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The Identification and Application of Generalizable Spatial Patterns of Human-Wildlife Conflict

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ABSTRACT

Many human-wildlife conflict studies focus on one location or one individual species or taxonomic group; fewer comparative studies analyze patterns of conflict across species and regions. As a result, numerous studies report similar conclusions across diverse cases of human-wildlife conflict. I found 133 scholarly articles published between 1975 and 2017 referencing distance from a protected area boundary as a variable associated with human-wildlife conflict. I identified three generalizable patterns of human-wildlife conflict that appear across taxonomic groups and geographic locations. The family Felidae had the highest maximum average conflict distance and furthest distance from a protected area that conflict was recorded for any taxonomic group ($n = 23$, $\bar{x} = 33.67$ kilometers, $x_{max} = 100$ kilometers). There was a strong, positive correlation between species range size and average maximum conflict distance ($r^2 = 0.485$, $p = 0.0017$), and a weak positive correlation between average maximum conflict distance and herbivorous species body weight ($r^2 = 0.6017$, $p = 0.0142$). The abundance of research across 5 continents, 28 countries, and 51 diverse species illustrates a widespread recognition that spatial dimensions of conflict are important. These patterns may be explained in part by characteristics inherent to the species. This review suggests that further studies are needed to identify broader, more generalizable patterns of conflict.

I tested the applicability of three generalizable spatial patterns of human-wildlife conflict frequency identified in trends I observed in a literature review of human-wildlife conflict by surveying 368 conservation practitioners working in a range of locations with diverse species about their experiences with human-wildlife conflict. I received 58 responses (16% response rate). Survey respondents selected every available pattern across all three boundary distances (1km entry distance, 1km and 40km boundary distances), validating the generalized patterns of human-wildlife conflict. Species characteristics such as diet, body size, and home range were significantly associated with pattern type selection across subsetted groups of species such as carnivores, herbivores, medium-bodied species, and species with a medium size home range. Survey respondents indicated that conflict occurred most often at dusk, dawn, or throughout the night, due to species-specific sleep-wake cycles or adaptation of a species to human presence and human activity levels. Spatial patterns also vary depending upon the availability of

wildlife habitat. Gaining a better understanding of where and why conflict is likely to occur will assist people living in conflict-prone areas and improve efforts to manage and protect large and sometimes dangerous animals.

ACKNOWLEDGEMENTS

I would like to sincerely thank my advisor and mentor Philip Nyhus, who has guided and supported me over the last four years. You have instilled in me a passion for conservation, and I can never thank you enough for your invaluable time, expertise, and immense patience.

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I would like to extend my thanks the members of the IUCN SSC groups and task forces, as well as the authors of publications included in my literature review, who kindly completed my survey and shared their experiences with me.

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CHAPTER 1: AN INTRODUCTION TO HUMAN-WILDLIFE CONFLICT

Worldwide, the populations of many wildlife species are in decline (Dirzo et al. 2014). This is particularly true for larger-bodied mammals (Ripple et al. 2014, Ceballos et al. 2017). Among the many causes for declining populations of large carnivores and herbivores is human-wildlife conflict (Woodroffe and Ginsberg 1998, Treves and Karanth 2003, Loveridge et al. 2010). Human-wildlife conflict is broadly defined as any interaction between humans and wildlife where one or both parties involved are negatively impacted in any way (Inskip and Zimmermann 2009). Conflict can take many forms, often manifesting as predation on livestock, consumption or trampling of crops, destruction of property, and injury to or loss of human or animal life (Treves and Karanth 2003, Inskip and Zimmermann 2009, Linnell et al. 2010, Loveridge et al. 2010). Due to a range of factors, the frequency of human-wildlife conflict instances is on the rise in many parts of the world (Treves and Karanth 2003, Woodroffe et al. 2005, Manfredo 2015, Marchini and Crawshaw 2015).

Increasing human populations in many regions have continued to expand into areas of natural habitat in order to meet housing and nutritional needs through residential and agricultural development (Treves and Karanth 2003, Loveridge et al. 2010). The declining availability of grazing lands leads some herbivorous and omnivorous species to feed on crops as an alternative source of nutrition (Middleton 2003, Karanth et al. 2006). Additionally, species such as the Asian elephant have been observed consuming crops as part of a "high risk, high reward" strategy to achieve greater reproductive success through increased nutrition levels (Nath et al. 2013). Instances of conflict involving species like elephants can inflict large amounts of economic damage (Naughton-Treves 1997, Nath et al. 2015). In Africa, farmers can lose an entire season's worth of crops to these species in a single night (Naughton-Treves 1997).

Human hunting practices in some regions have diminished natural prey populations, resulting in increased instances of livestock predation by carnivorous species (Inskip and Zimmermann 2009, Loveridge et al. 2010). According to Loveridge et al. (2010), vulnerability of livestock species to predation is dependent upon the body size of both the prey and the predator. Sheep and goats are at risk of attack from smaller carnivores like lynx and caracal, while larger felids (e.g., tiger, lion) may prey on any

species of livestock (Loveridge et al. 2010). This competition over resources increases the likelihood of conflict between humans and wildlife (Inskip and Zimmermann 2009). Additionally, rural depopulation in some areas of the world is leading to increased instances of human wildlife conflict, as species are able to recolonize areas formerly occupied by a larger human population (Ohrens et al. 2015). In cases like these, the livestock and crops of the residents who remain in the region fall victim to the returning wildlife population.

Human-wildlife conflict is a universally experienced issue, but certain groups are at higher risk than others (Naughton-Treves and Treves 2005, Dickman 2010). Those residing in regions of the world where large megafauna are present are likely to experience extreme cases of conflict (Naughton-Treves and Treves 2005). Because protected areas of land are some of the last remaining spaces for these species, people living near or alongside these areas are at high risk of encountering wildlife (Naughton-Treves 1997, Woodroffe and Ginsberg 1998, Loveridge et al. 2002, Loveridge et al. 2010). In particular, many protected areas are not of an adequate size to support populations of large carnivorous species, which may wander beyond protected area boundaries in search of prey (Breitenmoser et al. 2005). The dietary requirements and large home range sizes of carnivorous species often draw them out of protected area boundaries and into conflict with humans (Linnell et al. 2001, Macdonald and Sillero-Zubiri 2002, Treves and Karanth 2003, Inskip and Zimmermann 2009).

Due to successful conservation efforts, species such as the gray wolf and Eurasian lynx have been reintroduced to areas of their geographic range they had been extirpated from due to conflict and habitat fragmentation (Musiani and Paquet 2004, Breitenmoser et al. 2010). At times, human-wildlife conflict can occur in regions that have adapted to the absence of the reintroduced species (Treves and Karanth 2003). In some areas, residents living along the edge of a protected area of land (e.g., national park, forest reserve) exploit the land through the illegal grazing of livestock, planting of crops, and the harvest of natural produced goods, including hunting, all within the boundaries of the protected area (Karanth et al. 2006, Loveridge et al. 2010).

In human settlements where more severe cases of human-wildlife conflict present themselves with relative frequency, wealthier residents are often better able to protect

themselves (Barua et al. 2013). For example, a study by Saberwal et al. (1994) found that in villages surrounding the Gir National Forest in India, wealthier community members lost less livestock to predation because they could afford to establish effective conflict prevention measures. Similarly, in households and communities reliant upon subsistence farming as a source of income, an entire season's worth of income can be lost in a single night to crop raiding by large-bodied species (Naughton-Treves 1997). In a study of fourteen cases of human fatality from human-elephant conflict in India, every victim was from the lowest socio-economic group (Das and Chattopadhyay 2011).

Human-wildlife conflict occurrences can impact households on an individual level. Instances of crop raiding can lead to food insecurity in households reliant upon subsistence farming for both income and nourishment (Barua et al. 2013), and female members of the household will often forego their portion of food to ensure the nourishment of their children (Ogra 2008). Human-wildlife conflict occurrences also have "hidden" costs and opportunity costs, which are often understudied (Barua et al. 2013). According to Barua et al. (2013), the psychological effects of human-wildlife conflict can be increased by the compounding of certain factors which increase the likelihood of someone experiencing human-wildlife conflict. These factors include poverty, poor access to resources, poor access to social capital, and ethnic and political marginalization (Barua et al. 2013). In households that are vulnerable to human-wildlife conflict and are reliant upon crops or livestock as a main source of income, residents often employ tactics such as guarding herds or fields as a way of protecting their livelihood (Naughton-Treves 1997, Barua et al. 2013).

In order to effectively guard against crop raiding, farmers must frequently guard their fields. In parts of Africa and Asia, men often watch over the fields at night, while children guard during daylight hours (Barua et al. 2013). This division of labor allows the men to pursue other jobs during the day, but results in decreased school attendance record and poor scholastic performance by the children (Haule et al. 2002, Mackenzie and Ahabyona 2012). Similarly, in households where a fatality occurs due to human-wildlife conflict, responsibilities are shifted. If the head of a household, generally a male, is killed during an interaction with a wild animal, the responsibility of keeping the household economically afloat falls to the women or children (Barua et al. 2013). A study conducted

by Jadhav and Barua (2012) in India found that death of a male member of a household oftentimes resulted in increased family debts and exacerbated poverty levels. Should the female member of a family be killed by wildlife, household responsibilities may be shifted to the children (Lamarque et al. 2009). Similar to cases where a child may be asked to guard crops during the day, the assumption of household duties also leads to decreased school attendance (Barua et al. 2013).

Whether through livestock predation, crop raiding, or loss of human life, people affected by human-wildlife conflict suffer economic losses that can range from mild to relatively severe. Due in part to economic losses, the frustration and anger felt in the wake of human-wildlife conflict occurrence can engender feelings of negativity towards certain species in some areas (Woodroffe et al. 2005). As a result, occurrences of human-wildlife conflict impact the perceptions, attitudes, and opinions of people involved (Woodroffe et al. 2005). Many individual animals fall victim to retaliatory killings due to involvement in instances of conflict (Woodroffe and Ginsberg 1998, Treves and Karanth 2003). Wildlife are poisoned, trapped, or shot by those impacted by human-wildlife conflict in an attempt to prevent conflict from reoccurring (Woodroffe et al. 2005). For some species, these killings further endanger an already declining population (Woodroffe and Ginsberg 1998, Treves and Karanth 2003, Woodroffe et al. 2005, Loveridge et al. 2010).

To prevent the populations of species—endangered or not— involved in conflict from continuing to decline, conservationists have sought effective methods of conflict mitigation and prevention. Various prevention techniques have emerged, including the construction of barriers (e.g., fences, tree planting formations, trenches), scare tactics (e.g., use of bee hives to prevent movement of African elephants, loud noises), lethal control (e.g., permitted hunting), and the translocation of problem animals (Woodroffe et al. 2005, Bisi et al. 2007, Gurung et al. 2008). Mitigation strategies include economic distribution (e.g., sharing of profits from eco-tourism or other industries) and monetary compensation (e.g., government reporting systems) (Nyhus et al. 2005, Woodroffe et al. 2005).

Unfortunately, conflict prevention techniques are not always successful. Fence upkeep requires time and economic commitment that community members may not

necessarily have, and in some cases can result in wildlife population decline (Ogra 2008, Anthony et al. 2010). In India, one farmer faced a possible misdeed conviction after his electric fence resulted in the death of three lionesses and two cubs (Ogra 2008). Similarly, the translocation of "problem" animals to a different location leads to reduced survival and reproductive rates for the animal involved (Linnell et al. 1997). Translocated wildlife may return to the area of removal, or perish due to inter-wildlife conflict, capture- and transport-related injuries, or instances of human-wildlife conflict in their new environment (Linnell et al. 1997).

Alternatively, some conflict prevention strategies have proven successful at reducing conflict instances while simultaneously producing additional income for users. The use of African honeybees as a deterrent for African elephants works to prevent human-elephant conflict as well as providing another source of income through the sale of products such as honey and wax (Bradbear 2009, King et al. 2009). Other economically viable prevention practices that have been tested include the planting of unpalatable crops like chili, tea, sisal, and medicinal and aromatic plants (MAPs) such as chamomile, lemongrass, basil, and turmeric, which provide income for farmers while preventing the occurrence of crop raiding (Parker and Osborn 2006, Gross et al. 2016, Gross et al. 2017).

In other cases compensation schemes in some areas of the world have increased tolerance for certain species, like the gray wolf near Yellowstone National Park, USA, and tigers near Corbett National Park, India (Nyhus et al. 2005, Ogra and Badola 2008). Compensation schemes face challenges, however, including high costs associated with the evaluation of damage claims, the determination of loss values, payment delivery, fraud, corruption, and maintenance of funding sources (Nyhus et al. 2003, Distefano 2005). In some cases, these barriers are so great that villagers do not report instances of conflict for compensation, and conservation professionals have recommended against using compensation schemes as a mitigation strategy. In a study conducted by Saberwal et al. (1994), 81% of villagers did not file for compensation upon losing livestock due to "procedural problems" in filing a claim. Similarly, the Human-Elephant Conflict Working Group of the IUCN has asserted that economic compensation schemes in Africa can worsen matters of human-wildlife conflict and advises against using them because

they do not address the fundamental causes of human-elephant conflict (African Elephant Specialist Group 2000).

One of the major problems with compensation schemes lies in the verifiability of economic damage. Human-wildlife conflict related-losses must be reported and assessed within a certain time period in some regions (Nyhus et al. 2005). Submitting a request for and receiving the assessment of a program official within this time window is difficult for many people (Nyhus et al. 2005, Linnell et al. 2010). Furthermore, some farmers suffering economic losses due to livestock depredation are aware of the loss of livestock but are unable to file a report for compensation because no animal remains were left behind (Steele et al. 2013). For example, the Sami people in Norway must prove their livestock was killed by a lynx or wolverine in order to receive compensation, but most herders only find the remains of 5% to 10% of the reindeer that are lost (Kintisch 2014). Similarly, the quantification of crop loss caused either by raids or wildlife thru-traffic is difficult (Hill 2004, Woodroffe et al. 2005). Whereas herders are able to place a price on each head of livestock, farmers encounter difficulties in assessing exact amounts of economic loss resulting from consumption or destruction of crops (Woodroffe et al. 2005). Problems of quantification and verification present difficulties across a wide range of species and geographic areas.

Human-wildlife conflict is a complex issue, and numerous environmental factors play a role in where, why, and how often instances of conflict may occur. Many scholars have researched conflict-prone areas in an attempt to understand different drivers of conflict. One seminal human-wildlife conflict publication by Woodroffe and Ginsberg (1998) examines the interface between humans and wildlife on the edge of protected areas. Woodroffe and Ginsberg (1998) found that conflict with humans at reserve borders is a major cause of mortality in large-bodied species with big home ranges. These species tend to encounter reserve edges relatively often due to the size of their home ranges, resulting in instances of conflict and the death of wildlife (Woodroffe and Ginsberg 1998). Another seminal human-wildlife conflict publication by Naughton-Treves (1998) investigates patterns of crop damage around Kibale National Park in Uganda. In this publication, Naughton-Treves explores the relationship between the frequency of human-wildlife conflict and the distance from the edge of the reserve where conflict occurred.

Naughton-Treves illustrates that as distance to the protected area boundary increases, instances of human-wildlife conflict decrease. Since the publication of Naughton-Treves' research, this relationship has been observed by many scholars in a wide range of locations across a diverse array of species.

Over time, many species have become increasingly restricted to protected areas of land as a result of severe habitat fragmentation (Loveridge et al. 2002). Thus, human-wildlife conflict frequently occurs near the boundary of protected areas, and research tends to focus on these spaces. Thorough investigation at a site- and species-specific level has uncovered spatial patterns of human-wildlife conflict on a local level. However, research on a broader scale is lacking and there has been limited discussion of generalizable patterns of human-wildlife conflict.

In this thesis I attempt to assess whether or not general spatial patterns of human-wildlife conflict emerge across taxa and geographic regions. In chapter 2, I compile published research on human-wildlife conflict through an in-depth literature review. In this review, I catalogue spatial patterns of human-wildlife conflict observed by researchers in a range of environments at varying scales. This aggregation of observed trends allows me to identify three generalized spatial patterns of human-wildlife conflict occurrence, which I synthesize into a typology introduced in chapter 2. In chapter 3, I analyze data from a survey that I sent to conservation professionals in order to assess whether they agree with the three identified generalizable human-wildlife conflict patterns. In an examination of survey results, I ask what biological and landscape factors may help to explain why specific spatial patterns are associated with certain study locations or species. I conclude with a brief summary that discusses the major research findings of this thesis and recommendations for future research on this topic.

CHAPTER 2: FACTORS INFLUENCING SPATIAL PATTERNS OF HUMAN-WILDLIFE CONFLICT: A REVIEW OF LITERATURE

Introduction

Globally, many populations of large animals are threatened with extinction (Ripple et al. 2014, Ceballos et al. 2017). Growing human populations and demand for land and resources have contributed to wildlife declines as a result of loss and fragmentation of wildlife habitat and illegal harvesting (Karanth et al. 2006, Loveridge et al. 2010, Young et al. 2010, Thapa et al. 2017). Boundaries between wildlife habitat and "human habitat" are also becoming more distinct in some regions, leading to greater levels of conflict between humans and wildlife (Treves and Karanth 2003, Woodroffe et al. 2005, Inskip and Zimmermann 2009, Manfredo 2015).

An increasing number of studies explore the causes of and solutions to human-wildlife conflict (Inskip and Zimmermann 2009, Dickman 2010). However, many human-wildlife conflict studies focus on one location or one individual species or taxonomic group; fewer comparative studies analyze patterns of conflict across species and regions (Nyhus 2016). As a result, numerous studies report similar conclusions across diverse cases of human-wildlife conflict. One example of this repetition is the relationship of distance from edges as a predictor of human wildlife conflict (Woodroffe and Ginsberg 1998, Nath et al. 2013, Nath et al. 2015). For example, studies of primates (Naughton-Treves 1997, 1998, Regmi et al. 2013), African and Asian elephants (Oppong et al. 2008, Graham et al. 2010, Pant et al. 2015), Asiatic black bears (Charoo et al. 2011), and tigers (Gurung et al. 2008) conclude that human-wildlife conflict decreases as distance from the boundary of protected areas increases.

The repetition of similar conclusions across diverse taxa and regions is a missed opportunity for novel synthesis and analysis of common patterns of human-wildlife conflict. In this study, I address this need by reviewing and synthesizing information from the human-wildlife conflict literature on how distance from protected areas and wildlife habitat are related to the prevalence of conflict. In particular I ask: (1) What spatial patterns appear in studies of human-wildlife conflict frequency and proximity to protected areas of land? (2) Do factors such as species home range, dietary preference,

and body weight help to explain spatial patterns of human-wildlife conflict? (3) Can these spatial patterns be generalized across geographic locations and taxonomic groups?

The growth in human-wildlife conflict studies has led scholars to numerous novel findings, but has also resulted in growing repetition of similar conclusions for different case studies. Having a better understanding of generalizable patterns may allow human-wildlife conflict scholars to move beyond this repetition of the most obvious conclusions and instead look for additional patterns and exceptions to these patterns. In addition, recognition of human-wildlife conflict trends across species and locations may allow those living in conflict-prone landscapes, managers, and conservation professionals to develop more effective human-wildlife conflict mitigation measures.

Methods

I reviewed scholarly publications (journal articles, books, book chapters, government reports, and NGO reports) published between 1975 and 2017 in the English language literature that describe spatial patterns of human-wildlife conflict. I used the search engines Scopus and Google Scholar to search for articles describing patterns of human-wildlife conflict occurring in the vicinity of core habitat areas, national parks and nature reserves, or human population centers. I used the following keywords: carnivore, conflict, conservation, distance, human-wildlife, national park, park, predation, raid, wild, wildlife, Africa, Asia, Australia, Europe, North America, and South America. I also carried out targeted searches for the following species: alligator, baboon, bear, bison, bobcat, bush pig, caracal, cheetah, cougar, coyote, crocodile, elephant, hyena, jaguar, leopard, lion, mountain lion, pig, puma, tiger, wild boar, and wolf. I searched for additional articles cited in the literature cited section of published articles on human-wildlife conflict. Finally, I used a "snowball" approach to find additional publications that have cited these papers describing patterns of human-wildlife conflict and distance from protected areas of land (Naughton-Treves 1997, 1998, Woodroffe and Ginsberg 1998, Woodroffe et al. 2005).

For each publication I documented author name(s), date of publication, continent, country, the name of the protected area or region of study, protected area size, the taxonomic group studied, wildlife abundance, human abundance, how results were

displayed, statistical test used, significant results, and the data collection technique. Publications were sorted into one of five "study area" categories: national parks, nature reserves, states and provinces, regions, and global reviews. Spatial patterns of human-wildlife conflict were only identified from publications examining study areas containing national parks or nature reserves.

Sources were assigned categories based on how they describe or illustrate the relationship between conflict occurrence and distance to protected area. I coded the methods used to analyze and present human-wildlife conflict occurrence data into one of five categories: figures displaying patterns of conflict (e.g., x-y plots with regression lines), spatial data (e.g., GIS maps), tables displaying relationships, or written statements describing relationships between distance and conflict. Articles using figures were further broken down into categories based on figure type: bar plots, scatterplots, and x-y plots. Field methods used in the studies were further coded as: surveys, field observations, aggregation of historical reports, camera traps, census data, GPS use, and literature reviews. The statistical tests were classified into one of five categories: regression (linear or logistic), chi-square tests, correlations, and "other."

The country of study for each article was coded using the United Nations M49 numeric code and mapped using ArcGIS*v.10.4.1.* (Environmental Systems Research Institute 2016, United Nations 2018).

Conflict Distance Relationships

For each study reporting a statistically significant ($p<0.05$) relationship between distance from the protected area (e.g. a national park or nature reserve) and incidents of conflict between wildlife species and humans, I recorded the maximum reported distance from the protected area where human-wildlife conflict occurred for each species. From these data I calculated the average of the maximum reported conflict distance from protected areas where conflict occurred for each species.

I recorded the home range size and body weight for each species with maximum conflict distance data (Laws 1966, Schaller 1967, Clutton-Brock and Harvey 1977, Krasińska et al. 2000, Sukumar 2003, Sankar and Goyal 2004, Hunter 2006, Macdonald 2009, Nyhus and Tilson 2010, Hunter and Barrett 2011, Furstenburg 2012). If more than

one source provided information on home range or bodyweight for one of the species of study, the estimates were averaged. Relationships between maximum conflict distance, home range size, and body weight were tested with ordinary least squares regression models using R *v3.4.4* (R Core Team 2018)

Identified Conflict Patterns

As a final step I identified three patterns of human-wildlife conflict in relation to distance from the boundary of a protected area that capture the range of conflict patterns I observed in the literature review. To determine these generalizable models of human-wildlife conflict frequency, I compiled spatial patterns of conflict frequency described by authors of the reviewed publications. Each individual pattern corresponds to descriptions provided by a number of studies and the generalizations I identified in the literature review.

Results

I found 133 publications published between 1975 and 2017 referencing boundary distance as a variable associated with human-wildlife conflict. Of these, 109 (82%) report data or make statements supporting a relationship between human-wildlife conflict occurrence and distance from many conservation landscapes. The number of studies published annually has increased steadily over time, from an average of 1 per year between 1975 and 2000 to an average of 6 per year from 2000 to 2017 (Figure 1). Studies were carried out in 28 countries on 5 continents (Africa, Asia, Europe, North America, and South America) (Figure 2). The majority of studies were conducted in Africa (n = 45, 42%) or Asia (n = 42, 40%), with more than two times as many sources discussing human-wildlife conflict and protected areas of land in India than any other country (n = 21, 20%).

Most studies were carried out in and near national parks (n = 47, 44%) or nature reserves (n = 29, 27%). A quarter of studies identified some other geographic area, state, province, or region (n = 28, 26%). Two studies were global reviews (2%). Distance is used as an independent explanatory variable in a majority of reviewed publications (n = 47, 78%).

The publications described 173 distinct species populations. The majority of studies (n = 79, 75%) described just one species. Carnivores were studied in approximately half of all publications (n = 85, 49%), and herbivores in one quarter of the publications (n = 40, 23%) (Figure 3). The most commonly studied groups were felids (n = 55, 32%), elephants (n = 23, 13%), and canids (n = 22, 13%) (Figure 3). The remaining publications reported on smaller wildlife: langurs (n = 2), porcupine (n = 1), parakeets (n = 1), partridges (n = 1), and mongooses (n = 1).

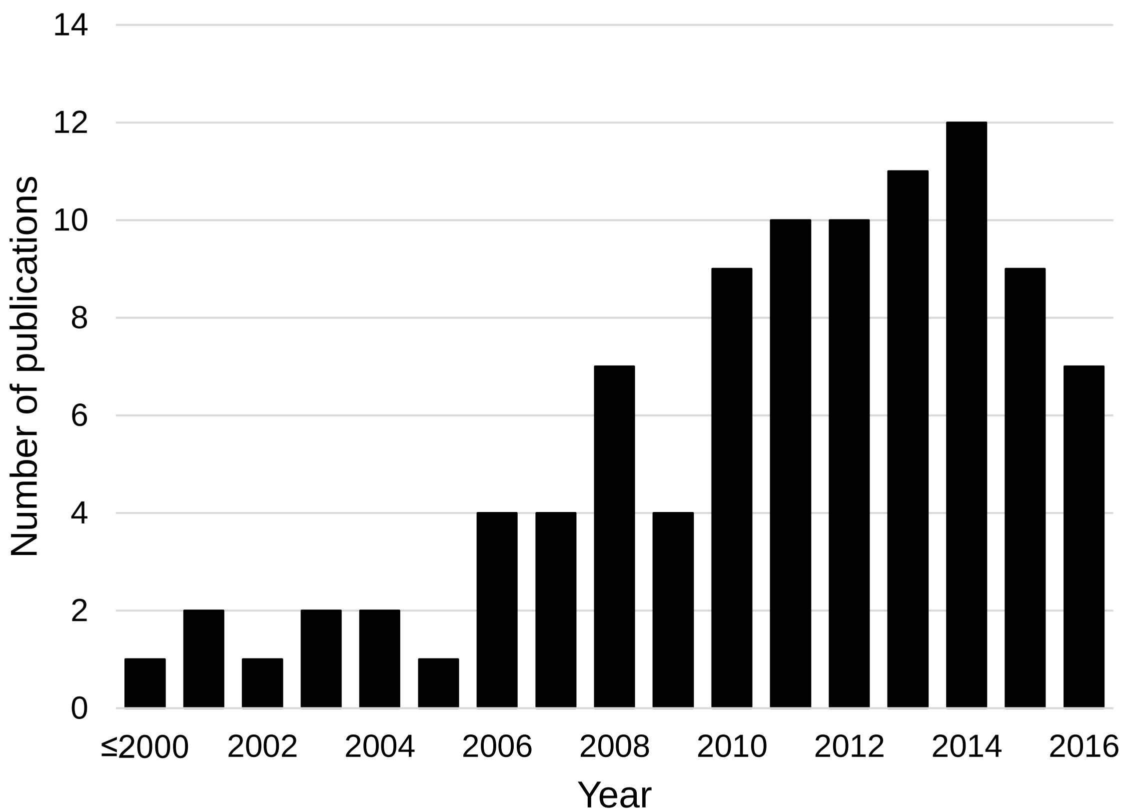


Figure 1. The number of publications discussing research on the relationship between human-wildlife conflict and distance from protected area 2000 - 2017 (n = 109).

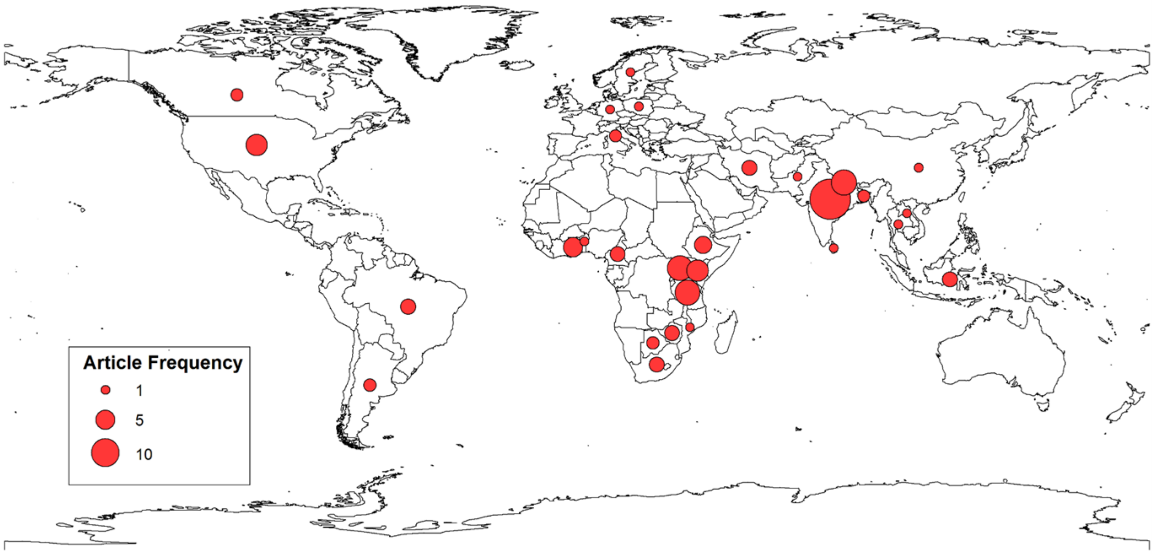


Figure 2. The distribution of reviewed publications describing the relationship between human-wildlife conflict and distance from the boundary of a protected area by country. The size of the circle represents the number of studies carried out in each country (n = 104).

Data on human-wildlife conflict were collected by researchers using surveys (n = 53, 50%), field observations (n = 27, 25%), the aggregation of historical reports (n = 23, 22%), camera traps (n = 6, 6%), GPS data (n = 4, 4%), literature reviews (n = 2, 2%), and census data (n = 1, 1%). Over half of all studies used a graph (n = 60, 57%) to show trends in conflict frequency and distance. These included scatterplots (n = 49, 46%) or bar graphs (n = 11, 10%). Other methods include spatial mapping (n = 30, 28%), the use of both spatial mapping and a graph (n = 13, 12%), or a table illustrating statistically significant relationships (n = 6, 6%). Seven studies (7%) reported a decrease in conflict occurrences as distance from the protected area increased in the form of a written statement only.

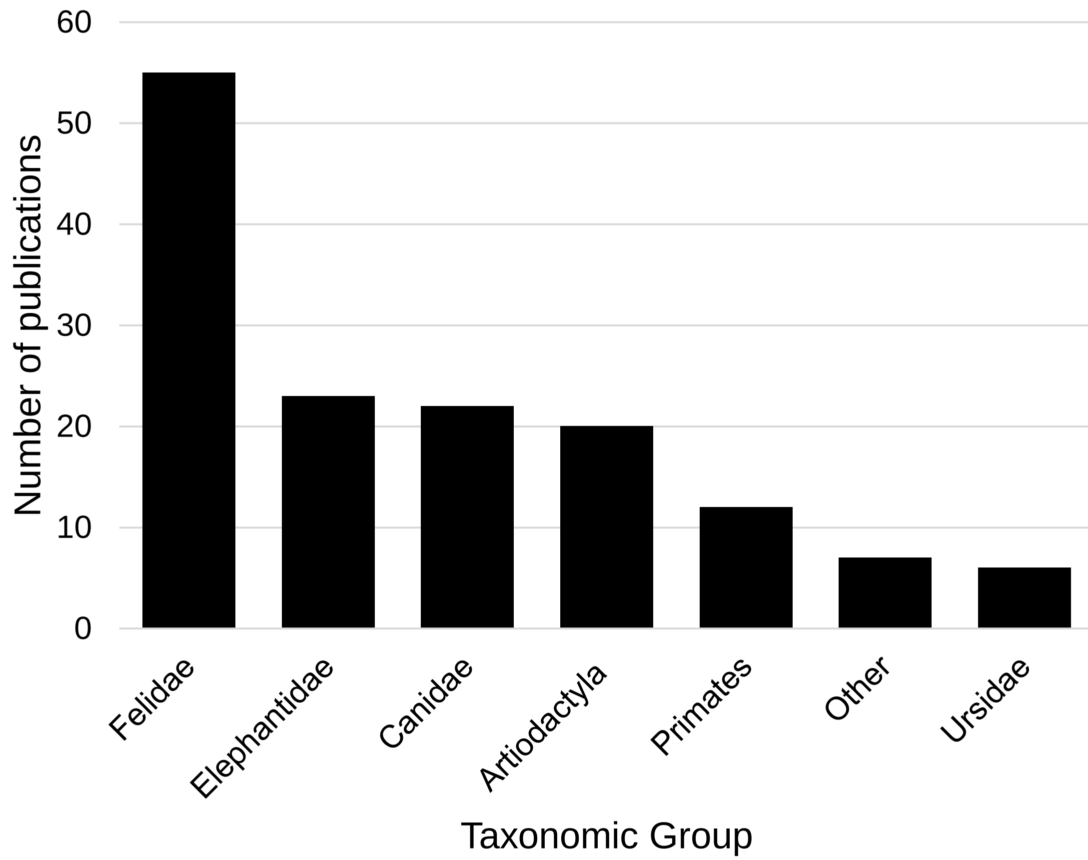


Figure 3. The number of publications researching specific taxa of wildlife in relation to human-wildlife conflict near protected areas (n = 145). Species were grouped into the most narrow taxonomic classification possible (e.g., family, order) to maintain taxa-specific characteristics within groupings (e.g. diet, physical build, body size).

Conflict Distance Relationships

The family Felidae had the highest maximum average conflict distance and furthest distance from a protected area that conflict was recorded for any taxonomic group (n = 23, $\bar{x}$ = 33.67 kilometers, x_{max} = 100 kilometers) (Figure 4). The family Canidae had the second highest maximum average conflict distance, but only a third as many studies (n = 8, $\bar{x}$ = 31.18 kilometers, x_{max} = 90). A larger maximum average conflict distance was calculated for family Ursidae ($\bar{x}$ = 12.52 kilometers) than Elephantidae ($\bar{x}$ = 11.16 kilometers) and Primates ($\bar{x}$ = 7.38 kilometers), despite studies of Elephantidae and Primates reporting further maximum conflict distances of 35 kilometers, compared to 27.5 kilometers for Ursidae.

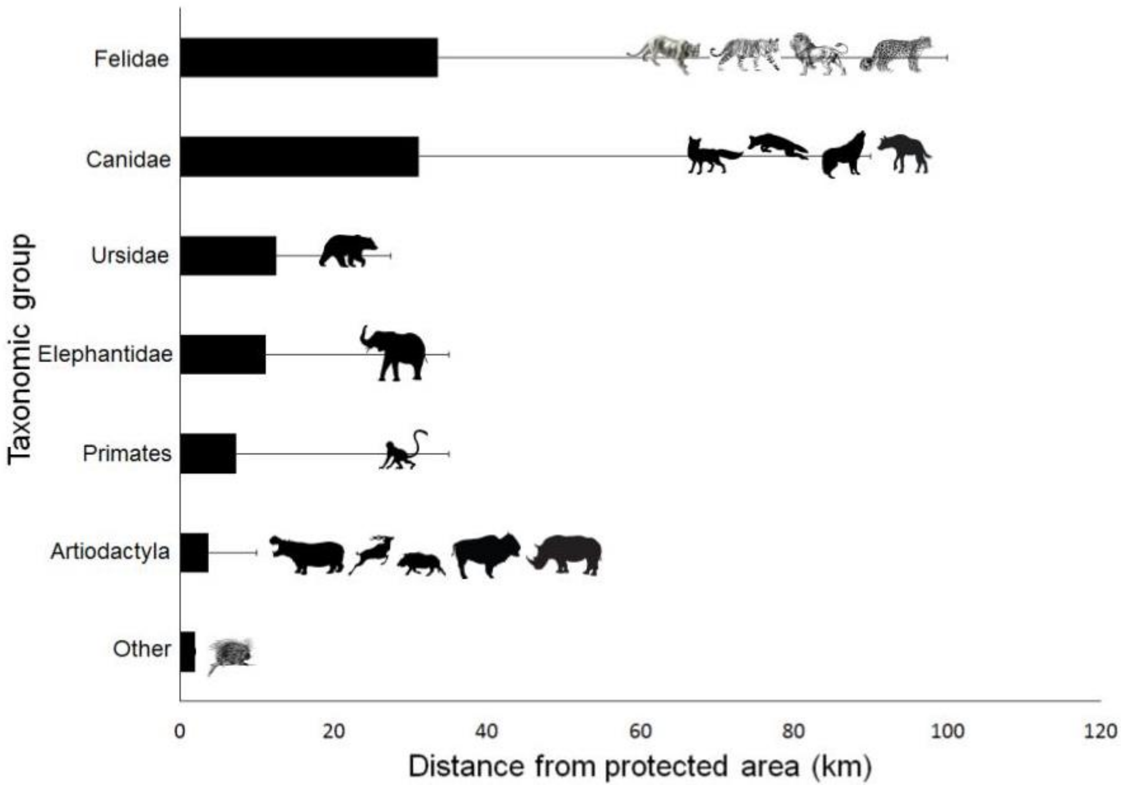


Figure 4. Distances from protected areas (e.g., national parks or nature reserves) where conflicts between humans and specific taxa of wildlife occur. Bars represent average maximum distance, error bar represents maximum reported distance. Published studies were included that reported a statistically significant relationship between increasing distance from the protected area and number of conflicts between wildlife and humans, or stated that there was a clear relationship between increasing distance and decreasing number of conflicts (Felidae, n = 23; Canidae, n = 8; Ursidae, n = 3; Elephantidae, n = 14; Primates, n = 7; Artiodactyla, n = 8; other, n = 1).

There is a strong, positive correlation between species range size and species average maximum conflict distance ($r^2 = 0.485$, $p = 0.0017$; Figure 5). This relationship holds true for broad taxonomic groups also: there is a weak positive relationship between range size and carnivorous species ($r^2 = 0.398$, $p = 0.0504$) and range size and herbivorous species ($r^2 = 0.529$, $p = 0.0408$; Figure 5).

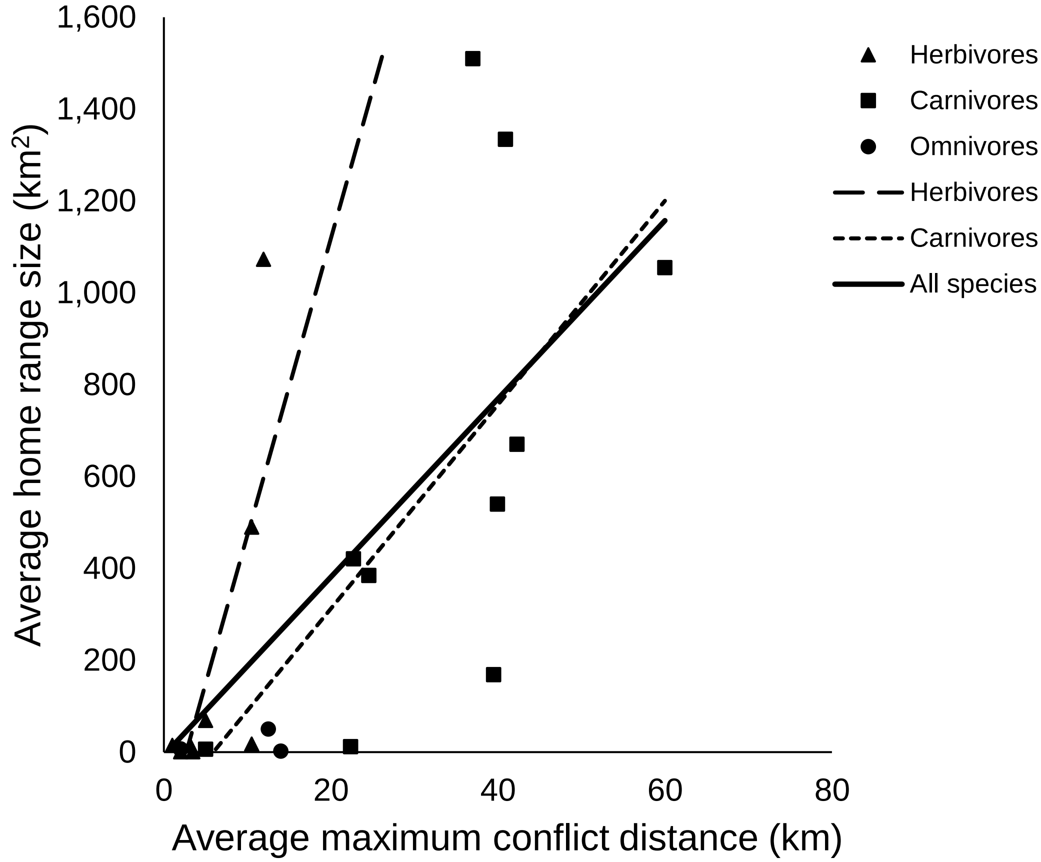


Figure 5. The relationship between animal range size and the average maximum distance from the protected area where conflict occurred in a given environment for all species included in this review ($n = 23$; $r^2 = 0.485$; $p = 0.0017$) and subsetted by carnivores ($n = 10$, $r^2 = 0.398$, $p = 0.0504$), and herbivores ($n = 9$, $r^2 = 0.529$, $p = 0.0408$).

I also assessed the impact of species body weight on average maximum conflict distance. I did not find a significant relationship between body weight and average maximum conflict distance for all species, but there is a weak positive correlation between average maximum conflict distance and herbivorous species body weight ($r^2 = 0.602$, $p = 0.0142$; Figure 6).

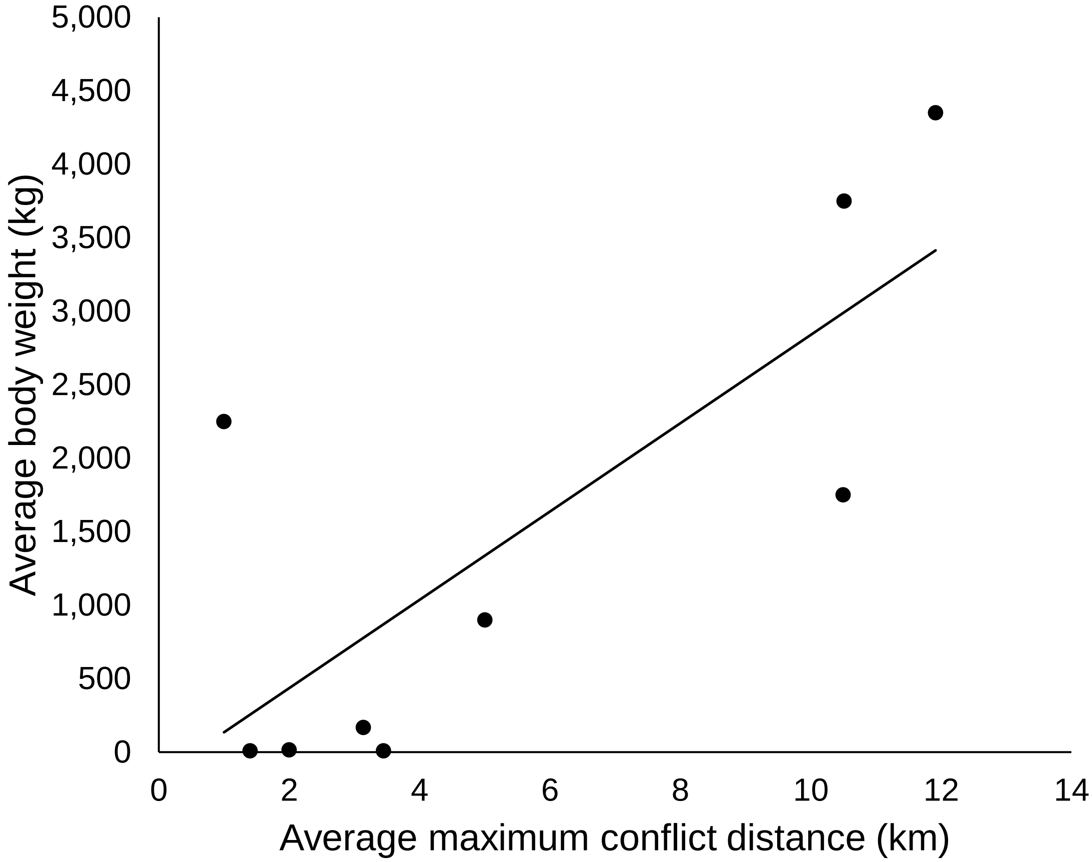


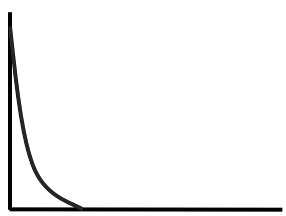
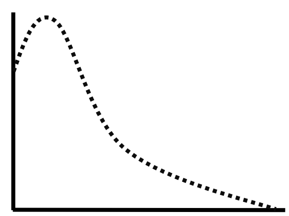
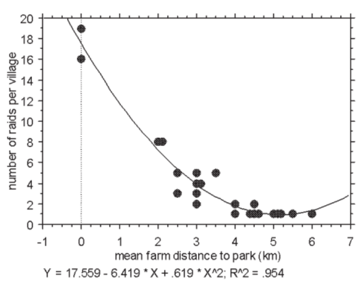
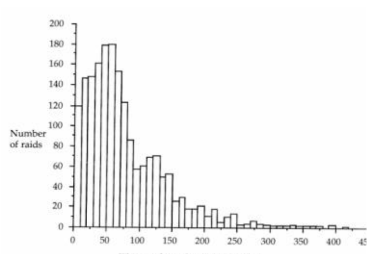
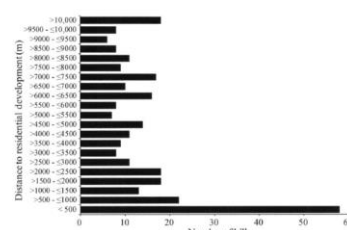
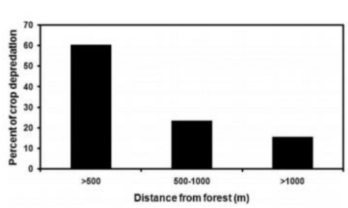
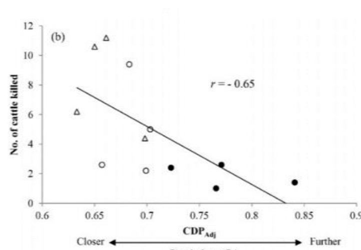
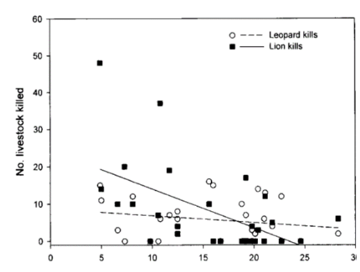
Figure 6. The relationship between herbivorous species body weight and the average maximum distance from the protected area where conflict occurred in a given environment (n = 9; $r^2 = 0.602$; p = 0.0142).

Identified Conflict Patterns

I identified three broad spatial patterns appearing in human-conflict. These patterns were identified from figures included in publications in the literature review (Table 1). Patterns were identified across a range of species and geographic locations. The recurring appearance of certain patterns allowed me to develop a typology of generalizable spatial patterns of human-wildlife conflict (Figure 7). Pattern type I could be associated with species with home ranges dependent upon specific aspects of the landscape such as tree cover or large bodies of water (e.g., primates, hippopotami, crocodiles, and rhinoceros) (Oppong et al. 2008, Graham et al. 2010, Regmi et al. 2013). The type II pattern illustrates a case in which conflict peaks some distance from the boundary of a particular protected area. Species following this pattern may have larger

home ranges (e.g., Asian Elephants, bears, tigers), and many appear to reside in protected areas that are surrounded by buffer zones (Kagoro-Rugunda 2004, Nath et al. 2013, Meena et al. 2014). The type III pattern was derived from studies of wide-ranging species not necessarily residing in clearly demarcated reserves (e.g., cougars, coyotes, foxes, leopards) (Sheiss-Meier et al. 2007, Kertson et al. 2011); species following this pattern may encounter variable levels of human population density. As a result, levels of human-wildlife conflict may fluctuate in the presence of suitable habitat near areas of increased human-population density.

Table 1. Typology of generalizable spatial patterns of human-wildlife conflict and publication figures associated with the identification of each pattern.

<table>
<tr><th>Pattern I</th><th>Pattern II</th><th>Pattern III</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Oppong et al. (2008)</td><td>Naughton-Treves (1997)</td><td>Kertson et al. (2011)</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Charoo et al. (2011)</td><td>Kuiper et al. (2015)</td><td>Sheiss-Meier et al. (2007)</td></tr>
</table>

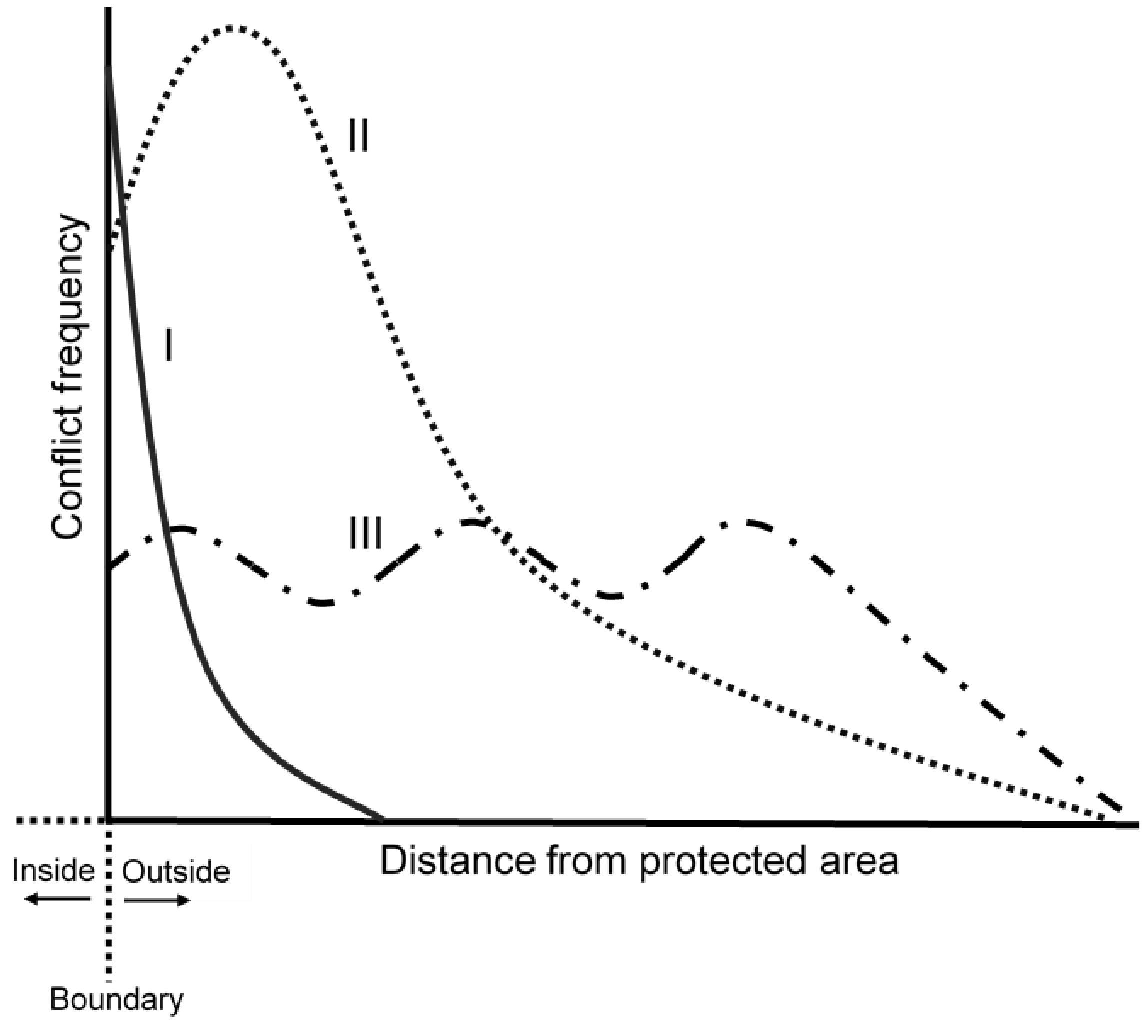


Figure 7. Typology of generalizable patterns of conflict occurrence between humans and wildlife with increasing distance from protected areas of land. (I) Species with a sharp drop-off in conflict occurrence, with ranges dependent upon specific variables such as tree cover or bodies of water (primates, hippopotami, crocodiles, rhinoceros, pigs). (II) Species with large home ranges. Some studies suggest an initial increase followed by a decrease (Asian elephant), while others display a decay more similar to (I) but with a shallower slope (bear, tiger). (III) An identified conflict-distance relationship for species with a wide distribution, part of which includes areas of variable human population density. Levels of conflict may fluctuate with habitat patches with a drop off appearing at a much further distance away from the protected area (cougars, coyotes, leopards, foxes). These patterns are idealized and actual conflict rates are situational, depending on a wide variety of geographic factors, including habitat type, patterns of cultivation, livestock density and location, and human settlements.

Discussion

One striking finding of this review is the large number of published papers that report a relationship between distance from a protected area boundary and the occurrence of human-wildlife conflict. The abundance of research across different continents, countries, and diverse species illustrates a widespread recognition that spatial dimensions of conflict are important. Studies included in this review primarily focus on conflict between humans and large-bodied species of wildlife: over 57% of the species have a body weight greater than 40 kilograms. Large animals (e.g., elephants and big cats) generally range further from protected area boundaries in order to meet nutritional needs, and can inflict large amounts of damage in a single conflict incident (Naughton-Treves 1997, Woodroffe and Ginsberg 1998, Nath et al. 2015, Nyhus 2016). In contrast, smaller species like porcupines, mongooses, and small primates (purple-faced langurs and pig-tailed macaques) tend to cause conflict much closer to protected area boundaries (Linkie et al. 2007, Chhangani et al. 2008, Nijman and Nekaris 2010, Regmi et al. 2013).

These patterns may be explained in part by characteristics inherent to the species. There was a significant relationship between the bodyweight of herbivorous species and the average maximum conflict distance. There was not a significant relationship between the bodyweight of carnivorous species and average maximum conflict distance. This difference may be because weight of herbivorous species included in this review range from the 4108kg African elephant (Laws 1966) to the 7 kg purple-faced langur (www.dilmahconservation.org). Carnivorous and omnivorous species both only ranged approximately 150kg, from the 7kg culpeo fox (Hunter 2006) to the 160kg lion (Hunter 2006, Nyhus and Tilson 2010, Hunter and Barrett 2011) and the 17kg gelada baboon (Clutton-Brock and Harvey 1977) to the 171kg nilgai (Schaller 1967).

Home range size may also explain trends between smaller and larger species. There was a significant relationship between home range size and average maximum conflict distance across all taxonomic groups. This relationship was also present for home range size subsetted by diet type. These findings are supported by other studies; Tucker et al. (2014) find a linear relationship between species body mass and home range size across all diet types. The herbivore data in the sample contain a wide range of body weights and range sizes, capturing some of the variation that occurs across the dietary

group. Contrary to Tucker et al. (2014), I did not find a relationship between home range size and body weight for the species included in my dataset.

Average conflict distance varies among taxonomic groups. Twice as many studies report on carnivore damage than herbivore damage, and four times as many as omnivore damage. Felid species account for more than twice as many papers as any other taxonomic group, and lions, leopards, tigers and mountain lions are the most studied species. On average, felids caused conflict further from boundaries than other taxa. This is consistent with findings of Dhanwatey et al. (2013), Kushnir et al. (2014) and Michalski et al. (2006) who found that conflict between humans and tigers, lions, jaguars, leopards, and cougars can occur 60 to 100km from protected area boundaries.

The nutritional requirements of wide ranging, carnivorous species place them in conflict with humans, and decreasing natural prey populations in some regions have led some carnivores to prey upon livestock (Woodroffe and Ginsberg 1998, Patterson et al. 2004, Inskip and Zimmermann 2009, Loveridge et al. 2010). Loss of natural habitat and a greater agricultural presence near remaining areas of wildlife habitat have led to increased instances of human-wildlife contact (Naughton-Treves 1997, Woodroffe et al. 2005, Inskip and Zimmermann 2009, Dickman 2010, Loveridge et al. 2010). Similarly, grazing of domestic livestock has diminished natural nutritional resources of some herbivorous species, leading to increased crop raiding incidents (Karanth et al. 2006). Woodroffe and Ginsberg (1998) found a relationship between female home range size and critical reserve size for carnivorous species, and studies have shown that carnivore home range size typically increases in a linear fashion with body mass (Gittleman and Harvey 1982, Lindstedt et al. 1986).

An alternative explanation for the relationship between herbivore bodyweight and maximum conflict distance may relate to reporting bias. A number of studies have found that people are more likely to report conflict with larger and more charismatic species like elephants, rhinoceros, and tigers than with smaller species because larger species typically cause more damage in a single conflict occurrence (Naughton-Treves 1997, 1998, Karanth et al. 2013, Nath et al. 2015). Elephant raids can severely diminish or completely destroy the crop harvest for some farmers, at times causing farms to be completely abandoned (Naughton-Treves 1997, 1998, Nath et al. 2015). In a "worst pest"

ranking system in Africa, African elephants emerged as the worst pest at local levels and in communities near protected area borders, but were not ranked as such in national level “worst pest” assessments (Woodroffe et al. 2005). This difference in rankings indicates both the restricted range of larger-bodied species like African elephants due to habitat loss as well as the disproportionate amount of damage inflicted in a single instance of human-elephant conflict. Species falling into the “pest” category are likely to be present across a wide geographic range, leading those living further from protected area boundaries to mark them as “worst pests,” while those living closer to protected area boundaries experience higher levels of damage from megafauna, labelling them as the “worst pests” for their area of residence (Naughton-Treves 1997, 1998, Woodroffe et al. 2005).

A third notable finding of this study is that a majority of human-wildlife conflict studies that reported spatial patterns of conflict can be categorized into one of three broad idealized patterns. The first two patterns display a decay in conflict frequency as distance from the protected area boundary increases, while the third pattern shows conflict frequency fluctuating over distance. Type I patterns display a high frequency of conflict very close to the boundary, with conflict frequency declining rapidly over a relatively small distance. This pattern may illustrate patterns of conflict for smaller species dependent upon the vegetative cover provided by protected areas (e.g., macaques and redtail monkeys), in addition to larger species that reside in protected areas and occasionally leave to raid crops or prey on livestock, such as African and Asian elephants, tigers, and Asiatic black bears (Naughton-Treves 1998, Gurung et al. 2008, Oppong et al. 2008, Graham et al. 2010, Charoo et al. 2011, Regmi et al. 2013, Pant et al. 2015). Type II patterns display conflict frequencies that peak at some distance from the protected area boundary. Following this peak, conflict frequency also declines steadily with distance. This pattern appears to be associated with areas where there may be a buffer between the protected area or habitat edge and spaces where conflict may occur. Larger-bodied herbivores (e.g., Asian elephants) and carnivores (e.g., lions) follow this pattern. For example, Meena et al. (2014) found that hot spots of Gir lion predation in India occurred in areas where forest and grassland reserves were used as corridors to travel to other habitats, while Nath et al. (2015) suggests that the development of buffer

zones between Manas National Park in India and human settlements is necessary to prevent overlap of land use between humans and elephants.

The type III patterns illustrate an undulating conflict frequency eventually declining to zero as the species involved reaches the limits of its home range. This pattern attempts to capture conflict frequencies for wide ranging species residing in areas that are heavily interspersed with human populations (e.g., leopards, mountain lions). Kertson et al. (2011) and Sheiss-Meier et al. (2007) found that use of residential areas by cougars in Washington state, USA was highly variable and the frequency of leopards attacks was relatively stable regardless of distance to protected area.

These patterns illustrate three examples of spatial patterns that emerge in instances of human-wildlife conflict, but there may be other patterns that exist. The three patterns proposed in this chapter are based solely on observations of commonly discussed trends throughout this literature review. Additionally, pattern types may not be mutually exclusive within each study location. In certain landscapes, combinations of patterns may appear. For example, Kertson et al. (2011) illustrate human-wildlife conflict with cougars in Washington state, USA which appears to be pattern type I at a close distance to human settlement, but when examined on a larger scale follows pattern III more closely. Pattern types may shift in different spaces around a protected area, across different scales of measurement, spans of time, and may depend on data resolution. Landscape characteristics may also be associated with determining patterns of conflict. Research shows that environmental variables such as forest cover, elevation, and cropping system may play a role in conflict frequency (Karanth et al. 2012, Karanth et al. 2013).

One limitation of the analysis is that this review focused on papers finding a significant relationship between conflict frequency and distance from protected area boundaries. To date, many of these papers have focused on a relatively small number of species. Access to data on a greater number of species would allow for a fuller examination of the relationships between average maximum conflict distance and species bodyweight or home range size across all species and dietary groups.

Another important aspect to consider is that of reporting bias toward larger-bodied organisms. This review, along with many human-wildlife conflict studies, is reliant upon the reports of study area residents as a way of establishing when, where, and

how much damage has occurred in conflict incidents. The tolerance levels and species-specific attitudes of residents may impact how often conflicts are reported. While "pest" species may cause more damage to farmers on average over time, heavy economic losses or injuries or deaths of people inflicted by megafauna like elephants and tigers may lead to a disproportionate amount of time and energy spent researching conflict between humans and larger-bodied species (Naughton-Treves 1997, Karanth et al. 2012, Nath et al. 2015).

I found that many human-wildlife conflict studies describe patterns of human-wildlife conflict for one species or location, but few synthesize data at larger spatial scales. Only two studies included in this review seek to explain trends in human-wildlife conflict on a larger scale. Harcourt et al. (2001) describe the relationship between human population density, reserve size, and human-cause mortality of carnivores in Africa and Inskip and Zimmermann (2009) investigate variables and patterns determining the severity of human-felid conflict worldwide. However, this review almost certainly includes only a subset of the relevant literature. I only included English-language sources, did not include unpublished literature, and, some studies may use different keywords not captured by the search terms used in this review.

While numerous site- and species-specific studies have contributed to the idea that there is a relationship between human-wildlife conflict frequency and proximity to natural or protected area boundaries, this review suggests that studies are needed to identify broader, more generalizable patterns of conflict. Expanding human-wildlife conflict research beyond site- and species-specific studies would reduce the volume of papers simply identifying distance as an important variable associated with the presence of human-wildlife conflict. By examining more nuanced patterns of human-wildlife conflict, conservation practitioners could identify species or study locations that do not fall within those generally recognized patterns and work to understand what environmental variables or species characteristics contribute to novel or outlier conflict patterns. Understanding where and why human-wildlife conflict is likely to take place is a crucial step towards employing effective conflict mitigation strategies.

Future research on spatial patterns of human-wildlife conflict would benefit from two types of assessment in particular. The first is a continued investigation into the

impact of landscape variables and species characteristics on conflict frequency and location through the use of empirical conflict data. The second would be to present the identified pattern typologies proposed in this thesis to conservation professionals to query whether or not conservation practitioners associate these patterns with their own data and experiences.

The growth over the last twenty years in the number of scientific publications discussing human-wildlife conflict indicates that finding these generalizable patterns is becoming increasingly important (Dickman 2010, Nyhus 2016). In addition to encouraging effective conflict mitigation strategies, the ability to map where and how often conflict is likely to occur across a range of landscapes and species will allow conservation practitioners to track how spatial patterns of human-wildlife conflict shift with changing global conditions.

CHAPTER 3: FACTORS INFLUENCING SPATIAL PATTERNS OF HUMAN-WILDLIFE CONFLICT: A SURVEY OF CONSERVATION PROFESSIONALS

Introduction

In many countries, instances of human-wildlife conflict are increasing as a result of habitat fragmentation and competition for resources (Middleton 2003, Inskip and Zimmermann 2009, Nath et al. 2015). Human-wildlife conflict poses a challenge for both wildlife and people because it can result in economic losses, human death or injury, and retaliatory killings of wildlife (Woodroffe et al. 2005, Dirzo et al. 2014, Ripple et al. 2014). Conflict can also reduce support for conservation by engendering negative opinions in communities experiencing conflict (Woodroffe et al. 2005, Loveridge et al. 2010). However, a stronger understanding of the drivers of wildlife behavior is informing the implementation of conflict mitigation and prevention techniques like economic compensation and the construction of barriers to promote human-wildlife coexistence (Nyhus et al. 2005, Dickman et al. 2011, Reidinger Jr and Miller 2013).

A growing number of scholars and practitioners have sought to understand where, why, and how human-wildlife conflict occurs (Woodroffe et al. 2005, Inskip and Zimmermann 2009, Karanth et al. 2013, Dickman and Hazzah 2016, Soulsbury and White 2016). One challenge is that many studies are limited to one study species or taxonomic group and location. Less has been done to synthesize understandings of human-wildlife conflict patterns that are generalizable across multiple species and locations. As a result, numerous studies report similar conclusions across diverse cases of human-wildlife conflict. For example, studies of primates in Uganda (Naughton-Treves 1997, 1998, Regmi et al. 2013), African elephants in Ghana and Kenya (Oppong et al. 2008, Graham et al. 2010), Asian elephants in Nepal (Pant et al. 2015), Asiatic black bears in India (Charoo et al. 2011), and tigers in Nepal (Gurung et al. 2008) conclude that human-wildlife conflict decreases as distance from the boundary of protected areas increases. The repetition of similar conclusions across diverse taxa and regions is a missed opportunity for novel synthesis and analysis of common patterns of human-wildlife conflict, and researchers have called for further research on the appearance of human-wildlife conflict patterns (Karanth et al. 2013, Nyhus 2016).

I identified three generalizable spatial human-wildlife conflict frequency patterns and developed a typology derived from trends I observed in a literature review of human-wildlife conflict (see chapter 2). To create these three generalizable models of human-wildlife conflict frequency, I compiled spatial patterns of conflict frequency described by authors of the reviewed publications. Each individual pattern corresponds to descriptions provided by a number of studies and the generalizations I identified in the literature review. The type I pattern could be associated with species with home ranges dependent upon specific aspects of the landscape such as tree cover or large bodies of water (e.g., primates, hippopotami, crocodiles, and rhinoceroses) (Oppong et al. 2008, Graham et al. 2010, Regmi et al. 2013). The type II pattern illustrates a case in which conflict peaks some distance from the boundary of a particular landscape or protected area. Species following this pattern may have larger home ranges (e.g., Asian Elephants, bears, tigers), and many appear to reside in protected areas surrounded by buffer zones (Kagoro-Rugunda 2004, Nath et al. 2013, Meena et al. 2014). The type III model was derived from studies of wide-ranging species not necessarily residing in clearly demarcated reserves (e.g., cougars, coyotes, foxes, leopards) (Sheiss-Meier et al. 2007, Kertson et al. 2011); species following this pattern may encounter variable levels of human population density. As a result, levels of human-wildlife conflict may fluctuate in the presence of suitable habitat near areas of increased human-population density.

In order to test the applicability of these patterns across a variety of taxonomic groups and habitat types, I surveyed conservation practitioners working in a range of locations with diverse species. From this survey, I particularly wanted to know: 1) Do practitioners agree with the three identified spatial human-wildlife conflict patterns? 2) What biological and landscape factors may help to explain how specific patterns are associated with certain study locations or species? 3) Are there outliers, and if so, why? By asking human-wildlife conflict scholars and practitioners to comment on the identified human-wildlife conflict spatial patterns I hope to affirm or reassess the pattern types that were initially proposed. External validation would provide a framework for other scholars to build on the proposed pattern types through confirmation of the accuracy and applicability of each pattern, leading to further pattern refinement or feedback leading to reevaluation and redesign of pattern appearances.

Methods

Survey Implementation

I developed an online survey instrument to ask conservation professionals about their experiences with spatial patterns of human-wildlife conflict frequency. This survey was approved by the Colby College International Review Board (IRB) and survey responses were anonymous. Email invitations were sent in March 2018 to 368 conservation professionals. Names and addresses were derived from two sources: corresponding authors on scholarly articles describing spatial patterns of human-wildlife conflict (see chapter 2), and members of six of the International Union for the Conservation of Nature's (IUCN) Species Survival Commission (SSC) specialist groups or task forces.

Specialist group and task force participants came from the Cat Specialist Group (CSG), the Canid Specialist Group (CaSG), the Human Wildlife Conflict Task Force (HWCTF), the Bear Specialist Group (BSG), and the Asian (AESG) and African Elephant Specialist Groups (AfESG). Approximately 15 survey participants belong to more than one specialist group. Contact information for CSG members was obtained from the CSG website (Cat Specialist Group 2018). A list of members of the CaSG, BSG, and HWCTF are available on each group's website (Bear Specialist Group 2018, Canid Specialist Group 2018, Human-Wildlife Conflict Task Force 2018). Members of the AfESG Data Review and Human-Elephant Conflict Working Groups were selected as survey participants. Similarly, selected participants of the AESG are all members of the *Gajah* Editorial Board—a complete list of members of the AESG and AfESG were not available at the time of this study (Asian Elephant Specialist Group 2017, African Elephant Specialist Group 2018). Contact information for members of the CaSG, BSG, HWCTF, AfESG, and AESG were gathered from personal biographies or recent publications.

The survey was completed online using Qualtrics software (Qualtrics 2018). A template letter containing a link to the survey was sent by email to each participant. Reminder emails were sent one week and two and a half weeks after the initial email was delivered.

Survey Design

The survey consisted of 22 questions, including four multi-part questions (see Appendix A). The questions were derived from the results of a literature review of patterns of human-wildlife conflict (see chapter 2). The survey included multiple choice questions in both single choice and "select all that apply" formats, open-ended questions, and one constant sum question. All questions were optional response, and provided either "I do not know," "other, please specify/explain," or "none of the above" as response choices. Survey respondents were encouraged to provide additional comments with these choices.

The survey covered six major topics relating to spatial and temporal patterns of human-wildlife conflict: country and area of study, study area boundary and human population characteristics, species spatial human-wildlife conflict frequency patterns based on identified typologies of human-wildlife conflict frequency, daily and yearly patterns of conflict frequency, wildlife compensation patterns, and basic respondent demographic information. The first section contained questions on the country, province or state, and protection designation of the area described within each survey response. Respondents were asked to describe the nature of the protected area edge and the structure and concentration of human settlement within or surrounding the protected area. Survey participants were provided the option of completing the survey more than once for multiple species or study areas.

Responses were classified as having a "low" proportion of distinct edge if $< 33\%$ of the administrative boundary of the protected area had "distinct habitat edge," "medium" if 34 - 66%, and "high" if distinct edge proportions were 67 – 100%. Species were classified as having a small ($<200 km^2$), medium ($201 – 1000 km^2$), or large ($>1001 km^2$) home range, and a small (<15kg), medium (15 – 100kg), or large (>100kg) body size.

In the second section, survey respondents were asked to fill out responses for one species or taxonomic group. Participants were asked to select one of three patterns best illustrating changes in human-wildlife frequency over an increasing distance from the boundary of a protected area or natural habitat (Figures 2 & 3, Appendix I). Survey participants were asked to select the pattern best illustrating conflict frequency at three

distances: 1 kilometer outside, 40 kilometers outside, and 1 kilometer inside a protected area boundary. These distances were selected as a result of observations made in a literature review of human-wildlife conflict (see chapter 2). Many publications in the literature review reported that a majority of conflict instances occurred close to protected area boundaries, leading to the 1 kilometer entry and boundary distances. The highest average maximum conflict distance for any of the taxa included in the literature review was just short of 40 kilometers, resulting in the use of a 40 kilometer boundary distance in the survey.

For each selection, participants were also asked to describe their level of confidence using a three-point Likert scale, where the most confident response was "very confident" and the least confident response was "not confident." Respondents were given the option to explain "other" responses.

Participants were asked what percentage of conflict they had observed typically occurring throughout the day over six four-hour spans of one day, beginning and ending at midnight (0:00 – 4:00, 4:01 – 8:00, 8:01 – 12:00, 12:01 – 16:00, 16:01 – 20:00, and 20:01 – 23:59).

The third section contained two questions on wildlife compensation. The first asked whether residents living in the study area received compensation for human-wildlife conflict; the second asked respondents to select the generalizable human-wildlife conflict spatial pattern best illustrating compensation receipt for the study area described within their survey response.

The final three questions asked respondents to describe their affiliation(s), the nature of their work, and geographic areas where they had been or were involved in human-wildlife conflict research.

Data Analysis

Survey results were analyzed using R *v.3.4.4* (R Core Team 2018) and Microsoft Excel. Chi-square tests with an applied Monte Carlo simulation were used to test if species or landscape characteristics, or respondent characteristics were significantly associated with the generalizable spatial human-wildlife conflict patterns. A Monte Carlo simulation was applied to account for the small sample size and zeros appearing

throughout the subdivided results (Hope 1968). ArcGIS *v.10.4.1* was used to map response countries using the United Nations M49 numeric coding system (Environmental Systems Research Institute 2016, United Nations 2018).

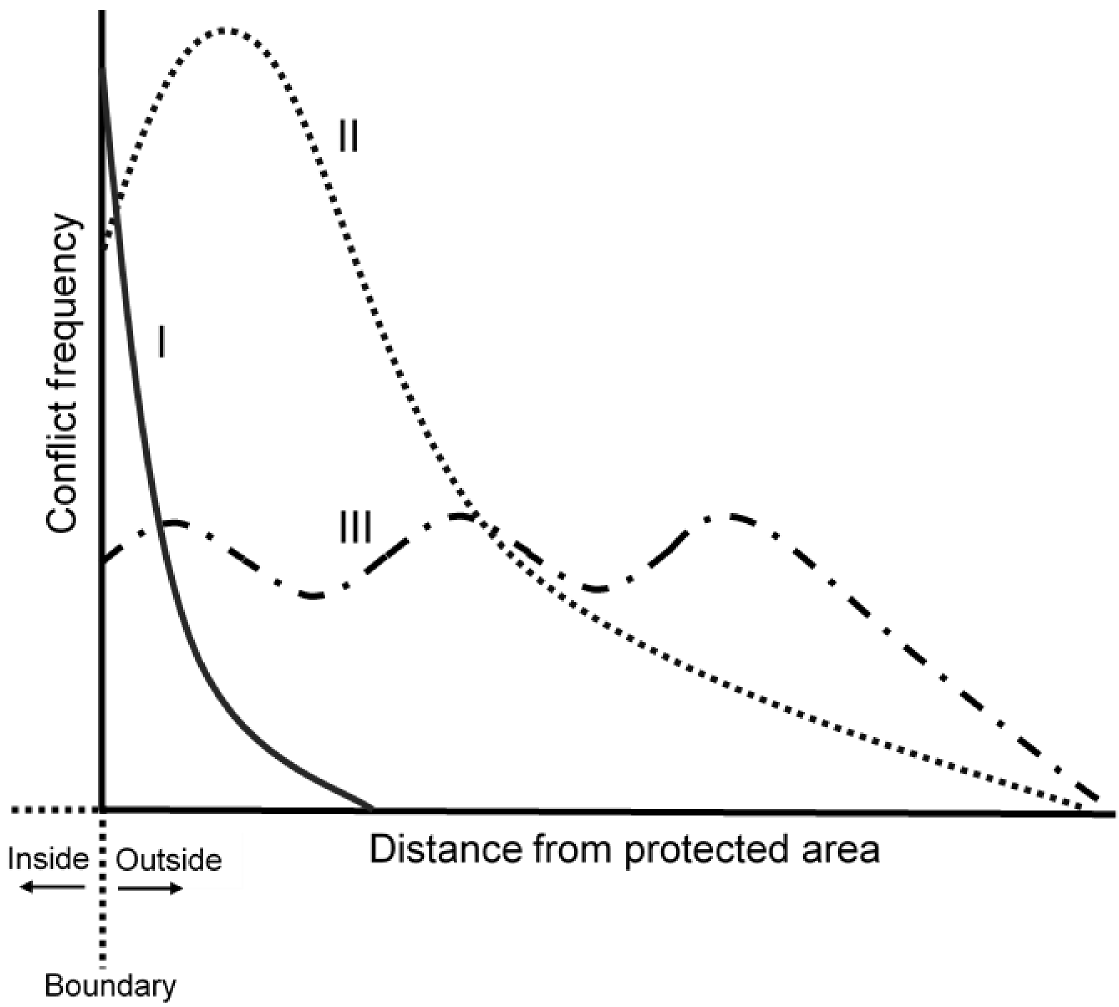


Figure 2. Typology of generalizable patterns of conflict occurrence between humans and wildlife with increasing distance from protected areas of land. (I) Species with a sharp drop-off in conflict occurrence, with ranges dependent upon specific variables such as tree cover or bodies of water (primates, hippopotami, crocodiles, rhinoceros, pigs). (II) Species with large home ranges. Some studies suggest an initial increase followed by a decrease (Asian elephant), while others display a decay more similar to (I) but with a shallower slope (bear, tiger). (III) An identified conflict-distance relationship for species with a wide distribution, part of which includes areas of variable human population density. Levels of conflict may fluctuate with habitat patches with a drop off appearing at a much further distance away from the protected area (cougars, coyotes, leopards, foxes). These patterns are idealized and actual conflict rates are situational, depending on a wide variety of geographic factors, including habitat type, patterns of cultivation, livestock density and location, and human settlements.

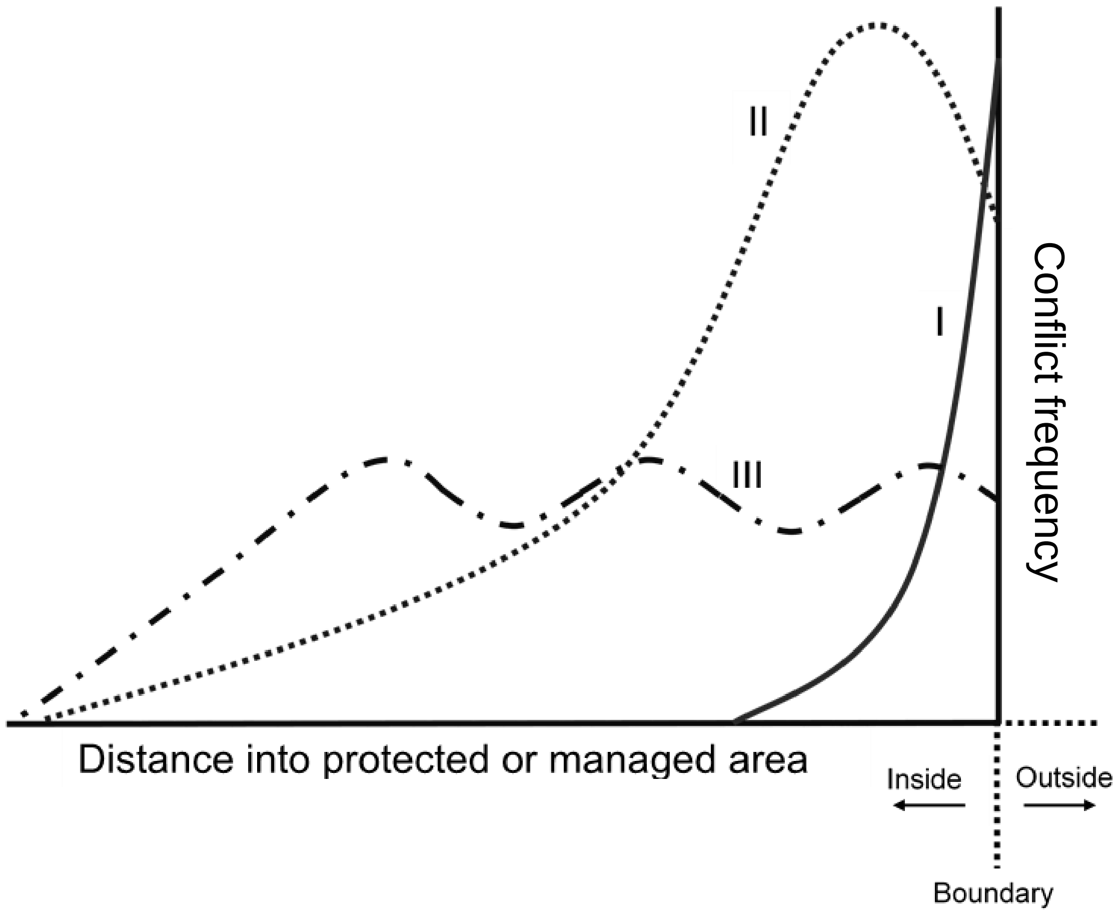


Figure 3. Typology of generalizable patterns of conflict occurrence between humans and wildlife as distance within the boundary of a protected area increases. (I) Species with a sharp drop-off in conflict occurrence, with ranges dependent upon specific variables such as tree cover or bodies of water (primates, hippopotami, crocodiles, rhinoceros, pigs). (II) Species with large home ranges. Some studies suggest an initial increase followed by a decrease (Asian elephant), while others display a decay more similar to (I) but with a shallower slope (bear, tiger). (III) An identified conflict-distance relationship for species with a wide distribution, part of which includes areas of variable human population density. Levels of conflict may fluctuate with habitat patches with a drop off appearing at a much further distance away from the protected area (cougars, coyotes, leopards, foxes). These patterns are idealized and actual conflict rates are situational, depending on a wide variety of geographic factors, including habitat type, patterns of cultivation, livestock density and location, and human settlements.

Results

I received 58 responses from 368 conservation professionals (16%). Response rates from selected participant groups ranged from 7% to 25% (Table 1). Respondents described patterns of conflict for 24 different species in 27 different countries (Figure 4).

No survey participants completed the survey for more than one species or study location. The largest groups of respondents describe study sites located in Asia (n = 21, 40%) and Africa (n = 14, 26%). The remainder of responses are from study sites in North America (n = 6, 11%), South America (n = 8, 15%), and Europe (n = 4, 8%). India represented the largest source of responses from a single country (n = 5, 9%), followed by Nepal, Sri Lanka, Tanzania, and Uganda (n = 4, 7% each).

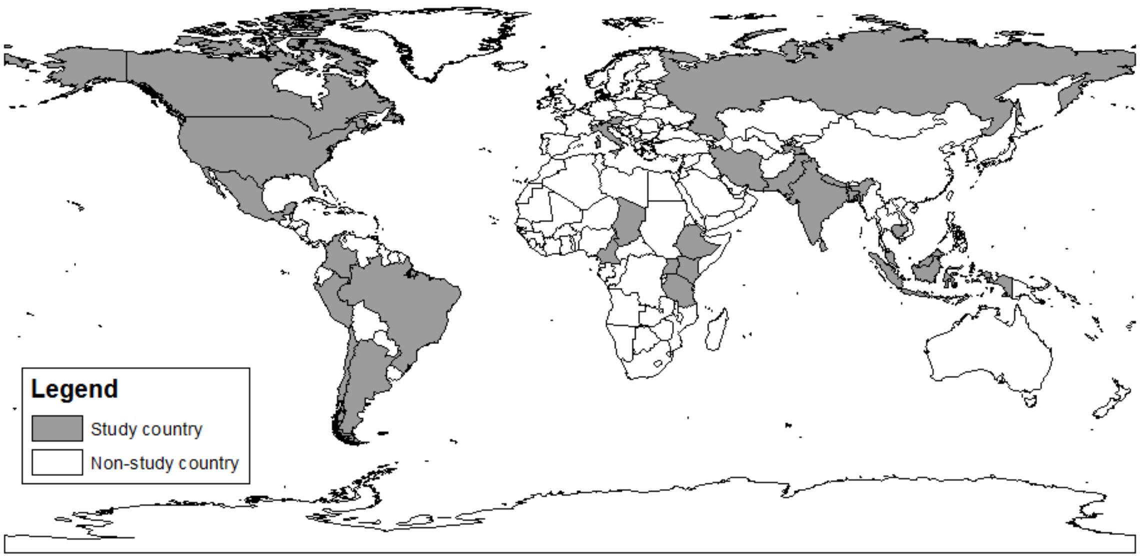


Figure 4. The distribution of survey study country locations. Shading indicates that at least one respondent completed the survey for an area located within the shaded country (n = 54).

Table 1. A breakdown of survey email distributions and response rates. Response rates are calculated within each individual group, rather than the entire email pool (n = 368).

Group name	**Sent emails**	**Total responses**	**Response rate (%)**
Cat Specialist Group (CSG)	184	29	16%
Corresponding authors	91	20	22%
Canid Specialist Group (CaSG)	51	4	12.75%
Bear Specialist Group (BSG)	15	2	7.5%
Human-Wildlife Conflict Task Force	15	1	7%
Asian Elephant Specialist Group (AESG)	8	2	25%
African Elephant Specialist Group (AfESG)	4	0	0%
Total	368	58	16

Pattern Type Selection

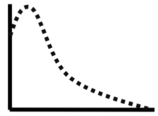
Survey respondents selected every available pattern across all three boundary distances. For the one kilometer entry distance into a protected area, over half of respondents (n = 21, 54%) chose the type I pattern and pattern choice differed significantly across all three patterns ($\chi^2 = 11.2$, $p = 0.0045$) (Table 2). There was no significant difference in confidence levels across or within patterns.

At a one kilometer boundary distance, no pattern was selected significantly more than another, but type III pattern was selected by over a third of respondents (n = 18, 38%). The majority of respondents (n = 32, 76%) reported they were either "very confident" (n = 18, 43%) or "somewhat confident" (n = 14, 33%) in their pattern choice. Respondents were significantly more likely to be "somewhat confident" about pattern II compared to pattern I or III at a one kilometer boundary distance, and they were significantly more likely to feel "somewhat confident" compared to "not" or "very" confident for pattern type II ($\chi^2 = 9.57$, $p = 0.0069$; $\chi^2 = 1.47$, $p = 0.0039$).

At a 40 kilometer boundary distance, a significant majority (n = 24, 51%) of survey participants selected the type III pattern ($\chi^2 = 8.21$, $p = 0.0235$). Respondents were significantly more likely to select "not confident" for pattern type III ($\chi^2 = 12.7$, p = 0.0039.

Nearly half of respondents selected a different pattern type for the 40 kilometer distance compared to the 1 kilometer boundary distance (n = 17, 40%). Out of these respondents, a majority switched their choice from the type II to the type I pattern (n = 7, 64%). Respondents were typically less confident in their pattern selections at a 40 kilometer distance than they were at a one kilometer distance. More than one third of respondents (n = 20, 37%) expressed different levels of confidence at 1 and 40 kilometers—less than one third were "very confident" (n = 12, 29%), and close to half were "somewhat confident" (n = 18, 44%) in their pattern choice at a 40 kilometer boundary distance.

Table 2. Distribution of pattern type selections across different confidence levels at a 1 kilometer entry distance and 1 and 40 kilometer boundary distances (p < 0.05 = *, p < 0.01 = **, p < 0.001 = ***).

Pattern type							**p-value**
	n	%	n	%	n	%	
1 kilometer entry							
Selected pattern (n = 39)	21	54	4	10	14	36	0.0045**
Confidence level (n = 34)							
Very confident	8	24	1	3	6	18	0.0910
Somewhat confident	8	24	1	3	4	12	0.0664
Not confident	1	3	2	6	3	9	0.8886
Total	17	50	4	12	13	38	
p-value	0.0615		1.000		0.6837		
1 kilometer distance							
Selected pattern (n = 48)	14	29	16	33	18	38	0.8091
Confidence level (n = 39)							
Very confident	6	15	4	10	8	21	0.5622
Somewhat confident	1	3	10	26	3	8	0.0069**
Not confident	4	10	0	0	3	8	0.2279
Total	11	28	14	36	14	36	
p-value	0.2159		0.0039**		0.2034		
40 kilometer distance							
Selected pattern (n = 47)	15	32	8	17	24	51	0.0235*
Confidence level (n = 39)							
Very confident	5	13	3	8	4	10	0.9390
Somewhat confident	6	15	3	8	9	23	0.2464
Not confident	1	3	0	0	8	21	0.0039**
Total	12	31	6	15	21	54	
p-value	0.2769		0.3898		0.4878		

Species- and Taxa-Specific Variables

Diet

Generalizable spatial pattern selection was significantly related to dietary group at a one kilometer boundary distance ($\chi^2 = 12.028$, p = 0.0114) (Table 3). Nearly half of participants completing the survey for a carnivorous species selected the type III pattern across all boundary distances (n = 41, 49%). Herbivores were significantly more

associated with pattern type II at a 1 kilometer boundary distance but were not significantly more likely to be associated with a pattern across other distance classes (χ^2 = 6.2, p = 0.0450). No significant relationships emerged between omnivorous species and pattern type selection.

Body size

Pattern choice differed significantly across all three body sizes at a one kilometer boundary distance (χ^2 = 14.5, p = 0.0025) (Table 3).

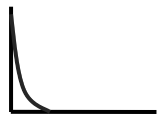
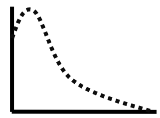
Over half of respondents (n = 29, 52%) selected the type III pattern for medium-bodied species across all boundary distances. At a one kilometer boundary distance, medium-bodied species were significantly less likely to be associated with pattern type I (χ^2 = 7.9, p = 0.0185).

More than half of survey participants (n = 26, 54%) selected the type I pattern for large-bodied species across all boundary distances. However, no significant relationships were found between large- or small-bodied species and pattern type selection.

Home range

Pattern type III was selected half of the time for species with medium home range sizes across all distances (n = 27, 50%). For entry distance into the protected area, medium-range species and pattern type I were significantly related (χ^2 = 9.5, p = 0.0065) (Table 3). Species with large and small home range sizes were not significantly associated with any pattern type.

Table 3. Distribution of pattern type selections across different species characteristics at a 1 kilometer entry distance and 1 and 40 kilometer boundary distances (p < 0.05 = *, p < 0.01 = **, p < 0.001 = ***).

Pattern type							**p-value**
	n	%	n	%	n	%	
1 kilometer entry							
Diet (n = 34)							
Carnivore	12	35	4	12	10	29	0.1284
Herbivore	4	12	0	0	1	3	0.1279
Omnivore	1	3	0	0	2	6	0.7681
Total	17	50	4	12	13	38	
Species body size (n = 34)							
Small	1	3	0	0	2	6	0.7681
Medium	9	26	2	6	7	21	0.1394
Large	7	21	2	6	4	12	0.2694
Total	17	50	4	12	13	38	
Species range size (n = 34)							
Small	5	15	1	3	2	6	0.2924
Medium	10	29	0	0	6	18	0.0065**
Large	2	6	3	9	5	15	0.6002
Total	17	50	4	12	13	38	
1 kilometer distance							
Diet (n = 43)							
Carnivore	7	16	8	19	14	33	0.2379
Herbivore	2	5	7	16	1	2	0.0450*
Omnivore	3	7	0	0	1	2	0.3348
Total	12	28	15	35	16	37	
Species body size (n = 42)							
Small	2	5	2	5	1	2	1.0000
Medium	1	2	8	19	11	26	0.0185*
Large	10	24	5	12	2	5	0.0685
Total	13	31	15	36	14	33	
Species range size (n = 42)							
Small	3	7	6	14	2	5	0.4023
Medium	5	12	4	10	10	24	0.2214
Large	4	10	5	12	3	7	0.9410
Total	12	29	15	36	15	36	
40 kilometer distance							
Diet (n = 42)							
Carnivore	6	14	5	12	17	40	0.0089 **
Herbivore	6	14	2	5	3	7	0.4178
Omnivore	2	5	0	0	1	2	0.8011
Total	14	33	7	17	21	50	

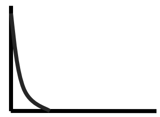
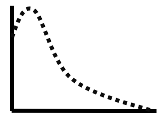
Species body size (n = 40)							
Small	2	5	0	0	2	5	0.5672
Medium	3	8	4	10	11	28	0.0530
Large	9	23	2	5	7	18	0.1339
Total	14	35	6	15	20	50	
Species range size (n = 41)							
Small	5	12	2	5	3	7	0.6177
Medium	4	10	4	10	11	27	0.0944
Large	5	12	1	2	6	15	0.2824
Total	14	34	7	17	20	49	

Protected Area Designation

Protected area designation and pattern type selection were significantly related at both a 1 kilometer (χ^2 = 6.54, p = 0.0420) and 40 kilometer (χ^2 = 14.6, p = 0.0009) boundary distance (Table 4). Nearly half of respondents completed the survey for study areas containing multiple types of protected areas (n = 25, 45%). Multiple protected area study areas were significantly associated with pattern type III across all three distances (χ^2 = 6.4, p = 0.024; χ^2 = 10, p = 0.002; χ^2 = 13, p = 0.001), and pattern type II at a 40 kilometer distance (χ^2 = 6, p = 0.0395). Respondents were significantly less likely to select pattern type II than type I or III for multiple protected area study areas at a 1 kilometer entry distance (χ^2 = 2.34, p = 0.0435) and pattern type III over other pattern types at a 40 kilometer distance (χ^2 = 5.74, p = 0.0229).

A majority of respondents (n = 14, 82%) completing the survey for study areas with a national park selected the type I pattern across all boundary distances. At a 40 kilometer boundary distance, all survey participants describing a study area containing a national park (n = 5, 100%) selected pattern type I.

Table 4. The distribution of pattern type selections across different protected area designations at a 1 kilometer entry distance and 1 and 40 kilometer boundary distances (p < 0.05 = *, p < 0.01 = **, p < 0.001 = ***).

Pattern type							**p-value**
	n	%	n	%	n	%	
1 kilometer entry							
Protected area (n = 22)							
National park	4	18	0	0	1	4	0.1324
Multiple PAs	7	32	1	5	9	41	0.0435 *
Total	11	50	1	5	10	45	
p-value	0.5517		1.0000		0.0199*		
1 kilometer distance							
Protected area (n = 27)							
National park	5	19	2	7	0	0	0.0750
Multiple PAs	5	19	5	19	10	37	0.3283
Total	10	37	7	26	10	37	
p-value	1.0000		0.4508		0.0014**		
40 kilometer distance							
Protected area (n = 27)							
National park	5	19	0	0	0	0	0.0150 *
Multiple PAs	3	11	6	22	13	48	0.0229 *
Total	8	30	6	22	13	48	
p-value	0.7371		0.0395*		0.0004**		

Daily and Yearly Conflict Patterns

Nearly half of respondents said they observed the frequency of human-wildlife conflicts changing appreciably over the course of the day (n = 23, 42%). Those that did not observe frequencies changing throughout the day were significantly less likely to select pattern type I at a one kilometer entry distance ($\chi^2 = 7$, $p = 0.0305$) (Table 5). Survey responses indicate higher conflict frequencies throughout the night or at dusk and dawn than during daylight hours (Figure 4). Most notably, 4 out of 5 respondents completing the survey for African lions said they observed shifting frequencies of human-lion conflict throughout the course of a day, as did 2 out of 3 Asian elephant respondents, both mountain lion respondents, and the sole respondents for spotted hyenas and white-tailed deer. All of these participants indicated in their response that the

majority of conflict taking place between humans and their study species occurred at night, between the hours of 0:00 – 8:00 and 20:00 – 23:59.

When asked if they noticed spatial patterns of human-wildlife conflict occurrences changing appreciably over the course of a day, nearly one-third of respondents said yes (n = 16, 29%). At a one kilometer entry distance, pattern type II was selected significantly less often than type I or III by respondents observing shifting spatial patterns ($\chi^2 = 9.38$, $p = 0.009$). When asked to describe these shifts, participant statements discussed movement of conflict frequency away from forest edges toward human settlements at night due to humans keeping livestock close to the home or in corrals and heightened levels of wildlife activity.

A majority of participants observed spatial patterns of human-wildlife conflict frequency changing over the course of a year (n = 30, 55%). Many respondents indicated that conflict location and frequencies fluctuate as a result of seasonally driven human activities or seasonally dependent wildlife activity levels.

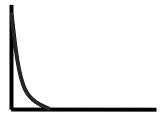
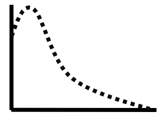
Other Variables

I also examined relationships between pattern type choice and the proportion of distinct protected area edge, human settlement patterns, country of study, continent of study, respondent affiliation, and respondent field of work, but did not find any of significance.

Compensation Occurrence

Almost half of respondents completed the survey for a study area where residents receive compensation for losses related to instances of human-wildlife conflict (n = 27, 48%). A majority of those respondents selecting compensation patterns observed type I patterns (n = 8, 80%), indicating a sharp decline in compensation receipt as distance from the boundary of the protected area increases. Five of these respondents also selected the type I pattern as the best illustration of conflict at a one kilometer boundary distance.

Table 5. The distribution of pattern type selections across different observed trends in temporal patterns at a 1 kilometer entry distance and 1 and 40 kilometer boundary distances (p < 0.05 = *, p < 0.01 = **, p < 0.001 = ***).

Pattern type							**p-value**
	n	%	n	%	n	%	
1 kilometer entry							
Daily pattern shifts							
Frequency (n = 32)							
Yes	10	31	2	6	6	19	0.0705
No	7	22	2	6	5	16	0.2994
Total	17	53	4	12	11	35	
p-value	0.6372		1.0000		1.0000		
Spatially (n = 30)							
Yes	9	30	0	0	4	13	0.0094 **
No	7	23	4	13	6	20	0.7456
Total	16	53	4	13	10	33	
p-value	0.8171		0.1299		0.7516		
Annual pattern shifts							
Spatially (n = 32)							
Yes	11	34	3	9	8	25	0.1394
No	6	19	1	3	3	9	0.1634
Total	17	53	4	13	11	34	
p-value	0.3418		0.6232		0.2349		
1 kilometer distance							
Daily pattern shifts							
Frequency (n = 34)							
Yes	7	21	6	18	7	21	1.0000
No	0	0	7	21	7	21	0.0305 *
Total	7	21	13	38	14	41	
p-value	0.0179 *		1.0000		1.0000		
Spatially (n = 35)							
Yes	2	6	5	14	8	23	0.1824
No	5	14	9	26	6	17	0.6077
Total	7	20	14	40	14	40	
p-value	0.4378		0.4278		0.7936		
Annual pattern shifts							
Spatially (n = 37)							
Yes	8	22	8	22	10	27	0.9070
No	2	5	5	14	4	11	0.6632
Total	10	27	13	35	14	38	
p-value	0.0989		0.5682		0.1809		
40 kilometer distance							
Daily pattern shifts							

Frequency (n = 33)							
Yes	4	12	3	9	11	33	0.0599
No	4	12	3	9	8	24	0.3393
Total	8	24	6	18	19	58	
p-value	1.0000		1.0000		0.6477		
Spatially (n = 33)							
Yes	2	6	4	12	6	18	0.4173
No	9	27	3	9	9	27	0.2484
Total	11	33	7	21	15	45	
p-value	0.0634		1.0000		0.6082		
Annual pattern shifts							
Spatially (n = 37)							
Yes	8	22	4	11	14	38	0.4473
No	2	5	3	8	6	16	0.4078
Total	10	27	7	19	20	54	
p-value	0.1099		1.0000		0.1074		

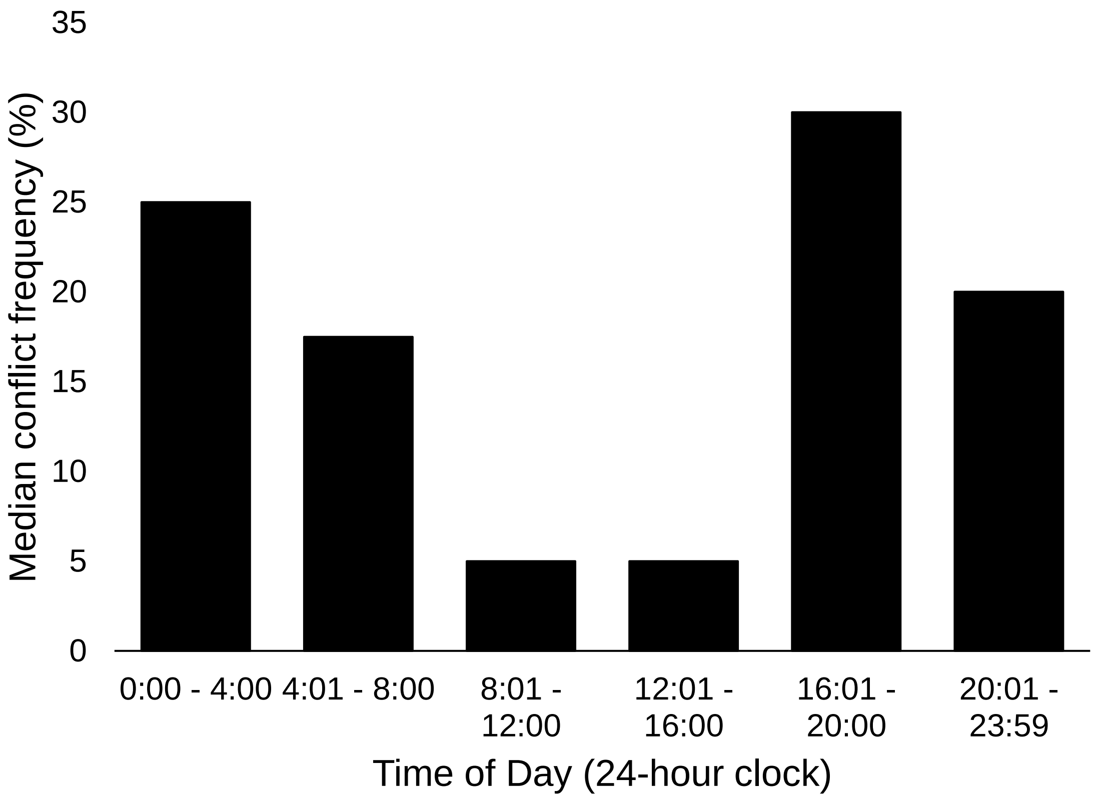


Figure 4. The median percentage of human-wildlife conflict that occurs within a four-hour block of time on a daily basis. Greater median percentages indicate higher levels of conflict frequency (n = 22).

Respondent Characteristics

Respondents were most commonly affiliated with academic institutions (n = 27, 40%) or non-profit or non-governmental organizations (n = 26, 38%). Other affiliations included government agencies (n = 8, 12%), consulting work (n = 6, 9%), and government research institutes (n = 1, 1%). A majority of respondents described their work as related to the natural sciences (n = 48, 72%), while the remainder were social scientists (n = 12, 18%) or administrators (n = 2, 3%). Participants who opted to fill out the "other, please explain" choice described roles as conservationists (n = 2, 3%), community and landscape ecologists (n = 1, 1%), and involvement in the management of non-governmental conservation organizations (n = 1, 1%). Areas identified by respondents as their major work locations included Africa (n = 17, 30%), South and East Asia (n = 14, 25%), North America and the Caribbean (n = 8, 14%), West Europe (n = 7, 12%), North and central Asia (n = 4, 7%), and meso- and South America (n = 3, 5%). I also received single responses for East Europe, West Asia, Antarctica, and the Caucasus.

Discussion

The most notable result of this survey is that a large majority of respondents accepted one or more of the identified patterns of human-wildlife conflict frequency. A small number of respondents (n = 6, 11%) did not select one of the three patterns for at least one of the boundary distances, and only 8 (14%) suggested an alternate pattern. This result indicates that spatial patterns of human-wildlife conflict can be generalized across a range of taxonomic groups and study locations.

Pattern Type Selection

Many respondents selected different pattern types for a 1 kilometer and 40 kilometer boundary distance. One reason for this difference could be the scaling of conflict occurrences across a wider range from protected area boundaries. While each pattern was designed to fit certain species, it may be that conflict frequency patterns for each species appears as either a type I or type III pattern depending upon the scale at which conflict frequency is being examined. For example, in a study carried out by Nath et al. (2013), crop raiding incidents involving Asian elephants near Manas National Park

in India typically occurred close to the park boundary. Similarly, Naughton-Treves (1997) observed that a “narrow band” of properties within 200 meters of Kibale National Park incur most of the damage caused by wildlife. When examining these conflict frequency patterns on a small scale, it appears that conflict frequency declines rapidly as boundary distance increases, mirroring a type I pattern. In a study conducted by Karanth et al. (2013), researchers observed heightened patterns of conflict frequency near the boundaries of five reserves in the Western Ghats, India for wildlife species including Asian elephants, tigers, and leopards. However, the presence of multiple reserves in close proximity allowed this study to examine patterns of conflict on a larger scale, resulting in a type III conflict pattern. Pattern type I is well-suited for examinations of conflict frequency surrounding isolated fragments of habitat, while pattern type III is illustrative of conflict frequencies among a matrix of habitat fragments. The significant relationships found between respondents selecting pattern type I in study areas with just one national park and pattern type III in study areas with multiple protected areas illustrates this concept. However, due to the high volume of publications focusing on human-wildlife conflict at a species- and site-specific scale near and around protected areas, there is a lack of research on conflict occurrences at increasing boundary distances.

It is possible that this lack of research on a wider scale is due to limited reports of human-wildlife conflict beyond a certain boundary distance. As discussed in chapter 2, conflicts between humans and larger-bodied species resulting in large amounts of economic loss are more likely to be reported than smaller incidents (Treves and Naughton-Treves 2005). Because those living at a further boundary distance often do not report less damaging conflicts with “pest” species, it may appear that human-wildlife conflicts do not take place beyond a certain distance from protected area boundaries (Naughton-Treves 1997, Treves and Naughton-Treves 2005).

Additionally, researchers examining this issue may simply not have the data or information on hand to feel as comfortable in their choice of a 40 kilometer pattern as they do in a 1 kilometer pattern. At a distance of 40 kilometers from the protected area, respondents noted that conflict occurs very occasionally or does not occur at all, making selection of a pattern more difficult. Other respondents noted difficulties in selecting patterns due to the layout of their study area. For example, one respondent stated that in

their research area there are several protected areas located close to one another; 40 kilometers away from one protected area would be inside of or next to another protected area. This scenario would also occur for Gir lions in India moving to the coastal forests or Bhavnagar, African elephants living in the land-use mosaic in the Sebungwe region of Zimbabwe, and wildlife moving among the Western Ghats protected areas in India, among others (Hoare 1999, Karanth et al. 2013, Meena et al. 2014).

The decision to ask respondents to select a pattern representative of conflict to a distance of 40 kilometers came from the literature review in chapter 2, where the largest average maximum conflict distance for any taxon was 33.67 kilometers. Changing the boundary distance from 40 kilometers to more or less could alter results. If this survey were to be repeated, I would suggest the addition of a question asking respondents to select one of the generalizable human-wildlife conflict patterns for a moderate boundary distance of 20 kilometers.

Species- and Taxa- Specific Variables

Another notable result from this survey is the difference in pattern selection across different dietary groups. Nearly all (n = 30, 94%) of the carnivorous species included in survey responses have large or medium home ranges. These species are oftentimes not contained within the boundaries of protected areas due to their wide-ranging tendencies in order to fulfill their nutritional needs (Woodroffe and Ginsberg 1998). In considering these characteristics, the finding of a significant relationship between the type III pattern and carnivorous species at a boundary distance of 40 kilometers makes sense.

When selecting patterns for herbivorous species, several respondents described protected area boundaries coupled with the presence of fallow fields or buffer zones. According to survey participants, these habitat features prevent conflict from occurring immediately adjacent to the protected areas, instead resulting in the delayed peak frequency as displayed in pattern type II, which was significantly related to herbivorous species.

Daily and Yearly Conflict Patterns

Survey participants note that as livestock graze during the day they roam over a wider area, oftentimes approaching protected area boundaries. Respondents claim that this daytime grazing provides predators with the opportunity to kill or injure livestock, should they approach areas of forest cover. At night, many herders bring livestock closer to human settlements and secure their herds in enclosures to prevent wandering. These relocations drive spatial patterns of human-wildlife conflict on a daily and yearly basis, depending upon the availability of grazing materials.

Many respondents stated that instances of conflict increased during the wet season, just after rainfall occurred, and during the dry season. According to participant comments, these conflict increases are due to seasonally shifting human patterns, such as the cultivation of agriculture and crops in the wet season, and the use of protected area edges during the dry season. Survey responses indicate that annual spatial patterns of crop raiding are dependent upon crop type and the location of each field. Some respondents noted that livestock stays closer to human settlements in the winter, shifting conflict occurrences closer to population centers. In mobile pastoral communities, changing seasons influence the direction of community movement. As these people move their communities to adjust to the climate, conflict follows. One survey respondent noted that in their study area, pastoralists move closer to the boundaries of the protected area during the cold, dry or hot, dry seasons of the year, shifting conflict occurrences closer to the protected area boundary. Survey questions regarding the selection of generalizable human-wildlife conflict patterns were purposefully open ended. In the future, I would suggest asking respondents to select which generalizable pattern best fits for different seasons, as many participant comments indicated that spatial patterns of conflict change seasonally.

Humans and wildlife have both adjusted their actions to compensate for the presence of one another. Some farmers in India have altered their cropping patterns, planting paddy almost exclusively in the winter to avoid elephant raiding, while male Asian elephants raid crops to boost their nutritional health and reproductive success in musth (Nath et al. 2013). One survey respondent noted that in their study area they had observed humans and leopards only overlapping during the early morning, sunrise, and sunset because the leopards had adapted to high levels of human activity during the day.

In this case, temporal patterns driven by wildlife have been altered by the presence of humans in their habitat rather than occurring as a standalone aspect of that species' activity level. This phenomenon could occur in many areas of the world across a range of species, and temporal patterns of conflict frequency may be driven more by human presence than species sleep-wake cycles.

Alternatively, A majority of the species reported by survey respondents (n = 17, 68%) are crepuscular or nocturnal, and are therefore more active at dusk and dawn or throughout the night. Increased wildlife activity levels at these hours of the day may lead to higher human-wildlife conflict frequency, as evidenced by high median conflict percentage numbers and feedback provided by survey respondents.

One limitation of this study is the lack of specification over which time frame respondents should have selected each generalizable human-wildlife conflict pattern for. As a result, it is not possible to estimate the observation time frame that each respondent had in mind when selecting a pattern. A second limitation is that of migration—if a certain species is in the process of relocating for the season and instances of conflict occur along the way, these identified human-wildlife conflict patterns would not apply. Additionally, the identified human-wildlife conflict patterns assumed stationary human populations (e.g., a wildlife population that is present year round, interacting with an established human settlement). The majority of publications read for the literature review of spatial patterns of human-wildlife conflict (see chapter 2) investigated instances of conflict that occur in or near settlements. Thus, the generalizable patterns identified in this study do not take into account conflict that may occur as a result of outdoor activities like hiking, or movement of wildlife or people from one location to another.

One respondent suggested another, alternative pattern: a low-frequency, flat pattern illustrating conflict frequencies between humans and wildlife when neither party exists as a permanent fixture. For example, if conflict occurs because of competition between hunters and wildlife or because of recreational activities, patterns of conflict will be stochastic and temporal rates are then predictable. To reflect this new pattern I added a type IV pattern to the identified patterns (Figure 5). Type IV patterns would then reflect low rates of conflict scattered across a landscape rather than concentrated in one specific area due to the presence of crops, livestock, or human settlement. The frequency of

conflict would depend upon how large the wildlife population in the area is as well as the level of human activity. This pattern would hold true both inside and outside of protected area boundaries.

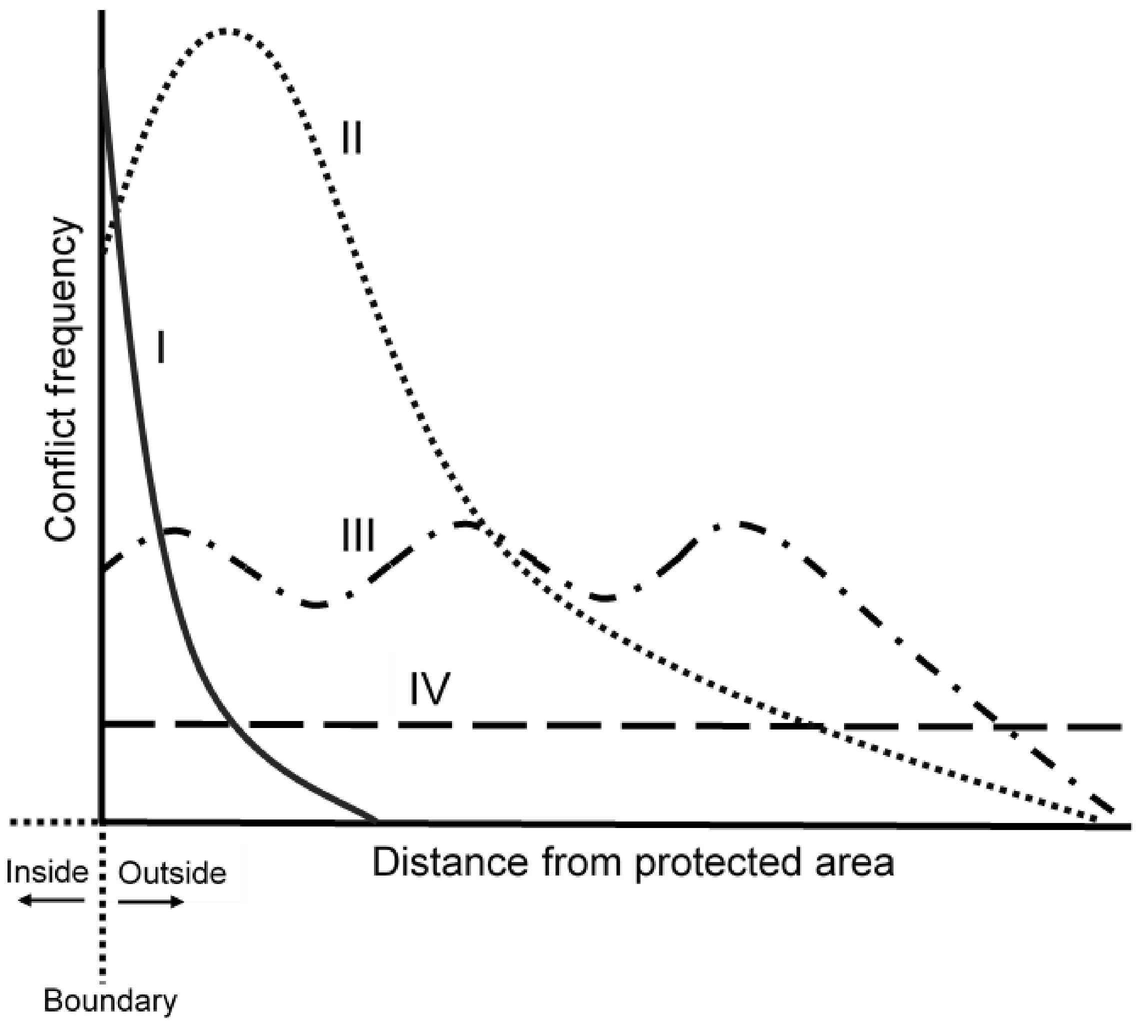


Figure 5. Typology of generalizable patterns of conflict occurrence between humans and wildlife with increasing distance from protected areas of land with the addition of a newly identified conflict pattern. (IV) The frequency of human-wildlife conflict in areas where both parties are both mobile and interact at random due to chance encounters (e.g., recreational use areas, hiking trails). These patterns are idealized and actual conflict rates are situational, depending on a wide variety of geographic factors, including habitat type and location.

Respondent Characteristics

Another limitation of this survey is that it was only available in the English language, limiting the number of respondents who were able to complete it. Another

limitation is that the availability of contact addresses was not equal across taxonomic groups, limiting communication to members of each IUCN SSC group with easily accessible contact information. Additionally, I received auto-reply emails from several intended participants, and 51 of the survey distribution emails bounced. All of these factors limited survey distribution. While the survey response rate was low, the goal of this survey was not to assess perspectives from all human-wildlife scholars but to receive information and input from a subset of conservation professionals making direct observations of wildlife activity. Conversely, the patterns observed in this paper were influenced in part by the survey responses we received. No respondents completed the survey for more than one species or study location, preventing the comparison of notable observations across taxa or geographic location for a single respondent. A larger response rate from a more broad set of the human-wildlife conflict community could lead to different patterns. Additionally, our relatively low response rate and small sample size make achieving statistically significant results difficult.

A large number of responses described study areas in Africa and Asia, particularly India. I believe this is because there is both increased prevalence of and commitment to research regarding human-wildlife conflict incidents in these areas of the world. In Europe, survey participants commented on the lack of separation between humans and wildlife. These respondents explained that habitat edges are not as distinct in these areas, and protected areas are smaller, more frequent, and play less of a role in species preservation than in other areas because wildlife tends to roam and intermix with people more often.

How survey participants interpreted the term "edge" varied across responses. In some cases the protected area edge was established by the banks of a river, while others are delineated by partially fenced boundaries. In both of these cases, the protected area has a very distinct boundary that prevents certain species from leaving the area. Other respondents noted that their study area is a national park surrounded by national forest or forest reserve lands, so distinct habitat edges do not exist around the national park but do appear at the edge of the forested lands.

The results of this survey indicate that conservation professionals observe spatial patterns of human-wildlife conflict that largely fit into one of three pattern types. Further

examination into the impact of species and habitat characteristics through the use of empirical conflict data would allow researchers to refine and actualize these generalizable spatial patterns of human-wildlife conflict. This continued research into the typology of patterns validated by this survey may allow for more specific analysis of the impact of landscape- and species-specific features and the patterns resulting from different feature combinations. Data-driven spatial pattern models would increase our understanding of how conflict frequency functions across different time periods and at a range of geographic scales. The development of these patterns would also allow conservationists to track how spatial patterns are shifting over time as a result of changing habitat conditions due to anthropogenic impacts. The creation and use of generalizable patterns will allow conservation practitioners to implement effective conflict mitigation techniques, preventing harmful actions such as retaliatory killings from occurring in the future.

SUMMARY

The literature review and the survey responses from conservation professionals suggest that generalizable spatial patterns of human-wildlife conflict do exist, but these patterns are dependent on a range of factors. The following are some of the highlights emerging from the results of these two chapters.

The most striking finding from this thesis is that generalized patterns of human-wildlife conflict do exist. In the literature review, I identified three broad patterns of conflict, each displaying a different frequency of conflict occurrence across an increasing distance from a protected area boundary. The responses I received to the survey I sent out to conservation professionals confirmed that these three patterns are viable and can be applied to an array of species and geographic locations. Using the survey results, I worked to assess different variables associated with each pattern type.

I found that species characteristics such as diet, body size, and home range all play a role in patterns emerging across different taxonomic groups. Respondents were significantly more likely to select pattern type II for herbivorous species at a 1 kilometer boundary distance, while pattern type III was significantly associated with carnivorous species at both a 1 kilometer and 40 kilometer boundary distance. For medium-bodied species, survey participants were significantly more likely to select pattern type II or III than type I at a one kilometer boundary distance, and pattern type III for a 40 kilometer boundary distance. Additionally, species with a medium home range size were significantly associated with pattern type III at a one kilometer boundary distance.

The literature review and the survey results both identified temporal patterns occurring on a daily and yearly basis as playing a role in human-wildlife conflict location and frequency. Survey respondents indicated that conflict occurred most often at dusk, dawn, or throughout the night, due either to species-specific sleep-wake cycles, or adaptation of a species to human presence and activity levels. Spatially, depredation of livestock by carnivores is influenced by the mobile nature of livestock and the daily and yearly movements of herds. Crop raiding by herbivores is influenced by which fields are in use seasonally. The decline of natural prey populations and fragmentation of wildlife habitat both result in increased instances of human-wildlife conflict by encouraging competition between humans and wildlife for resources.

Spatial patterns also vary depending upon the availability of wildlife habitat. Study areas containing one national park were significantly associated with pattern type I. In locations where a solitary protected area exists as an island, conflict frequency frequently peaks at the boundary due to the isolation of wildlife and the proximity of human populations. Study locations containing more than one protected area were significantly associated with pattern type III at a 40 kilometer boundary distance. It is possible that human-wildlife conflict does not occur as often in these spaces, as wildlife populations have a larger area to roam that is largely free of human presence.

In situations such as these, scale is important. Most publications included in the literature review were specific, location-based studies, with few researchers discussing human-wildlife conflict on a regional or global scale. The local-level at which conflict is investigated by researchers was clear in the confidence they expressed for the patterns they selected. Respondents were more confident in the selection of patterns at a 1 kilometer boundary distance than they were at a 40 kilometer boundary distance.

Finally, although the literature review allowed me to identify generalizable human-wildlife conflict patterns and the survey confirmed the applicability of these patterns to a range of species in a variety of locations, it is still uncertain whether or not they can be confirmed by empirical data. I had hoped to write an additional chapter further testing the proposed patterns using empirical data from conservation professionals to plot human-wildlife conflict frequency against increasing distance from protected area boundaries, but did not receive enough empirical data to do so. I believe testing the accuracy of the generalizable human-wildlife conflict patterns with empirical data would be a valuable next step in this study.

Gaining a better understanding of where and why conflict is likely to occur will assist people living in conflict-prone areas and improve efforts to manage and protect large and sometimes dangerous animals. Encouraging the development and implementation of effective conflict prevention and mitigation techniques will reduce animosity towards certain species and help retain the well-being of humans and wildlife populations alike.

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APPENDICES

Appendix I: Survey Questionnaire

Dear Conservation Professional,

My name is Vivian Hawkinson, a senior Environmental Studies major at Colby College, USA. I am writing to solicit your help with my honors thesis exploring spatial patterns of human-wildlife conflict. Many studies of human-wildlife conflict have identified distance from edges (e.g., protected area boundaries or forest edges) as a variable that helps to explain patterns of conflict frequency. I would appreciate your help sharing your own experience with human-wildlife conflict by completing the following survey using one primary study location and one species or taxonomic group. You are welcome to answer these same questions for additional locations and species by taking the survey more than once. This survey has 20 questions and should take approximately 5-10 minutes.

Your answers are anonymous and will only be used as part of my data analysis and summaries.

Please complete the survey by Friday, March 23rd, 2018.

I am also seeking empirical conflict occurrence data from different geographic regions and species or taxa to model patterns of human-wildlife conflict. If you have conflict incident data that you are willing to share, please follow the instructions provided at the conclusion of this survey.

Thank you in advance for sharing your observations and experiences; your input is very much appreciated.

Please contact conflictsurvey@colby.edu with any questions.

Please answer the following questions for one study location and one species or taxon. If you wish to add one or more additional locations, species, or taxa, we encourage you to fill out this survey again.

The following 7 questions should be answered for a single study location or area.

1) Please list the country in which your primary study area is located:

   ____

2) If your study area is transboundary, please provide up to two other countries which it crosses into:

   ____

3) Please provide the name of the state or province where your study area is located. If your study area crosses state or province lines, please include the name(s) of all states or provinces involved:

   ____

4) Which of the following protection designations best describe your study area? Please select all that apply, provide the name(s) of these areas.
   a) Strict Nature Reserve
   b) Wilderness Area
   c) National Park
   d) State or Provincial Park
   e) Habitat Monument or Feature
   f) Habitat or Species Management Area
   g) Protected Landscape or Seascape
   h) Protected area with sustainable use of natural resources
   i) No specific land use designations
   j) I do not know
   k) Other, please explain: __________________________

5) What proportion of the administrative boundary of the protected area has a distinct habitat edge? (e.g., national park forest next to agricultural lands)
    a) ¼
    b) 1/3
    c) ½
    d) 2/3
    e) ¾
    f) The entire boundary
    g) I do not know
    h) Other, please explain: ______________________________

6) Which of the following descriptions best fit the pattern of human settlement in your study area? Please select all that apply.
    a) Settlements are distributed evenly throughout my study area, but **generally not within** the protected area(s).
    b) Settlements are distributed evenly throughout my study area, **including within** the protected area(s).
    c) Settlements are clustered around the administrative boundary of the protected area(s).
    d) Settlements are clustered around a naturally occurring resource(s) (e.g. a river, lake, etc.)
    e) Settlements are primarily clustered in one section of the study area.
    f) There are no human settlements in the study area.
    g) I do not know
    h) Other, please explain: ______________________________

7) Please complete the following statement for your study area. On average, human population density ______ as the distance from the protected area(s) increases.
    a) Increases
    b) Decreases

c) Does not change
d) Is highly variable
e) I do not know
f) Other, please explain: ______________________________

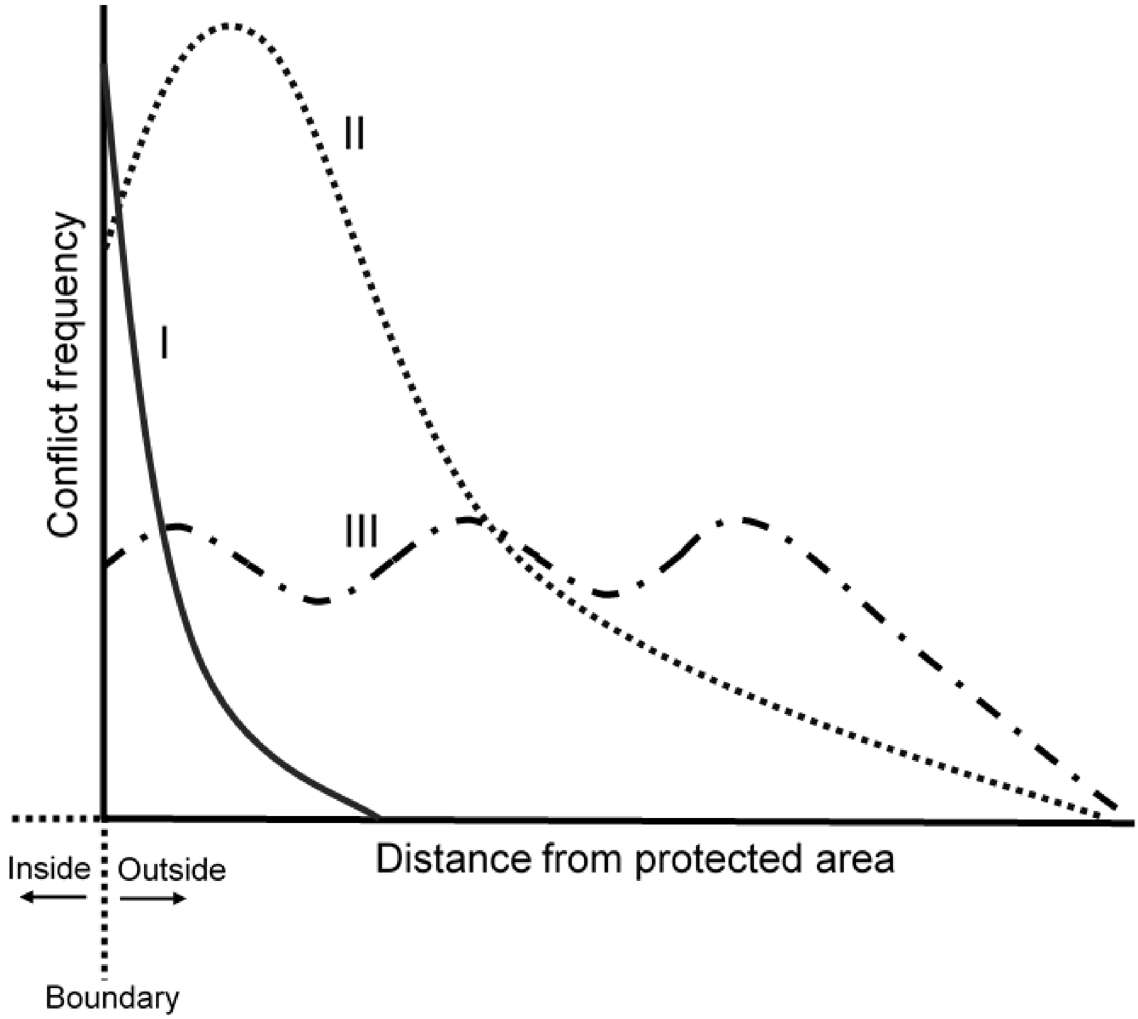
The following 9 questions should be answered for a single species or taxon of study, found in the study area or location you described above.

8) Please list the one species or taxon of study the following questions will be completed for: ______________________________

For the following 3 questions, please respond based on the figure displayed below.

9) For human-wildlife conflict occurring **outside of** the protected area(s):

   Assuming a distance of approximately **one kilometer**, select one pattern type from the figure that best fits the pattern of human-wildlife conflict frequency and proximity to designated protected area(s) for the species or taxon you identified. If none of the patterns fit, please describe a better fit.



a) Pattern I

b) Pattern II

c) Pattern III

d) None of the above. Please describe the better fit for your species or taxon:

____

____

____

10) For the pattern selected (or better fit described), how confident are you that this is a generalizable pattern of conflict frequency for this species or taxon?

   a) Very confident, this pattern appears frequently.

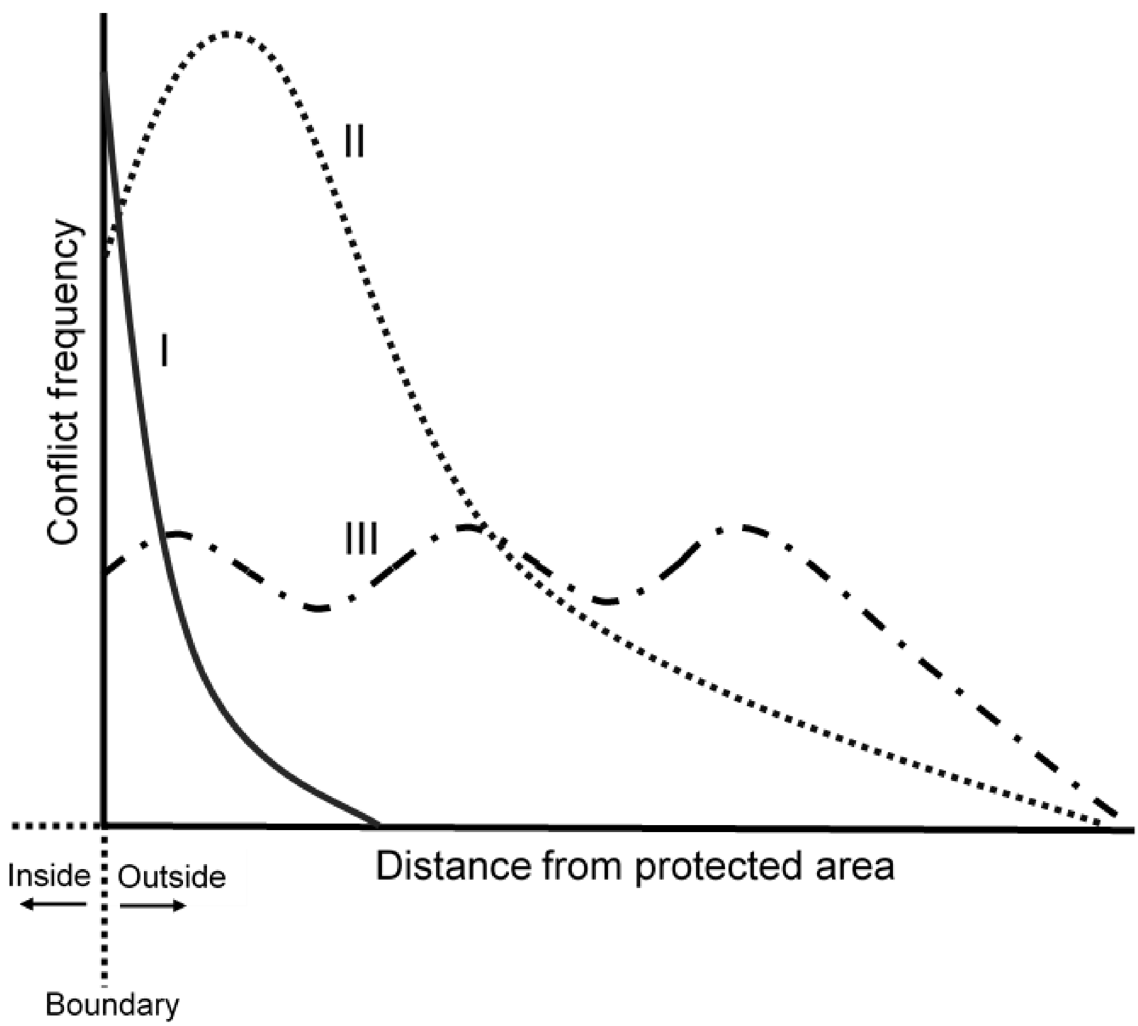
b) Somewhat confident, this pattern occasionally occurs.

c) Not confident, I sometimes see this pattern, but it is not clear.

d) I do not know.

e) Other, please explain: ______________________________

11) For human-wildlife conflict occurring **<u>outside of</u>** the protected area(s): Assuming a distance of approximately **<u>40 kilometers</u>**, select one pattern type from the figure that best fits the pattern of human-wildlife conflict frequency and proximity to designated protected area(s) for the identified species or taxon. If none of the patterns fit, please describe a better fit.



a) Pattern I

b) Pattern II

c) Pattern III

d) None of the above. Please describe the better fit for your species or taxon:

____

____

____

12) For the pattern selected (or better fit described), how confident are you that this is a generalizable pattern of conflict frequency for this species or taxon?

   a) Very confident, this pattern appears frequently.

   b) Somewhat confident, this pattern occasionally occurs.

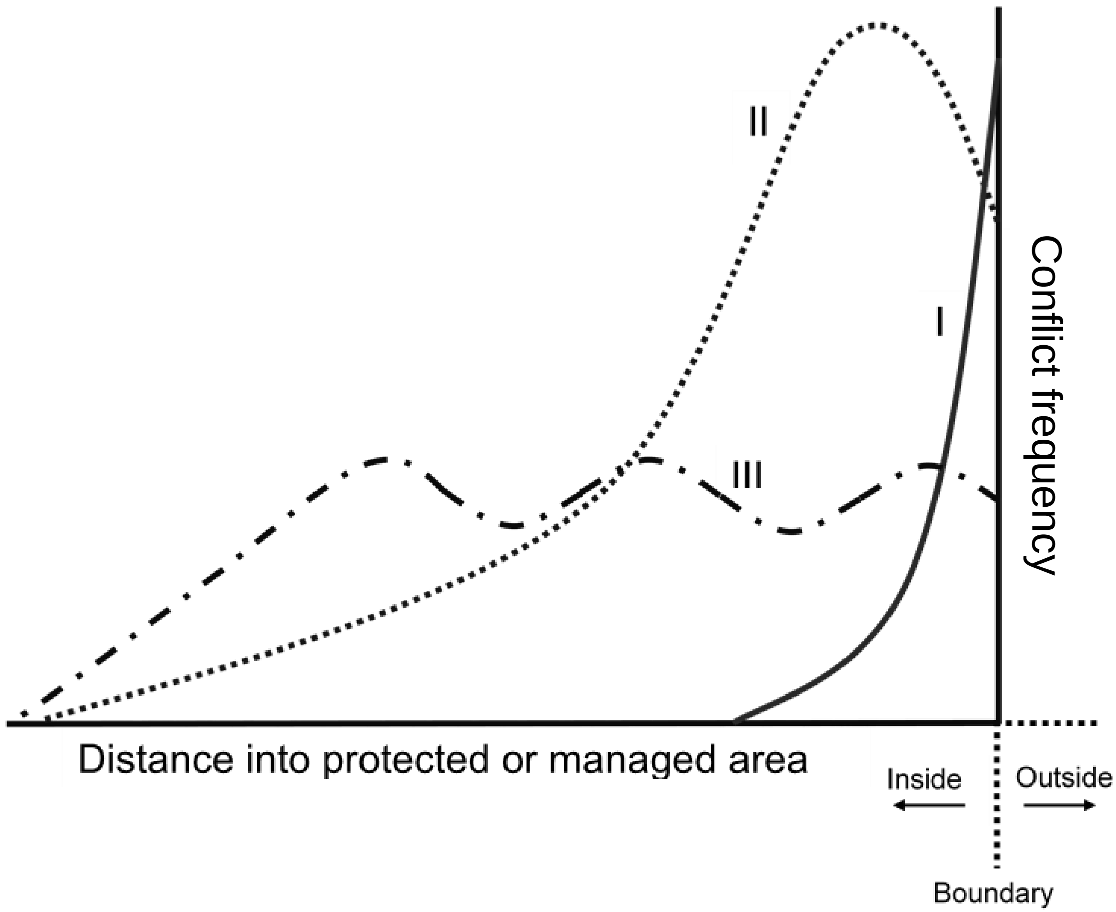
   c) Not confident, I sometimes see this pattern, but it is not clear.

   d) I do not know.

   e) Other, please explain: ___________________________

13) For human-wildlife conflict occurring **<u>inside of</u>** the protected area(s):

Please select one pattern type from the figure that best fits the pattern of human-wildlife conflict frequency and distance **<u>inside of</u>** the boundaries or borders of the designated protected area(s) for the identified species or taxon. If none of the patterns fit, please describe a better fit.



e) Pattern I

b) Pattern II

c) Pattern III

d) None of the above. Please describe the better fit for your species or taxon:

____

____

____

14) For the pattern selected (or better fit described), how confident are you that this is a generalizable pattern of conflict frequency for this species or taxon?

   a) Very confident, this pattern appears frequently.
   b) Somewhat confident, this pattern occasionally occurs.
   c) Not confident, I sometimes see this pattern, but it is not clear.
   d) I do not know.

15) For the identified species or taxon, do you observe the **frequency** of human-wildlife conflicts changing appreciably over the course of a day?

   a) Yes
   b) No
   c) I do not know
   d) Other, please explain: ______________________________

16) In your study, did you observe human-wildlife conflict occurring **more** or **less** **frequently** at different times of the day? Please input the approximate percentage of conflict that occurs within the hours of the day listed below (times are based on a 24-hour clock). Percentage totals may not exceed 100.

   a) 0:00 – 4:00, __________ %
   b) 4:01 – 8:00, __________ %
   c) 8:01 – 12:00, __________ %
   d) 12:01 – 16:00, __________ %
   e) 16:01 – 20:00, __________ %
   f) 20:01 – 24:00, __________ %

17) In your study area, do you observe **spatial patterns** of human-wildlife conflict changing appreciably over the course of a day?

   a) Yes (please explain how you see these patterns changing):
   ____
   ____
   b) No
   c) I do not know
   d) Other, please explain: ______________________________

18) In your study area, do you observe **spatial patterns** of human-wildlife conflict changing appreciably over the course of a **year**?

a) Yes (please explain how you see these patterns changing):

____

____

b) No

c) I do not know

d) Other, please explain: _____________________

The following question pertains to the receipt of compensation in instances of human-wildlife conflict for the species or taxon and study area described.

19) Do residents of your study area receive compensation for human-wildlife conflict?

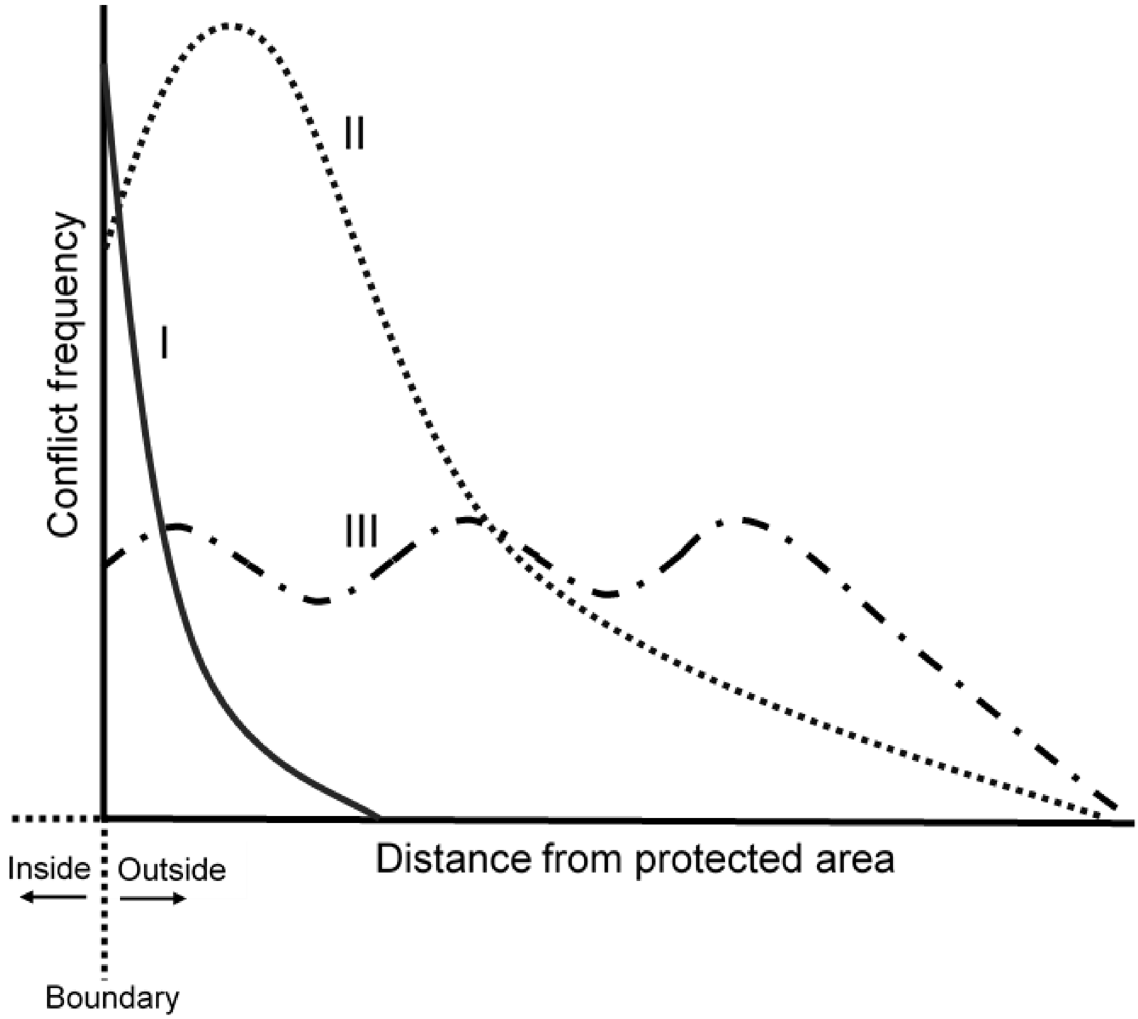
a) Yes

b) No

c) I do not know

d) Other, please explain: _____________________

20) Please select a pattern type on the figure below which best fits trends you have observed across the number of people receiving compensation for human-wildlife conflict incidents and proximity to protected areas to a distance of approximately **40 kilometers**. If none of the patterns fit the trends you have observed, please describe a better fit.



a) Pattern I
b) Pattern II
c) Pattern III
d) None of the above. Please describe a better fit for the frequency of compensation occurrences in your study area:

____

____

____

For the following 3 questions, please describe yourself.

21) Which of the following categories best describe your affiliation? Please select all that apply.

a) Academic

b) Non-profit/Non-governmental organization
c) Government agency
d) Consultant
e) Private enterprise
f) Other, please specify: ______________________________

22) Which of the following categories best describe the nature of your work? Please select all that apply.
a) Natural sciences (e.g. biology, ecology, environmental sciences)
b) Social sciences (e.g. economics, law, policy, sociology)
c) Administrative
d) Other, please specify: ______________________________

23) In addition to the area you described above, please identify other geographic areas where you have been significantly involved with human-wildlife conflict research. Please select all that apply.
a) Africa
b) Meso and South America
c) North America and the Caribbean
d) South and East Asia
e) West Asia
f) North and central Asia
g) East Europe
h) West Europe
i) Oceania
j) Other, please specify: ______________________________

Thank you for filling out this survey.

Please contact conflictsurvey@colby.edu with any questions.