CANADIAN WILDLIFE BIOLOGY & MANAGEMENT

CWBM 2018: Volume 7, Number 1 *ISSN: 1929–3100*

Point to Ponder

Concerns About Mammal Predator Killing Programs: Scientific Evidence and Due Diligence

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Abstract

The implementation of mammal predator killing programs is highly controversial and deserves discussion within the scientific community. In this opinion paper, I use specific examples to discuss the whys and hows of programs aimed at: 1) ensuring human safety and health; 2) addressing concerns of interest groups; and 3) safeguarding native and endangered species. Successful programs share some commonalities: they focus on the main factor that is responsible for the problematic situation and on culprit animals, and they are developed with an understanding of the ecology and behaviour of the predators. Public support for such programs requires that killing methods be species-specific, humane, and effective. I propose a stepwise strategy to properly assess the causes of human–predator conflicts and determine if a killing program should be implemented.

Key Words: Control, Human–Predator Conflict, Endangered Species, Hunting, Killing, Livestock, Predator, Stepwise Strategy

INTRODUCTION

Mammal predators inhabiting human-dominated landscapes are faced with a multidimensional problem ranging from human-caused mortality (persecution, utilization), to depletion of prey, and to habitat loss, degradation and fragmentation (Wultsch 2004; Ripple *et al.* 2014). Since European occupation in Africa (Naughton-Treves 1999), Australia (O'Neill 2002) and North America (Young and Goldman 1944), predators have been severely persecuted and even exterminated throughout most of their range (Mallinson 1978; Corbet and Harris 1991; Boitani 1995; Røskaft *et al.* 2007). Trapping, shooting, and poisoning were the preferred methods (McIntyre 1995; Coleman 2004; Smith and Ferguson 2005).

Killing mammal predators to resolve human– predator conflicts remains an integral part of many governments' wildlife management programs, and it affects many species throughout the world (Woodroffe 2001; Cavalcanti and Gese 2010; Proulx *et al.* 2016). While mammal predator killing management programs may be more or less successful depending on species and regions, they are highly

controversial (Goodrich and Buskirk 1995; Brook *et al.* 2015; Treves *et al.* 2016). Also, in many instances, little or no scientific evidence exists to justify their implementation (Proulx and Rodtka 2015; Proulx 2017).

This opinion paper is not an exhaustive review of management programs aimed at killing mammal predators. I use specific examples to address the whys and hows of programs aimed at 1) ensuring human safety and health; 2) meeting the interests of specific groups of people, namely farmers and hunters; and 3) safeguarding native and endangered species. I assess the necessity of these programs and the choice of methods. I also identify the commonalities of successful mammal predator killing programs. Finally, I propose a stepwise strategy to effectively address and monitor human−predator conflicts with adequate methods.

HUMAN SAFETY AND HEALTH

Reliable data on carnivore attacks on humans have proved to be few, often fragmentary, and difficult to find (Löe and Röskaft 2004). During the last few decades, large carnivore attacks on humans in developed countries have increased over time (Penteriani *et al.* 2016). However, similar to the increasing trend in attacks, the number of people engaging in outdoor leisure activities also has risen over time, and attacks often are caused by risk-enhancing human behaviours (Penteriani *et al.* 2016).

Under some circumstances, killing large predators may result in an increase in human safety. For example, the improvement of habitat quality in the buffer zone of Chitwan National Park, Nepal, and elsewhere across the region has increased the overall landbase where tigers (*Panthera tigris*) reside (Gurung *et al.* 2008). Villagers who venture into the buffer zone or illegally enter the park to graze livestock and collect forest products inevitably come into conflict with tigers. Killing man-eating tigers in the buffer zone has been effective in reducing attacks. Inside the park, however, action against the tiger was not taken because people were trespassing. Man-eating tigers usually are injured or aged, and may have difficulty in killing natural prey in marginal habitats. Therefore, establishing a system to regularly monitor tigers in cooperation with the locals, educating the villagers about tiger ecology and behaviour, and specifically removing problem animals may ensure tiger conservation and resolve the human-tiger conflicts (Gurung *et al.* 2008).

Reducing the number of predators is not always the solution when dealing with attacks on humans. Recognizing that the number of tiger attacks on humans may be higher in sub-optimal habitats with little wild prey (Jackson 1985; McDougal 1987; Gurung *et al.* 2008) may lead to preventive management actions to reduce tiger-human encounters. In Tanzania, more than 27% of lion (*Panthera leo*) attacks occur in the fields, usually when people are sleeping in makeshift huts while protecting their crops from bush pigs (*Potamochoerus larvatus*) (Packer *et al.* 2005). As bush pigs are the most likely the maintenance diet of lions in highly disturbed agricultural areas, controlling their numbers might be the best strategy to decrease the lions' attraction to populated areas.

Manipulation of host population size has been used to reduce the density of both the infected and susceptible individuals in a population (Artois *et al.* 2001). For example, the culling of red fox (*Vulpes* Vulpes) populations is one of the methods used at the regional level to reduce the number of animals coming into conflict with people. However, fox kills may be negated by compensatory immigration and reproduction (Baker and Harris 2006; Minnie *et al.* 2015). On the other hand, vaccination is the most effective means to control rabies in foxes (Morters *et al.* 2013) and other species such as raccoons (*Procyon lotor*) and striped skunks (*Mephitis mephitis*) (Rosatte *et al.* 2009). While the control of host carnivore populations on a very large scale is not an option (Hegglin *et al.* 2015), disease monitoring and the treatment of wildlife populations with vaccines and deworming agents is a feasible alternative to population reduction (Aubert *et al.* 1999; Littin and Mellor 2005; Inoue *et al.* 2007).

INTEREST GROUPS

In the last centuries, on most continents, predators have killed domestic animals (Meriggi and Lovari 1996; Palmeira *et al.* 2008; McKinney *et al.* 2010). In response to concerns over livestock predation, governments of many countries have implemented programs such as bounties (rewards offered for capturing or killing animals) to remove wild predators. However, bounties have been shown to be ineffective for the control of most predators (Proulx and Rodtka 2015).

Predator removal results in a recolonization of vacant territories by animals from surrounding areas (Knowlton *et al.* 1999; Treves and Naughton-Treves 2005; Bailey and Conradie 2013; Kilgo *et al.* 2017), many of them being subadults with a greater propensity for livestock depredation than older animals (Peebles *et al.* 2013). Compensatory immigration, along with compensatory reproduction, may actually result in an increase in predator abundance and predation (Brainerd *et al.* 2008; Wallach *et al.* 2015; Proulx *et al.* 2017; Schmidt *et al.* 2017). Following lethal control, profound changes to social dynamics have also been observed in predator groups (Haber 1996; Wielgus *et al.* 2001; Cooley *et al.* 2009; Kilgo *et al.* 2017) and these

changes may influence predator–prey dynamics (Wallach *et al.* 2015). The removal of large predators may result in a cascade of ecological events that can destabilize wildlife communities and ecosystems (Estes *et al.* 2011; Bergstrom 2017) because large predators have the dual role of potentially limiting both large herbivores through predation and mesocarnivores (e.g., coyotes, *Canis latrans*) through intraguild competition, thus structuring ecosystems along multiple food-web pathways (Ripple *et al.* 2014).

On the other hand, lethal control may be necessary to resolve specific depredation problems. Jaeger *et al.* (2001) found that relatively few coyotes were killing sheep (*Ovus aries*), and the selective removal of only the problem alpha coyotes effectively reduced sheep losses. Bradley *et al.* (2015) found that full wolf (*C. lupus*) pack removal reduced the occurrence of subsequent depredations by 79% over a span of 5 years, whereas partial pack removal reduced the occurrence of subsequent depredations by 29% over the same period. While livestock predation may fluctuate from year to year with the abundance of wild prey (Fernández-Gil *et al.* 2016; Imbert *et al.* 2016), non-lethal methods may be more effective than lethal methods in preventing carnivore predation on livestock on a yearly basis (Treves *et al.* 2016; Much *et al.* 2018).

The establishment of bounty programs and similar culling approaches in agriculture is largely the result of political decisions aimed at appeasing the concerns of livestock producers (Gill 1996; Proulx and Rodtka 2015). Similar programs also exist in game management. For example, in the United States, predator control experiments and programs to revive declining mule deer (*Odocoileus hemionus*) populations have resulted from political pressure (Ballard *et al.* 2001). In fact, past studies have shown that deer populations may be limited by habitat quality and food (e.g., Bishop *et al.* 2009), and predator (coyotes, bears, felids) control was not an effective method to increase mule deer populations (Pojar and Bowden 2004; Hurley *et al.* 2011). When habitat change and predation interact, conservation managers are provided with the opportunity to control predation impacts through habitat management rather than predator removal, which may provide a more cost-effective management strategy (Evans 2004; Knauer *et al.* 2010).

CONSERVATION OF NATIVE AND ENDANGERED SPECIES

In the past, the decline and loss of native species often coincided with the introduction of invasive predators to control pest species such as rats (*Rattus* spp.) and snakes (Yamada and Sugimura 2004; Marlow *et al.* 2015). Lethal control of invasive predators may improve the survival and recovery of some native species. In Australia, the control of stoats (*Mustela erminea*) has increased the reproductive and survival rates of native bird species (Dilks *et al.* 2003). However, there are consequences to the lethal control of invasive predators. In Australia, predation on woylies (*Bettongia penicillata*) by cats (*Felis catus*) increased where the density of red foxes had declined through poisoning (Marlow *et al.* 2015). The removal of 1 invasive predator therefore led to the increase of another invasive predator, thus suggesting that integrated fox and cat control is essential to ensure the success of fauna recovery programs (Marlow *et al.* 2015). The recovery of endangered species may also involve the removal of native predators. For example, in South Carolina, the targeted removal of coyotes utilizing a beach resulted in a significant decrease in depredation of the loggerhead sea turtle (*Caretta caretta*) nests (Eskew 2012).

An important assumption inherent in the control of predators is that mortality due to predation is additive rather than compensatory. For example, coyote removal was often recommended as a method for increasing swift fox (*V. velox*) populations by increasing survival, juvenile recruitment, and population density (Carbyn 1998; Kamler *et al.* 2003a). However, Karki *et al.* (2007) compared swift fox population demographics (survival rates, dispersal rates, reproduction, density) between areas with and without coyote population reduction. They found that coyote removal did not influence the reproductive parameters of the swift foxes. Even though juvenile survival increased in areas with coyote reduction, swift fox density remained similar between the areas due to the compensatory dispersal rate among juvenile foxes. Although coyote predation appeared additive in the juvenile cohort, it was compensatory with dispersal. Similarly, Cypher and Scrivner (1992) found that kit fox (*V. macrotis*) and coyote population trends both were significantly correlated to lagomorph abundance. Food availability probably was the primary factor influencing the population dynamics of both predators.

As it has been shown with interest groups, political pressure may lead to the implementation of inadequate lethal control programs that fail to meet the needs of endangered species. For example, in Alberta, Canada, the decrease of the Little Smoky boreal caribou (*Rangifer tarandus*) population is the result of low habitat carrying capacity (Proulx 2015) and continued habitat loss due to industrial activities (Proulx and Brook 2017). Without studies showing that wolves critically suppress growth of the caribou population (Proulx 2017), implementing a predator control program instead of a comprehensive habitat conservation program was a political decision aimed at protecting industry rather than caribou (Proulx and Powell 2016; Proulx *et al.* 2017). Habitat restoration and connectivity of caribou habitats, which can

be done within 20 years in some regions (Skatter *et al.* 2014; Coxson 2015; Proulx and Gillis 2017), are necessary to permanently reverse the decline of an individual herd (Wilman and Wilman 2017).

The most common threats facing imperiled species are habitat degradation and invasive species (Wilcove *et al.* 1998; Heinrichs *et al.* 2016). As a conservation tool for endangered prey, predator management alone is not a viable strategy. This strategy creates an artificial system requiring ongoing management unless the predator is completely eradicated. Careful planning of landscape patterns, and habitat conservation and restoration, can compensate for negative predation effects on endangered species (Schneider 2001; Proulx *et al.* 2017). Ecosystem degradation is a problem that causes both rarity of some species and abundance of others. Population control treats only symptoms of this problem (Goodrich and Buskirk 1995).

METHODS USED IN PREDATOR CONTROL PROGRAMS

Poisoning, fumigation, trapping and shooting are used extensively in predator control programs (Cowan and Brown 2012; Proulx and Rodtka 2015). Common toxicants include strychnine, sodium fluoroacetate (compound 1080), sodium nitrate, carbon monoxide, carbon dioxide, and sodium cyanide delivered in a mechanical delivery device known as the M-44 (Schmidt 1986; Cowan and Brown 2012; Proulx *et al.* 2015a). These poisons are found to be unacceptable or inhumane from an animal welfare point of view because they inflict unnecessary pain upon wild animals (Dubois *et al.* 2017; Proulx *et al.* 2015a).

Killing traps, namely neck snares, are commonly used for the removal of predators (Cowan and Brown 2012; Proulx *et al.* 2015b). Although humane killing traps (i.e., they quickly render animals irreversibly unconscious and cause little or no pain) have been developed for the capture of small- and medium-sized carnivores, most trapping devices used for killing large carnivores are considered inadequate (Proulx *et al.* 2012). Bounty hunters and trappers commonly use killing neck snares, which are known to be inhumane by today's animal welfare standards and are non-selective (Proulx *et al.* 2015b; Proulx and Rodtka 2017).

Helicopter shooting is popular among government agencies (Cowan and Brown 2012; Hervieux *et al.* 2014), but its ability to humanely kill carnivores has been poorly investigated. In areas of high-canopied vegetation, shooting has been found less adequate in killing detected animals (Bayne *et al.* 2000). Hampton *et al.* (2017) recommended that managers carefully select shooters (skill) and enforce training (aim points and shot number) to improve the frequency of humane kills.

When it comes to killing methods used for the control of mammal predators, there is an obvious need for further research to fill gaps in knowledge (Littin and Mellor 2005; Proulx *et al.* 2012). Unfortunately, on the basis of recent studies and reviews of methods used in management programs (e.g., Brook *et al.* 2015; Proulx and Rodtka 2015; Dubois *et al.* 2017), it appears that today's governments' philosophy often is that "the end justifies the means".

COMMON DENOMINATORS

Independently of the objective of the terrestrial mammal predator killing program, i.e., for human health, to accommodate interest groups, or to save native and endangered species, successful programs are based on scientific evidence and a proper understanding of ultimate (the 'real' reason causing the observed result) and proximate (event which is closest to, or immediately responsible for causing, some observed result) mortality factors for a wildlife population, or the causative agents responsible for the spread of a disease. Terrestrial mammal predator killing programs are successful when:

1) *They focus on the main factor that is responsible for the problematic situation* – In the case of human attacks by predators, just killing a culprit predator may not solve the problem if the cause of the human−predator conflict is not eliminated. In the case of the lion attacks in Tanzania, the solution is to remove the bush pigs which incite people to guard their crops at night. In the example about hunters requesting an increase in deer numbers, the main solution is in the improvement of habitat quality, as it is for the conservation of the swift fox.

2) *They focus on problem animals* – In order to stop tigers from killing people, to eliminate predation of livestock by wild canids, and to ensure the protection of turtle nests, managers focused their actions on specific animals (man-eating tigers) or group of animals (wolf packs, and beach coyotes). Killing tigers in the park, or establishing a bounty program to reduce wolves or coyotes, does not properly address the human−wildlife conflict.

3) *They are developed with an understanding of the ecology and behaviour of the predators* – When vaccinating or controlling predators, wildlife professionals must have a good understanding of the population dynamics and movements of the animals in order to develop a proper strategy.

It is noteworthy to mention that the level of public support, and therefore the acceptation of mammal predator killing

programs, requires that such programs be species-specific, humane, and effective (Fitzgerald *et al.* 2005; Dubois *et al.* 2017).

A PROPOSED STRATEGY TO ASSESS AND RESOLVE HUMAN-MAMMAL PREDATOR CONFLICTS

In Figure 1, I developed a stepwise human–predator conflict resolution strategy. I included some of the recommendations made by Leopold and Chamberlain (2002) and Dubois *et al.* (2017).

The implementation of a human-predator conflict resolution strategy requires that participants have a good understanding of critical thinking or scientific method (see Proulx 2004). Many organizations and people may request that a killing predator management program be established to reduce or extirpate a population of predators that is in conflict with their personal or communal interests. However, surprisingly, often the identity of the predator species is unknown, and there is a lack of scientific evidence (Proulx and Parr 2018). Identification of animals and of perceived problems based on anecdotal reports often are invalid and may lead to false conclusions (Aubry *et al.* 2017).

If the ultimate factor is habitat loss, then habitat restoration should be the main focus of a wildlife management program. Because habitat restoration is a relatively slow management approach, it may necessitate short-term predator population control at specific times of the year and in specific habitats, e.g., during the caribou calving period at known locations, and restrict or delay extractive resource development in some or all places (Goodrich and Buskirk 1995; Wilman and Wilman 2017).

Once it has been ascertained that a predator management program is required, it is important to determine if there are non-lethal alternatives to killing animals. Often, such programs are cheaper and more effective than killing predators and they impact less seriously on wildlife communities. For example, while livestock producers often request that a coyote killing program be implemented to address their losses (Bergstrom *et al.* 2014), non-lethal solutions such as the use of guard dogs and fladry may be more effective (Treves *et al.* 2016; Stone *et al.* 2107).

The selection of killing programs should rigorously discriminate between techniques. Killing methods should be humane and they should render animals irreversibly unconscious rapidly and without undue pain (Powell and Proulx 2003). Methods should also be selected for their efficiency and selectivity to keep the program affordable and to avoid impacting on the wellbeing of wildlife communities. Methods should not have ecological consequences on wildlife populations, as has been noted in the past with toxicants (Brook *et al.* 2015; Proulx *et al.* 2015a), trapping devices (Proulx *et al.* 2015b), and other techniques such as shooting (Bayne *et al.* 2000). Finally, selected methods must be socially acceptable. A recent study showed that people were generally supportive of predator management aimed at losses of agricultural or private property; however, non-lethal methods were perceived to be far more humane than lethal methods. Also, the public is increasingly skeptical of the methods employed in control actions (Slagle *et al.* 2017). Public attitudes toward predators has changed drastically in recent years (Musiani and Paquet 2004), and their preservation is now a high priority for wildlife conservation efforts (Kellert *et al.* 1996; Musiani and Paquet 2004).

Once killing methods have been selected, the program should be implemented. Predator populations should be closely monitored, and the success of the program in meeting its goal regularly assessed. If the program fails to resolve the human − mammal predator conflict, the ultimate and proximate factors should be re-evaluated, and the program should be redesigned (Figure 1). The implementation of a killing program should include public meetings to discuss the scientific evidence used to develop the program and update people on any progress in solving the human − predator conflict.

CONCLUSION

Conflicts between humans and mammal predators are complex. They impact on the wellbeing and activities of people, and they strongly affect the conservation of predators, wildlife communities, and ecosystems. The goal of contemporary wildlife biologists and conservationists is generally focused on accommodating human activity and occupancy while protecting biodiversity and the ecological functions and processes that maintain that diversity (Paquet and Darimont 2010). Solutions do exist to resolve such conflicts, but all stakeholders must agree to work together at finding compromises.

Mammal predators play a major role in the persistence of wildlife communities and their ecosystems (Estes *et al.* 2011; Ripple *et al.* 2014). Humans cannot fully replace the role of these predators (Berger *et al.* 2001; Ripple *et al.* 2014), and they should not have the innate reflex to kill animals when something is in disagreement with their lifestyle and interests. If killing mammal predators must be carried out to address a specific conflict with humans, it should be done only after the ultimate cause of the conflict has been identified and properly addressed by managers; it should focus on the right species and individuals; it should be based on a good understanding of the ecology and behaviour of the animals;

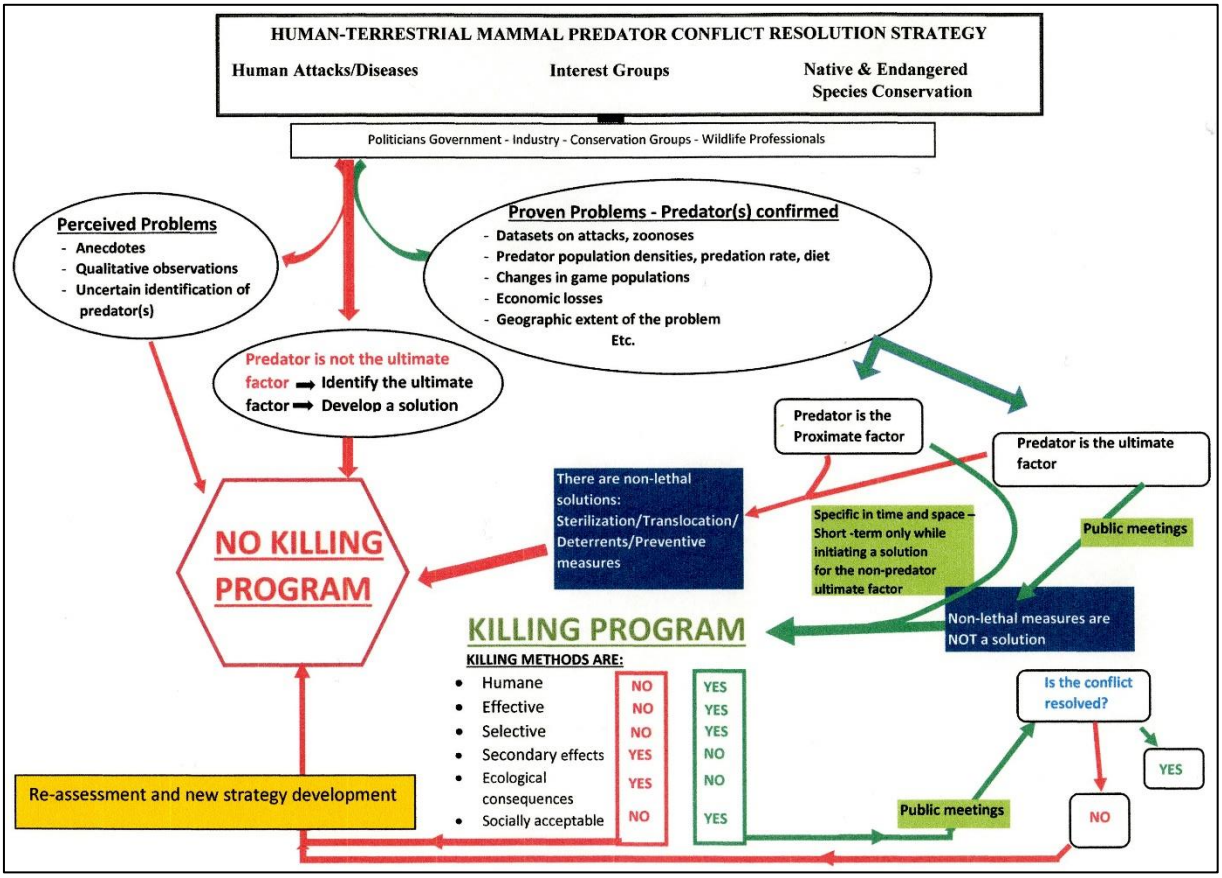

Figure 1. Stepwise strategy to resolve human-predator conflicts.

and it should be demonstrated that the predator management program will resolve the conflict in a socially acceptable manner. The management program should not dismiss the interests of wild animals and public attitudes toward wildlife (Bruskotter *et al.* 2015), and it should be developed with the use of a critical stepwise strategy such as the one proposed here.

ACKNOWLEDGEMENTS

I thank Associate Editor Pauline Feldstein, Brent Patterson and 2 other anonymous referees for their comments on an earlier version of this manuscript.

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Received 11 December 2017 – Accepted 15 March 2018.