The Impacts of Large Carnivores on Human Livelihood:

The Illusion of Carnivore Conflict, Costs of Coexistence, and Strategies for Mitigation

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Abstract

Incidents of what is commonly referred to as human-carnivore conflict (HCC) are increasing. Examples include livestock depredation and carnivores attacking humans. Since HCC occurs most frequently where humans and carnivores commonly inter-mix – near the periphery of human habitations – habitat loss and fragmentation may contribute to the rise of HCC, amongst other factors. Although HCC cannot be eliminated, it can be reduced by well-planned and implemented strategies. These strategies must approach the conflict holistically and address both the animal and the human sides of the problem. Since humans rely on the healthy functioning of the ecosystem for survival, implementing these solutions, especially in high-risk HCC areas, is important if the ecosystems comprising the world are to continue to function properly.

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Introduction

On November 2, 2018, the six-year-old tigress, Avni, also known as T1, was shot dead. She allegedly killed at least seven humans from 2016-2017, although only circumstantial evidence exists. Designated a problem animal, she was terminated from the wild over a year later (Govind & Sreedhar, 2018). Avni's death, and the controversy which sparked from it, highlight an important issue in the world of conservation today: human-carnivore conflict (HCC). With an increasingly fragmented landscape, an ever-growing human population, and desperate efforts focused on saving the 16,000+ endangered species of the world, human-wildlife conflict has been on the rise. Some of the most recognized species involved in this conflict are large carnivores (Barua et al., 2013; Hoekstra et al., 2004).

This apparent conflict often results in high numbers of carnivores dying by human hands through retaliatory killings. Since many of these species, such as tigers and lions, are threatened or endangered, these killings exacerbate their imperiled status and harm conservation efforts (Distefano, n.d.; Everatt et al., 2019; Inskip & Zimmermann, 2009). Many communities dislike charismatic carnivores, despite their cultural significance, because of the challenges they present (Barlow et al., 2010; Mulder et al., 2015). However, these animals fulfill an essential regulating role in ecosystems. Without them, diseases could spread more rapidly through overpopulating ungulates, and oxygen-producing vegetation communities would diminish (Dobson et al., 2006; Kawata, 2009). Since humans depend upon nature for their lives and livelihoods, protecting carnivores will promote healthy ecosystems and benefit mankind in the long-term.

What Is Human-Carnivore Conflict

Human-carnivore conflict (HCC) is defined in the literature several ways depending on the specific facet(s) the author(s) is discussing. One common definition of HCC is "any negative interaction between humans and carnivores" (Messmer, 2000, p. 100). These conflicts can be real or perceived. They range from being economic to aesthetic and social to political (Messmer, 2000). A second popular definition is when human goals are negatively impacted by the needs and behavior of carnivores [or vice versa] (Barua et al., 2013). Competition for shared resources (e.g. space or livestock and game species for food) between carnivores and humans is a third definition (Atwood & Breck, n.d.; Distefano, n.d.). There are a host of other definitions; all of which are equally valid in describing HCC. The main idea encapsulated by the term human-carnivore conflict, however broad or narrow the author(s) defines it, is a human having a negative experience with a carnivore, usually large and charismatic. This could be caused by the carnivore killing or injuring a human, preying on livestock or game species, introducing a zoonotic disease, evoking a human to feel fear, or producing any other negative consequence or emotion (Atwood & Breck, n.d.; Barua et al., 2013; Distefano, n.d.; Messmer, 2000).

The literature indicates HCC is on the rise (Graham et al., 2005; Inskip & Zimmermann, 2009). The reported reasons for this increase are numerous. Amongst the explanations cited is the growing human population. Linked with this are the rise of urbanization and the expansion of agricultural lands, both of which are associated with habitat fragmentation and loss (Barua et. al, 2013; Poessel et al., 2013). Since large carnivores require extensive home ranges, habitat fragmentation and loss force these animals into closer proximity to human-dominated landscapes, increasing the likelihood and frequency a person will encounter a carnivore (Graham et al., 2005; Michalski et al., 2005).

Habitat fragmentation and loss may have a negative effect on prey abundance because habitat reduction and shrinking habitat patches typically results in declining species abundances (Bender et al., 1998). The declining habitat coupled with pressure on the carnivore prey base from hunters decreases prey availability and may increase a carnivore's reliance on domesticated livestock. Domesticated livestock are easy pickings for carnivores because most have lost important anti-predator defenses (Graham et al., 2005). Additionally, when poor livestock management strategies are used, the probability of a depredation event rises (Barua et al. 2013; Graham et al., 2005). The success of conservation programs, which result in increased carnivore populations, has also been blamed for the recent escalation of HCC, as it was in the case of Avni (Fig. 1; Barua et al., 2013; Govind & Sreedhar, 2018; Messmer, 2000). The issue of HCC is complex, and all these factors likely play a role with varying weights, depending on the region where the conflict is occurring.

Figure 1. Because of successful conservation efforts, the tiger population in India is increasing, giving rise to higher rates of human-carnivore conflict. Photo by Ondrej Prosicky.
Source: Shutterstock (https://www.shutterstock.com/image-photo/indian-tiger-male-first-rain-wild-667856146)

The degree of HCC which an individual reports is influenced by attitude, perception, level of education, value system, religion, culture, and the economic importance of livestock to their own livelihood (Inskip & Zimmermann, 2009). These factors combine so each person has a unique tolerance of and perspective on HCC. The neighborhood effect – the idea people within the same region tend to have similar perspectives due to common experiences – may likewise play a role in determining a person's tolerance of wildlife interactions (Atwood & Breck, n.d.). If a person's view of carnivores is negative, they may exaggerate the severity of HCC experienced (Inskip & Zimmermann, 2009). Therefore, studies which rely on surveys to quantify HCC in an area where prevalence is relatively high might produce exaggerated results if the reported information is not rigorously checked (Barua et al., 2013; Distefano, n.d.).

Since those in urban environments typically do not rely on the land for their source of income, their experience of HCC will most often be minimal; thus, they tend to have positive views of carnivores. Those who rely on the land for their livelihood, especially those who raise livestock, tend to have negative views of carnivores since their experiences with them will more frequently result in economic losses (Messmer, 2000). Those most affected by HCC live in developing countries where dependence upon the land is high (Barua et al., 2013). These people suffer the largest proportion of economic losses, partly due to their inability to invest in simple livestock management techniques which reduce HCC such as fences and water troughs (Inskip & Zimmermann, 2009; Michalski et al., 2005).

Conservationists argue carnivores are beneficial and even vital for the flourishing of the land; however, those affected by HCC may have a difficult time seeing this when carnivores cause so much loss (Barua et al., 2013). The differing viewpoints on the role carnivores play in the environment and the resulting conflict of interest between conservationists and stakeholders of the community who view carnivores negatively may exacerbate perceived HCC and reinforce negative perceptions of large carnivores (Redpath et al., 2015).

The Importance of Framing: Drawbacks to the Term Human-Carnivore Conflict

The term, human-carnivore conflict, has a few drawbacks. Since it is used to describe both the real and perceived negative impacts carnivores exert on human lives and livelihoods, there is a lack of consistency for the definition across the literature. Additionally, this term is used to describe the conflict between conservationists and stakeholders who oppose them, which is not a conflict between carnivores and humans at all, although it is masked as such. However, there is a problem with this term which runs even deeper and has to do with how the use of language influences our perceptions (Peterson et al., 2010; Redpath et al., 2015).

Words are powerful. The way issues are spoken about affect how people interpret reality and vice versa. One person may describe a concept or experience using words with positive connotations while another individual may explain the same concept or experience with language carrying negative implications (Peterson et al., 2010). For example, the words childish and youthful both refer to a young person, but the first word carries a negative connotation implying immaturity while the second conveys the idea of innocence and fun (“Connotation”, n.d.).

A terministic screen, a concept introduced by the literary theorist Kenneth Burke in 1966, is the idea the words one chooses serve to emphasize some experiences of life and deemphasize others (Peterson et al., 2010). Terministic screens can be used to either reinforce or alter the perceptions in our minds. The term, human-carnivore conflict, defined as any action a carnivore performs which causes a human to experience a negative consequence, either real or perceived, is a terministic screen (Messmer, 2000; Peterson et al., 2010).

The problem with this term is the word “conflict”. Human-carnivore conflict implies carnivores are conscious antagonists who knowingly steal livestock or otherwise cause harm to human lives and livelihoods (Peterson et al., 2010). However, this is not the case since animals are not aware of the negative or positive effects of their actions. They are no more conscious of the pleasure they elicit when they present themselves to a group of tourists than they are aware of the sense of grief they create when they take a human life.

There are two dimensions of HCC, both of which are obscured by framing the problem as such. In fact, because of the psychological priming effect, framing the issue as HCC may even hinder the ability to find effective solutions which will promote peaceful living with large carnivores (Redpath et al., 2015). The psychological priming effect is the idea exposure to a stimulus (perceptual, semantic, or conceptual) triggers the subconscious mind to activate certain pathways and makes some thoughts easier to access than others (Kahneman, 2011).

There are two ideas compressed into the expression HCC which could be better captured by splitting the term apart. The carnivore dimension is most heavily indicated by the phrase, albeit skewed by the word “conflict”. Particularly, the carnivore dimension encompasses the reality large carnivores tend to be difficult to live with in close proximity because they require large tracts of land, may consume livestock, and may cause human injury and death, or may have other negative impacts on human lives and livelihoods. This component can be called human-carnivore impacts (HCI) to refer to these challenges which result from sharing the land (space and resources) with carnivores (Redpath et al., 2015). The human aspect of the problem, which involves the conflict between conservationists seeking to preserve nature and those who oppose them, often in the name of increasing human wellbeing, is obscured by the term HCC. This facet could be more appropriately labeled human-human conflict (HHC), specifically referring to the conflict between conservationists and other stakeholders over how to best manage the landscape and the animals within it. When used in conjunction, the terms, HCI and HHC, fully portray the issues behind what has been popularly called HCC (Peterson et al., 2010; Redpath et al., 2015).

Separating HCC into the divisions of HHC and HCI highlights the animal side of the problem while rejecting the implication carnivores are conscious antagonists. It also accentuates the human dimension of the problem which is frequently minimized or ignored although there has been growing awareness of it in recent times (Atwood & Breck, n.d.; Redpath et al., 2015). By acknowledging the human aspect, the door opens for conservationists to see themselves and the opposing stakeholders as part of the problem (Redpath et al., 2015). Reframing the issue in this light may encourage conservationists to initiate discussions with the opposing side and might open the door to find effective and untried solutions which will benefit both the carnivores and the community experiencing HCI.

Costs of Coexistence

Human-carnivore impacts and human-human conflict occur worldwide at varying intensities across the globe. Much of the HCI and HHC experienced in a region depends on the carnivores involved, the culture, and the history between conservationists and other stakeholders (Graham et al., 2005; Inskip & Zimmermann, 2009; Madden & McQuinn, 2014). Human-carnivore impacts include both visible and hidden costs, although much of the literature focuses on the visible consequences (Barua et al., 2013).

Visible Impacts

The visible costs of HCI are typically economic in nature or relate to injury and loss of life. Others occur when carnivores kill game species or when they are killed in vehicular collisions, sometimes causing damage to the automobiles (Graham et al., 2005; Messmer, 2000).

These costs are relatively easy to quantify. However, since there is no standard method for measuring economic losses and injury or death resulting from HCI, the literature containing this type of data is impossible to compare (Distefano, n.d.; Inskip & Zimmermann, 2009). Actual economic losses caused by HCI tend to be small on a national scale; however, these losses can be devastating at the local and individual level, especially since those who bear the brunt of the economic losses are low-income pastoralists who live in developing countries (Bulte & Rondeau, 2012; Graham et al., 2005).

One study calculated lions in parts of west and central Africa cause economic losses of up to US$130,000, a price which is extremely high for rural farmers to shoulder (Barua et al., 2013; Bauer et al., 2001). Another study stated predators take between 0.02-2.6% of livestock annually in a given region. In some Nepal villages, a loss of 2.6% of livestock resulted in a per capita income loss of 25% (Graham et al., 2005). Michalski et al. (2005) reported large felids in the Amazon are responsible for up to 30.8% of livestock losses. In the United States, livestock depredation results in economic losses exceeding US$73 million (Messmer, 2000).

Livestock depredation is discussed in the literature more frequently than attacks on humans because of its higher economic impact. However, injury and loss of life are devastating consequences of sharing the land with carnivores. In Tanzania, between 1990 and 2004, 800 people died from lion attacks. This amounts to roughly 57 people killed each year (Barua et al., 2013). In the Denver Metropolitan Area, CO, USA (DMA), coyotes attacked 13 humans during a span of eight years. Half of the attacks involved pets and resulted from the human trying to save their dog. No one was reported dead. This amounts to approximately one to two attacks each year in the DMA (Poessel et al., 2012). Because these studies differ in scale and did not report total population, they are incomparable in terms of the total percentage of people attacked.

Hidden Impacts

The hidden impacts of HCI remain largely uninvestigated despite their close link with the visible costs. They include uncompensated monetary expenses which do not directly result from depredation (e.g. money spent on mitigation strategies). They may also be temporally delayed or psychosocial in nature (Barua et al., 2013). As with the visible impacts, the severity experienced by an individual varies depending on the type of HCI as well as a person's degree of poverty, access to resources, and social capital (Barua et al., 2013; Distefano, n.d.).

When HCI result in the death of a human, the primary hidden impact is grief. The experience of losing a loved one through an attack is traumatic, not only because it is unexpected, but also because the body is often unable to be recovered. This prevents the family from being able to perform the traditional funeral rites in their region (Barua et al., 2013). In the developing countries where HCI are experienced most severely, the death of a loved one can alter the entire structure of a family's day-to-day life, thus causing significant levels of stress and secondary effects. For example, the loss of the primary bread-earner, which is typically the male of the family, shifts the wage-earning responsibility to the woman and her children. Conversely, the death of the woman could shift the household chores to the children. Both these situations increase the likelihood of the children dropping out of school. Furthermore, post-traumatic stress disorder (PTSD) has sometimes been observed in the family members of the victims of carnivore attacks (Barua et al., 2013). In some cases, HCI cause a family to experience a lack of food security. The stress in this situation may diminish a person's state of psychological well-being. If depredation of livestock results in high enough losses, the family may need to find an alternative source of income (Barua et al., 2013).

Sometimes, the mitigation strategies implemented to minimize HCI carry negative impacts which may increase perceived HCI, even if the strategies are effective in reducing depredation and other forms of HCI. These costs are important to consider when conservationists and other stakeholders work together to determine the best strategies to minimize both HCI and HHC (Barua et al., 2013; Inskip & Zimmermann, 2009). A common mitigation strategy is livestock guarding. Livestock guarding increases the risk of contracting Malaria and Trypanosomiases (African Sleeping Sickness) since it requires extensive periods outdoors at times when mosquitoes and other insects are most active. Both these diseases may be fatal if left untreated. Livestock guarding carries other costs as well. The task of protecting the livestock primarily falls on the adult male at night and on the children during the day while the male engages in other wage-earning activities. This results in a lack of sleep and poor mental health on the part of the adult male as he tries to make ends meet for his family. Guarding of crops from elephants is known to increase alcohol consumption in adults (Barua et al., 2013) – the same may be true for those who protect livestock at night. When the children guard the livestock during the day, they are often forced to drop out of school which hinders them from future opportunities (Barua et al., 2013).

Compensation is another mitigation strategy meant to diminish economic losses and boost a community’s tolerance of carnivores (Barua et al., 2013; Distefano, n.d.). There are several recognized problems with compensation schemes (Bulte & Rondeau, 2012; Inskip & Zimmermann, 2009). One of which is the high transaction cost to make a claim to receive compensation. Making a claim might involve travel which not only costs money but also requires a family member to sacrifice valuable time away from work (Barua et al., 2013). Those who most need compensation to alleviate the economic losses of HCI are less likely to consider this option because of the high transaction cost. Many times, even when compensation is pursued as an avenue, it is not received (Barua et al., 2013). In the United States, the economic costs of HCI might increase the price of meat to enable ranchers to compensate for their monetary losses. If the price does not increase, these ranchers will suffer from a reduced profit margin (Messmer, 2000).

Human-carnivore impacts, both hidden and visible, may reduce community support for conservation. This is especially true when the community feels their plight is ignored by those who are trying to protect and even increase large carnivore populations. As a result, it is important for conservationists to understand the devastating consequences individuals may experience because they share their land with carnivores (Barua et al., 2013; Okello, 2005; Redpath et al., 2015).

Patterns of Human-Carnivore Impacts

Human-carnivore interactions tend to occur most commonly where wildlife habitats, such as forest cover, borders human-dominated landscapes. For example, HCI are common where high numbers of humans live in close proximity to a nature reserve or when properties are near wildlife corridors (Atwood & Breck, n.d.; Distefano, n.d.; Michalski et al., 2005). In the Amazon, occurrences of HCI tend to rise as distance from city center increases (Michalski et al., 2005). Poessel et al. (2012) reported coyote encounters in the DMA were greatest in an area surrounded by natural land cover on three sides. Because these high-impact areas may be population sinks for large carnivores due to the increased retaliatory killing which occurs near them, conservationists must prioritize these areas when working toward effective solutions for mitigating HCI. Successful long-term solutions will help maintain viable carnivore populations (Distefano, n.d.; Inskip & Zimmermann, 2009; Michalski et al., 2005).

In a review investigating patterns of felid depredation, HCI increased with felid body mass; felids with masses greater than 50 kg (110 lbs) caused the highest levels of negative impacts (Inskip & Zimmermann, 2009). Graham et al. (2005) reported male carnivores as most frequently responsible for livestock depredation. Seasons may also play a role in influencing HCI. In the DMA, coyotes were seen twice as often in winter and reported incidents of attacks on pets and humans increased by 150% (Poessel et al., 2012). A similar trend was noted in Chicago (Gehrt & Riley, 2010). The reasons suggested for this observed increase included 1) coyotes becoming more aggressive and territorial in the winter due to the breeding season and 2) shorter days which cause human activities to coincide more frequently with the coyote's crepuscular circadian rhythm (Poessel et al., 2012). However, this trend is not consistent across all regions since a separate study found coyote attacks on pets were more common during summer when coyotes are rearing their pups (Lukasik & Alexander, 2011). This indicates seasonal patterns depend not only on species but also on the region (Poessel et al., 2012).

Since carnivores prefer natural prey, when prey populations are low, depredation rates typically increase, although this does not hold true across all regions (Graham et al., 2005; Inskip & Zimmermann, 2009). In the Amazon, felid depredation rates increased with bovine herd size; however, the largest proportion of cattle were taken from smaller herds (Michalski et al., 2005). Additionally, in the Amazon as well as in parts of Africa, depredation rates increase during the dry season. This is thought to occur because as pools dry up, prey and predators are forced to converge on limited water sources. Food availability and vegetation cover likewise decrease during this time (Michalski et al., 2005).

Where depredation rates are high, poor husbandry or lack of resources may play a role. As the level of husbandry decreases, the number of cattle taken by carnivores increases (Graham et al., 2005). For example, if cattle do not have access to permanent manmade sources of water, such as a trough, they must use natural ones which puts them in more regular contact with predators (Michalski et al., 2005). Ironically, although predator density is unrelated to the amount of livestock killed, as predator density increases and thus the perceived risk of depredation increases, husbandry practices tend to improve which lowers depredation risk (Graham et al., 2005).

During the breeding season of either the livestock or the predators, livestock depredation might also increase (Graham et al., 2005). Michalski et al. (2005) reported most of the livestock taken by Amazon felids tended to be young animals, less than 15 months of age. The authors speculate predators can capture these animals more easily than the adults since the young are curious and less able to defend themselves. Calves between the ages of 0-5 months were most vulnerable to depredation (Michalski et al., 2005).

Nearness to natural cover, season, and level of husbandry are patterns commonly observed for many of the large carnivores responsible for livestock depredation and other forms of HCI. However, these trends only provide a starting place when seeking to understand HCI within a specific region and should not be assumed to hold true for every large carnivore. Fine-scale patterns will vary with species and local demographics. These region-specific patterns must be carefully researched and understood to effectively mitigate HCI within the given area (Inskip & Zimmermann, 2009; Poessel et al., 2012). Additionally, it is important to keep HCI in perspective. Disease, poor nutrition, livestock injury, and poaching frequently result in more serious livestock losses. However, because large carnivores are high profile and because HCI tend to be overblown in proportion, these animals are easy to blame for livestock losses which they did not necessarily cause (Graham et al., 2005).

Retaliatory Killing

Those who experience HCI tend to strongly dislike large carnivores. Thus, they often resort to solving the problem of HCI ineffectively through retaliatory killing, whether legal or illegal, much to the chagrin of conservationists (Inskip & Zimmermann, 2009; Okello, 2005). Retaliatory killing does not usually work because depredation levels are unrelated to predator density (Graham et al., 2005). For some species, retaliatory killing is even known to increase levels of depredation, as in the case of the gray wolf (Fig. 2). For wolves, retaliatory killing disrupts their social structure and only exacerbates the problem, making them more reliant on livestock as a food source. Only when hunting reaches unsustainable levels does depredation rate fall (Wielgus & Peebles, 2014).

Figure 2. Retaliatory killing of the grey wolf increases their reliance on livestock since it disrupts their social structure. Photo by David Dirga. Source: Shutterstock (https://www.shutterstock.com/image-photo/three-wolves-marching-together-299796383)

The scale of retaliatory killing is unknown for many large carnivores. Studies which examine deaths of carnivores from retaliatory killing do so on different spatial scales making them impossible to compare (Inskip & Zimmermann, 2009). However, the numbers which are reported are concerning, especially since many large carnivores are already under heavy pressure from poaching and habitat degradation. Several of them are endangered (Barlow et al, 2010; Dobson et al., 2006; Graham et al., 2005; Inskip & Zimmermann, 2009).

In certain regions, it has been calculated 47% of cheetahs, 46% of Eurasian lynx, and up to 50% of tigers are killed annually from retaliatory killing (Inskip & Zimmermann, 2009). Michalski et al. (2005) estimated 75% of mountain lions in the Amazon die from HCI, although not all of them are killed in retaliation. Charismatic carnivores persecuted in the name of retaliation may be opportunistically harvested for parts to be sold in the black market. A disconcerting study by Everatt et al. (2019) found 51% of lions are killed near Limpopo National Park in the name of retaliation. Of these, 48% had body parts removed, most commonly teeth and claws. The authors proposed these parts, which are highly valuable on the black market, were harvested to be sold as an alternative source of income. After 2014, there was a sharp rise in body parts removed from the lions killed. The cause of the sudden increase is unknown, but the implications

Figure 3. Lions are threats to livestock. Their body parts are also highly valuable on the black market. Photo by Maciej Wlodarczyk. Source: Shutterstock (https://www.shutterstock.com/image-photo/lion-lioness-260725412)

are clear: retaliatory killing might be incentivized by the valuable nature of the body parts of carnivores like lions and tigers (Fig. 3; Everatt et al., 2019; Inskip & Zimmermann, 2009).

A Carnivore's Role in Maintaining Ecosystem Services

Humans rely on the ecosystem for their livelihoods; therefore, the ecosystem and the economy are intrinsically linked. The Millennium Ecosystem Assessment (MEA), a document published in 2005, attempted to describe human dependence on a healthy ecosystem as well as the impacts human activities have on the ecosystem. In so doing, it popularized the term ecosystem services (ES) and defined ES as the benefits humans reap from the natural world, particularly from healthy, well-functioning ecosystems (Fig. 4; Mulder et al., 2015).

Ecosystem services are divided into four categories: provisioning, regulating, supporting, and cultural (Table 1; Mulder et al., 2015). Each category contains subcategories. In a simple model, these subcategories can be linked to the trophic level which provides the majority of the particular service. The sensitivity of a trophic level to extirpation determines how vulnerable or resistant a single ES is to function loss within a given biome (Table 2; Dobson et al., 2006). For example, carnivores play an important role in prey regulation, and they help maintain high levels of biodiversity (Atwood & Breck, n.d.; Michalski et al., 2006). However, because carnivores are at the top of the trophic chain and comprise a relatively small number of organisms compared to lower trophic levels, the ES provided by these animals are classified as brittle. In other words, if a single carnivore species is lost, the regulating ES will be crippled since few species, if any, could take over the function of the extinct carnivore (Dobson et al., 2006).

Table 1. Ecosystem services, categories and definitions (Mulder et al., 2015).

Category	Definition
Provisioning:	nature's production of food and water
Regulating:	climate regulation such as plants' absorption of carbon dioxide, buffer zones such as coral reefs which help minimize the impacts of tsunamis, waste treatment, and disease regulation
Supporting:	this includes functions such as nutrient cycling and soil formation
Cultural:	spiritual and recreational benefits such as hiking, boating, and fishing

[redacted]

Figure 4. The relationship between ecosystem services (ES) and societal well-being as introduced by the Millennium Ecosystem Assessment. The width of the arrows shows the estimated interaction strengths between biodiversity and ES (left) and human well-being (right) (Millennium Ecosystem Assessment, 2005; https://www.millenniumassessment.org/documents/document.356.aspx.pdf [pg. 10]).

Conversely, services provided by an abundance of species are less sensitive to function loss. For example, the ES provided by plants, such as maintaining air quality, will decline at a minimal rate per species lost because a vacant role will be quickly filled by a competing species (Dobson et al, 2006). This service will function relatively well until a threshold of species losses is achieved. After this point, the ES will decline and deteriorate. Other ES have a level of vulnerability between these two extremes where each species extirpated functions as the loss of a single “unit” (Dobson et al., 2006). This simplified model fails to consider trophic interactions, which are important in the maintenance of ES. The real-life patterns observed in the decline of biodiversity and ES are much more complex. Despite this, the basic principle remains the same: The ES provided by few species are more susceptible to function loss than the ES provided by many species (Dobson et al., 2006).

Biodiversity is one signal of a healthy ecosystem. When the species at the top of the trophic chain are lost, herbivores overpopulate, vegetation thins, and species such as fungi increase. Thus, the food web is restructured, the trophic chain is shortened, and species thinning occurs. Finally, ecosystem services collapse (Dobson et al., 2006). This indicates the higher trophic levels which provide the more brittle ES act as a protective layer for the resistant ES. If large carnivores and species at the top of the trophic levels can be maintained, it is likely biodiversity will be preserved, and the less vulnerable ES will remain intact (Dobson et al., 2006). The significance of large carnivores to ES should provide the basis of the argument for their need to be protected.

Table 2. Ecosystem services provided in different ecosystem types, broken into categories and subcategories. Each service is rated by function loss sensitivity level. Services rated as Type A are resistant to degradation. Types B-E are successively more sensitive to degradation, with Type E services being the most sensitive to function loss (Dobson et al. 2006).

	Ecosystem type									
Ecosystem service	Urban	Cultivated	Drylands	Forests and woodlands	Coastal	Inland water systems	Island	Mountain	Polar	Marine
Provisioning										
Fresh water	A	E	A	A	NA	C	A	A	A	NA
Fiber	A	A	A	A	A	E	A	A	E	A
Fuel wood	A	E	A	A	E	NA	A	A	E	E
Food	A	A	A	C	A	E	A	A	E	E
Genetic resources	NA	E	C	C	E	C	C	C	C	C
Biochem and pharmaceuticals	NA	A	C	C	E	C	C	C	E	E
Ornamental resources	NA	A	E	E	E	E	E	E	C	E
Regulating										
Air quality	B	A	A	A	A	A	A	A	A	A
Climate regulation	C	A	A	A	A	A	A	A	A	A
Erosion control	C	A	A	A	E	E	A	A	A	NA
Storm protection	A	A	A	C	E	C	A	A	A	NA
Water purification and waste treatment	C	A	B	B	E	A	C	C	A	A
Regulation of human diseases	E	E	B	C	?	D	C	C	A	A
Detoxification	C	A	C	C	E	A	C	C	E	A
Biological control	D	E	D	D	E	E	C	C	A	E
Cultural										
Cultural diversity and identity	C	A	D	D	C	E	E	E	C	C
Recreation and ecotourism	D	A	D	D	C	E	E	E	C	C
Supporting										
Primary production	A	A	A	A	A	A	A	A	A	A
O_2 production	A	A	A	A	A	A	A	A	A	A
Soil formation and retention	A	A	A	A	E	A	A	A	A	NA
Pollination	C	E	C	C	A	NA	C	C	E	NA
Nutrient cycling	C	E	C	C	C	A	C	C	E	A
Provision of habitat	D	E	C	C	E	D	C	C	A	E

Unfortunately, it is easy for people to be short-sighted and focus on avoiding economic losses through retaliatory killing and other short-sighted solutions which ultimately harm the carnivore population and contribute to the loss of ES. While humans can, to some extent, substitute for the role large carnivores play, this situation is far from ideal. Carnivores are known to feed on weak and sick animals, thus strengthening the prey population, while human hunters tend to target the larger and stronger game species. Additionally, carnivores are more adept than human hunters at controlling the spread of ungulate diseases (Kawata, 2009).

Habitat loss and fragmentation in all regions are leading to species extinctions. Because large carnivores have high spatial needs, they are some of the most vulnerable to decline (Dobson et al., 2006). Although each species will be affected by habitat loss and fragmentation uniquely, depending on natural history and habitat preference, the general trend is species decline with increased habitat fragmentation and loss. This is because habitat fragmentation creates habitat islands with varying levels of hostile environments between them. Each island contains a subset population with an extinction rate higher than the whole population. A reduction in habitat permeability and connectivity limits species dispersal and population viability further increasing extinction rates (Bender et al., 1998).

The cause for carnivore extirpation or extinction does not matter. In the end, it will result in the decline of ES and thus human well-being (Bender et al., 1998; Brooks et al., 2002; Dobson et al., 2006). As habitat continues to be converted to human-dominated uses, there has been a growing cry amongst conservationists to focus on protecting what are called biodiversity hotspots. These areas house thousands of known endemic species and are most likely the homes of hundreds more which are yet to be discovered. Of the 12% of habitat classified as biodiversity hotspots, only 1.4% of this remains and not a single hotspot possesses greater than 1/3 of its original habitat (Brooks et al., 2002). Although the focus on biodiversity hotspots is important, this view of conservation is not holistic and fails to acknowledge the importance other environments have in maintaining ES.

If the sole focus is on protecting biodiversity hotspots, many of the ecosystems which work together to sustain life and benefit society will be lost. Rather than focusing on biodiversity hotspots, entire at-risk ecosystems distributed around the globe should be conserved. This strategy will allow for maximal preservation of biodiversity and ES (Hoekstra et al., 2004). Since only around 12% of the world's land surface area is protected from human infringement, these at-risk ecosystems must include human-dominated landscapes (Hoekstra, 2004; Mulder et al., 2015). In the areas where carnivores remain, we must manage the land wisely to protect them.

Carnivore Conservation: Challenges and Suggestions for Effective Mitigation

The suggested technical strategies to minimize HCI are numerous, and the literature is riddled with praises and pitfalls for many of them. The solutions vary from compensation schemes to insurance policies to lethal control of problem animals to fences and livestock guarding (Bulte & Rondeau, 2005; Distefano, n.d.; Graham et al., 2005; Inskip & Zimmermann, 2009; Michalski et al, 2006; Poessel et al, 2013). While technical strategies are important in mitigating the economic and hidden costs associated with HCI, the perceived conflict often runs deeper than simple economic losses or losses of lives. Among conservationists, there is increasing recognition for the need to address the psychosocial facet of the issue (Atwood & Breck, n.d.; Poessel et al, 2013; Redpath et al., 2015).

The Human Dimension

The Levels of Conflict model, adapted from the Canadian Institute for Conflict Resolution (2000), recognizes three levels of conflict: the dispute, the underlying conflict, and the identity-based or deep-rooted conflict (Fig. 5; Madden & McQuinn, 2014). In the case of HCI and HHC, the dispute is the perceived conflict between the carnivores and the humans. This is often what conservationists seek to ameliorate through technical solutions, while subsurface HHC tensions are ignored. Acknowledging the human dimension through proper framing is one of the keys to finding a long-lasting conservation solution which will satisfy both the conservationists and the other stakeholders (Barua et al., 2013; Redpath et al., 2015).

The underlying conflict is frequently the human-human aspect between conservationists and the community experiencing the HCI. Because history influences the present, historical dealings between conservationists and the community in which they work will influence the severity of the present conflict. Upon close analysis, the past may even inform how conservationists should work with their community to mitigate HCI and minimize HHC. If conservationists are trying to or have tried to gain the upper hand by implementing legal means such as lobbying for carnivore protection laws, the community may feel marginalized which could lead to resentment and bitterness (Madden & McQuinn, 2014; Redpath et al., 2015). These conflicts might even run down to the identity-based level if a community feels conservationists oppose their beliefs or way of life. When identity-based values are threatened, the community may lash out, fighting vehemently over the surface-level dispute when the real issue rages deep below the surface (Madden & McQuinn, 2014). In this scenario, the community may even oppose the technical solutions meant to help them, thus exacerbating the surface problem. To prevent this situation, there is a need to partner with communities most threatened by HCI to pinpoint a viable solution (Madden & McQuinn, 2014).

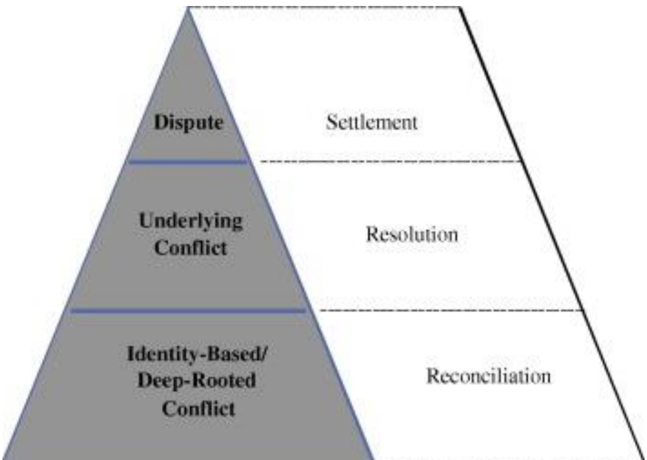

Figure 5. The three levels of conflict and the method used to address each one.
Source: Canadian Institute for Conflict Resolution, 2000; Madden & McQuinn, 2014.

Barlow et al. (2010) lay out a framework to minimize tensions while partnering with the community to discuss options of mitigation which will satisfy all parties. When following the procedure, the objective is to be as unbiased as possible by not censoring potential solutions until the end of the process when each suggested solution is evaluated based on its likely costs and benefits. The key to success is to avoid solutions which value carnivores above people as this would be inhumane. Similarly, solutions which consider short-term human needs as primary should be rejected since this would most likely lead to carnivore extinction (Barlow et al., 2010). This framework is a useful tool in the solution-making process. However, it tends to focus on solving only the dispute-level conflict.

To resolve the deeper conflicts which lie beneath the surface, The Conflict Intervention Triangle model may be a useful tool to ensure all levels of the conflict are properly addressed (Fig. 6). The three corners of the triangle represent the substance of the conflict, the process of the conflict, and the relationships of the conflict (Madden & McQuinn, 2014). In the case of HCI and HHC, the substance of the conflict is the negative impacts carnivores have on human lives and livelihoods. The process encompasses the idea of being flexible and adaptable toward accomplishing the goal of mitigating HCI and the underlying HHC. The relationship vertex draws attention to the cultural and psychosocial aspects of the conflict (Madden & McQuinn, 2014). To best minimize HHC, conservationists should work with the community within the existing political context rather than by

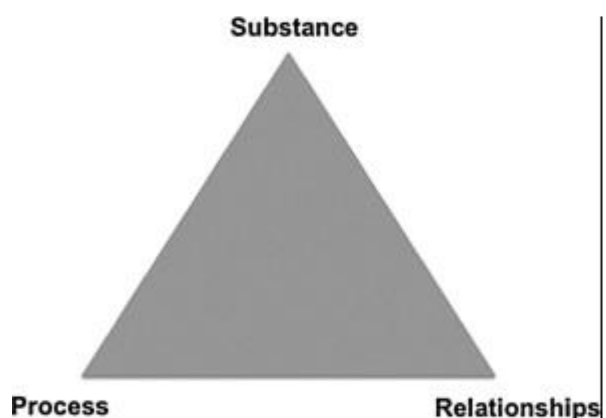

Figure 6. The Conflict Intervention Triangle model.
Source: Madden & McQuinn, 2014.

attempting to force their ideals onto the community through implementing laws (Madden & McQuinn, 2014; Okello, 2005; Redpath et al., 2015).

To minimize HCI and HHC, we need a holistic approach. Incorporating the Conflict Intervention Triangle into Barlow et al.'s (2010) framework may be a useful starting place when searching for long-term sustainable solutions for mitigating HCI and HHC. Human-carnivore impacts might appear simple on the surface, but they encompass much more than losses of numbers. Technical solutions, as emphasized by Barlow et al. (2010), are certainly important, but valuing the community, including them in the process, and building relationships with them can go a lot farther toward helping long-term conservation goals (Madden & McQuinn, 2014).

There is no single solution for mitigating HCI due to the wide range of cultures affected by this issue, and the technical solutions utilized by each community will be unique. However, the common goal, to minimize HCI and work toward human and animal flourishing, remains the same. The principles and frameworks outlined above may provide a good starting place toward creating peace between humans and carnivores as well as between conservationists and the communities in which they work.

Conservation Principles

Although there are no universal technical solutions to solve HCI, foundational conservation principles must be considered in every case. The priority when searching for technical solutions is to balance short-term human needs with long-term conservation goals. The primary objective is for humans to live peacefully alongside carnivores, despite the inevitable challenges. Achieving this aim will promote both human and carnivore flourishing.

Because habitat fragmentation contributes to carnivore decline, planning to maintain or restore habitat connectivity will facilitate viable populations of carnivores. This will protect ES from function loss. Habitat corridors, paths of unbroken or relatively hospitable landscape, help maintain habitat connectivity by linking smaller patches. Thus, corridors help to lower a species probability of extirpation because they help to form larger patches from smaller ones. Corridors also promote genetic diversity (Brodie et al., 2016). Unfortunately, when human habitations lie near corridors this might promote HCI (Michalski et al., 2005). To solve this problem, Atwood and Breck (n.d.) suggest corridors should not pass through hostile land since the corridor which is meant to benefit a species' population could create a population sink due to increased HCI (Atwood & Breck, n.d.; Distefano, n.d.; Inskip & Zimmermann, 2009; Michalski et al., 2005). However, this severely restricts the options for viable corridors (Atwood & Breck, n.d.). Additionally, corridors which pass through inhospitable land might be essential for maintaining viable carnivore populations since animals tend to utilize the landscape in specific ways (Brodie et al., 2016).

If animal movement regularly passes through a region, a corridor should be established to help the population remain viable. Ideally, the corridor would be located through a hospitable landscape, but at times this option may be unavailable. Sometimes, it might be necessary for a corridor to be placed across land where a community may be particularly hostile to large carnivores. When this occurs, conservationists may be able to utilize the Conflict Intervention Triangle and Barlow et al.'s (2010) framework to work with the hostile community to help them achieve effective solutions for mitigating HCI. Aside from corridors, improved agricultural methods might be effective in helping both carnivores and humans by decreasing the need to clear more land.

In impoverished communities, solutions may need to include humanitarian efforts. For example, one important solution for minimizing HCI may be to help pastoralists build and maintain fences or to provide them with a permanent well for watering their cattle. Other strategies may involve altering livestock practices. For example, pastoralists and ranchers may need to keep young calves closer to areas where there is more human activity until the calves are grown enough to be less susceptible to predators (Michalski et al., 2005).

As stated earlier, including the community in the search for solutions is valuable for conservationists to garner support and achieve long-term conservation success. With community aid, creative and practical solutions might be more easily thought of and implemented. In one African community in Kenya near Nairobi National Park, a young boy developed a strategy for warding away lions by stringing flickering lights around the pasture. Because he was a member of the community, the local support for his invention was high, and several of his neighbors asked him to install the light system in their yards (Kermeliotis, 2013). Additionally, when implementing HCI mitigation strategies, conservationists should monitor their effectiveness over time as well as keep track of community support since unsuccessful strategies might increase HCI and HHC (Atwood & Breck, n.d.; Inskip & Zimmermann, 2009).

Conclusion

Holistic mitigation strategies are essential to help humans flourish. Implementing strategies to reduce the occurrence of HCI while simultaneously addressing HHC is an essential part of conservation today. If humans continually push animals to the fringes of civilization while consuming more and more land without learning to coexist, particularly with those animals causing the majority of HCI, ES will eventually fail. To fully protect the world's ecosystems and maintain ES, areas designated as protected and areas designated as unprotected must both be kept healthy. Strategies must be put in place to reduce HCI and to maximize the results of conservation efforts. Although these technical solutions will look different across the globe, in every case the human dimension must be addressed for the conflict to be resolved successfully. Addressing the human dimension will likely require extra work, but it will be worth accomplishing long-term, community-supported solutions which will help the given community live peacefully with their wildlife neighbors.

"We all strive for safety, prosperity, comfort, long life, and dullness. The deer strives with his supple legs, the cowman with trap and poison, the statesman with pen, the most of us with machines, votes, and dollars, but it all comes to the same thing: peace in our time…But too much safety seems to yield only danger in the long run. Perhaps this is behind Thoreau's dictum: In wildness is the salvation of the world." ~ Aldo Leopold. Thinking Like a Mountain.

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