupled human–natural systems and complexity theory (139) offers fertile opportunities to better understand how nonlinear dynamics, tipping points and thresholds, reciprocal feedback loops, and time lags may be applied to human–wildlife conflict (140). Linked ecological and social assessments of conflicts are still not widespread (141). For example, are there changes in wildlife or livestock population abundance or conflict frequency above or below which coexistence is more feasible? A better understanding of tipping points and complex adaptive systems could further inform our understanding of appropriate policy responses.

7.4. Collaboration to Fill Data Gaps

One of the constraints to undertaking more comparative scholarship is the difficulty in accessing data and different approaches to measuring data from different taxonomic groups and regions. A growing number of governments and organizations are making data available for entire regions but global data sources remain scarce for most species. The International Shark Attack File (51) is an example of a global network that serves as a clearinghouse to collect and disseminate data on shark–human conflict. Further development of regional and global databases and standard protocols for data and metadata collection could help to catalyze collaborations and larger analyses. Another example is the pan-European collaboration to study large carnivore conservation and reintroductions across the continent (32). A third possible model is the One Health approach developed to recognize the inter- and multidisciplinary challenges associated with integrating human, animal, and environmental health in studying and mitigating threats posed by zoonotic diseases (142). A similar approach might be feasible for human–wildlife conflict and coexistence studies.

7.5. Hypothesis Testing, Comparative Studies, and Quantitative Analysis

Many studies are descriptive or draw conclusions based on one location or species with limited applicability to other taxa and regions. More comparative and predictive studies are needed that are explicitly designed to test generalizable hypotheses. For example, many studies have found that conflict tends to increase closer to protected areas, but these observations are rarely compared to findings from other regions. Similarly, numerous studies have described and evaluated individual compensation programs, but few studies have explicitly tested assumptions about factors that might influence the success of these programs by setting up experiments to control for specific variables (e.g., the amount or timing of compensation payments).

A growing number of studies are moving beyond simple surveys and using increasingly sophisticated and rigorous quantitative methods and adapting analytical approaches from other disciplines to assess conflict (107). One specific step toward effective evaluations of population impacts is to consider the science of sampling design on population monitoring (143). The application of rigorous statistical sampling methods revolutionized the use of camera traps for monitoring tigers and other wildlife (144), and progress in quantitative analyses could have a similar impact on human–wildlife conflict studies.

7.6. New Tools and Technologies

The technology available to study and to mitigate conflict is changing rapidly. The emergence of inexpensive mobile phones and communication networks, digital photographs, satellite imagery, global positioning systems, lighter and longer-lasting radio collars, and powerful portable tablet computers are just a few technologies already transforming the study and mitigation of human–wildlife conflict. The recent emergence of inexpensive drones and the global ubiquity of electronic social networks are almost certainly going to revolutionize how information is gathered and used.

7.7. Our Changing World

Climate change is one of the most important threats facing people and wildlife and is a focus of considerable research in every discipline, including biodiversity conservation (145). Studies of conflict in the face of changing climate, including strategies for resilience, how climate change will stress coupled human–natural systems, and how current patterns of conflict are likely to change in the future, are few.

Land use, land cover, and entire ecosystems are changing because of the changing climate and the growth and scale of the human enterprise. Efforts to conserve wildlife populations in the face of these changes, efforts to manage new species assemblages, or successful wildlife restoration may lead to novel challenges.

Ambitious plans to protect and increase populations of large carnivores in human-dominated landscapes, like those to recover wild tiger populations in Asia, will have to account for these changes and how they may influence human–wildlife conflict (see sidebar, Human–Tiger Conflict and Coexistence). Some of the boldest proposals, such as the controversial idea of Pleistocene rewilding (the proposed reintroduction of proxies for Pleistocene megafauna, such as introducing elephants to North America to mimic the ecological impacts of extinct mammoths) (146), are gaining traction, but basic empirical research on trophic rewilding is still limited, including how to reduce human–wildlife conflicts.

Our increasingly connected planet offers abundant opportunities to consider how to expand the definition or zone of influence of what constitutes human–wildlife conflict. For example, the global growth of persistent synthetic chemicals (e.g., chlorinated and fluorinated compounds) impacts human and wildlife health. There is a need to consider whether ubiquitous stressors (e.g.,

HUMAN–TIGER CONFLICT AND COEXISTENCE

Tigers (*Panthera tigris*) were once widespread throughout South, East, and Southeast Asia. In the past century three tiger subspecies have gone extinct, and one subspecies persists largely in captivity. More than 90% of historic tiger habitat has been lost, and more than one-third of the world's human population now lives in tiger range states (152, 153). Tiger predation on people and livestock historically led to widespread official and unofficial persecution (27). Today, only approximately 3,000–4,000 wild tigers remain and are spread across fragmented protected areas and habitats (**http://globaltigerinitiative.org**). Habitat loss and poaching are primary threats, but human–tiger conflict remains a significant impediment to the conservation and recovery of wild tiger populations in Asia in some areas (27). Reduced conflict through nonlethal prevention (e.g., better livestock husbandry and barriers), mitigation (e.g., compensation), and an increase in the perceived ecological and economic value of tigers (e.g., tigers as apex predators influencing trophic cascades or drivers of tourist revenue) would promote human-tiger coexistence. Additional pressures caused by agricultural expansion, economic and infrastructure growth, pollution, and climate change are daunting. But these challenges also afford extraordinary opportunities to apply lessons learned from decades of human–wildlife conflict and coexistence scholarship and practice to envision and to carry out one of the twenty-first century's boldest conservation challenges: a future where people, wild tigers, and the region's extraordinary biological diversity can coexist in some of the world's most human-dominated landscapes.

endocrine disruptors) may in fact represent an insidious and chronic form of human–wildlife conflict.

7.8. Further Defining Conflict and Coexistence

Several important debates are ongoing within the human–wildlife conflict community. Some of the most interesting scholarship in recent years has explored to what extent large carnivores and people can share the same landscape, and where this vision of coexistence is applicable outside of Europe and North America. In these regions, numerous large carnivore populations are stable or increasing in human-dominated landscapes, often outside protected areas (32), but it is unclear whether this model is transferable globally or what would be needed (e.g., resources, improved governance) to export this model. A growing number of studies describe how carnivores and people can coexist at smaller spatial scales near protected areas (147) or even within some of the world's largest cities (148). At the same time, calls to fence threatened carnivores in Africa have been proposed and debated (149). The relative benefits and drawbacks of these approaches are likely to engender continued and strenuous debate. There is still a need to meaningfully define coexistence and to further understand the complex and interacting biological, social, economic, political, and cultural factors that ultimately determine why some regions and species may be more amenable to human–wildlife coexistence than others, whether this is an enduring concept, and the constraints to achieving this goal.

7.9. Toward a Field of Human–Wildlife Conflict and Coexistence

The diversity of scholars and practitioners representing many disciplinary backgrounds and diverse taxonomic and geographic specializations involved in the study and management of human–wildlife conflict is strong; however, this diversity is also a constraint to developing a legitimate field of human–wildlife conflict and coexistence studies. This field arguably already exists in the form of scholars associated with human dimensions of wildlife management, wildlife damage management, conservation biology, and affiliated disciplines, including organizations, academic affiliations, and journals that address human–wildlife conflict and coexistence directly or indirectly; however, these still tend to be relatively balkanized (e.g., by discipline or even by country and region) (94, 150, 151). The time may be ripe for a convergence of these approaches into a field with a distinct name: Anthrotherology (from the Greek *Anthropos*, meaning human, and *ther*, meaning wild animal) might be a reasonable starting point for discussion. (Anthropotherian symbiosis might more accurately represent human–wildlife conflict and coexistence but would be a mouthful.) Regardless of the name, the study of human–wildlife conflict and coexistence has emerged as an important interdisciplinary field that is certain to grow in significance. This will undoubtedly lead to advances in our ability to conserve the world's biological diversity while simultaneously addressing the health and welfare needs of people.

SUMMARY POINTS

1. Human conflict with wildlife has contributed to the decline and extinction of many species, particularly large terrestrial carnivores.
2. Important underlying drivers of conflict include expanding human populations and associated growth in agriculture and livestock, urbanization, energy, and transportation.

3. Numerous factors may predict why some animals or groups of animals are more likely to damage crops, or kill or injure livestock or people. These include animal life stage, sex, season or time of day, proximity to cultivation, and proximity to natural habitat. Frequency of interaction is often an important predictor of conflict between people and ocean predators.
4. Human relationships with wildlife are influenced by differences among different stakeholder groups over perceived threats to lifestyles, values, and worldviews. Risk perception, historic context, and social, cultural, and political influences can increase or decrease opportunities for conflict.
5. Throughout history people have killed animals to minimize or eliminate property damage or threats to human safety. Diverse lethal and nonlethal methods are available to prevent conflict before it occurs or to ameliorate the impacts of conflict after it occurs, including economic tools such as compensation or insurance payments.
6. There is growing recognition that people and wildlife can coexist in human-dominated landscapes with appropriate tools and management, public policies, and societal support.

FUTURE ISSUES

1. How can scholarship from diverse disciplinary perspectives—such as the study of genetics, evolution, trophic cascades, common property resources, conservation psychology, and environmental justice—inform our understanding of human–wildlife conflict and coexistence?
2. How can scholars and practitioners design comparative and predictive studies, including from underrepresented taxa and regions, to better understand patterns of human–wildlife conflict at different scales and levels of complexity?
3. Can regional and global databases and standard protocols for data and metadata collection be developed or enhanced to further catalyze collaboration?
4. How can novel analytical methods and emerging technologies such as mobile phones, electronic social networks, high-resolution satellite imagery, and drones inform our understanding of human–wildlife conflict and promote human–wildlife coexistence?
5. How will patterns of human–wildlife conflict shift in the face of global change, and what opportunities and challenges will this pose for efforts to encourage human–wildlife coexistence in an increasingly human-dominated world?
6. How will successful recovery of wildlife populations increase or decrease the frequency and distribution of human–wildlife conflict and encourage or discourage human–wildlife coexistence?
7. Can we improve our understanding of the ecological, economic, cultural, institutional, political, social, and technological factors necessary to promote human–wildlife coexistence?

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149. Emerging debate in the conflict and coexistence literature; i.e., what role do fences play?

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