F:/3-PAGINATION/PWC/2-FIRST_PROOF/3B2/0521825059C06.3D – 86 – [86–106/21] 18.3.2005 2:54PM

6

Evaluating lethal control in the management of human–wildlife conflict

ADRIAN TREVES AND LISA NAUGHTON-TREVES

INTRODUCTION

Throughout human history, agriculturists have used an array of techniques (irrigation, cultivation, fertilizer, herbicides, pesticides, fences, etc.) to give domesticated species a competitive edge over wild plants and animals. Often the cheapest and most practical strategy came down to killing the competition – especially large vertebrates. Government agencies traditionally responded to agriculturalists' needs without concern for wildlife survival. In fact, the original mission of many wildlife management agencies was not to protect wildlife, but rather to kill all wild animals that threatened human safety or agricultural development (Graham 1973). Because of their slow reproductive rates and low density, large vertebrates proved relatively easy to eliminate, especially as people added poison, guns and bounty payments to their arsenal. Thus in the name of economic progress wolves were extirpated from most of the USA in a few decades (Young and Goldman 1944). Similarly, colonial officers 'liberated' vast tracts of fertile land in Africa from elephants, leopards and other threatening species (Naughton-Treves 1999). Elsewhere in the world, formal and informal lethal control programmes have driven the decline and even the extinction of several wildlife species (Breitenmoser 1998; Naughton-Treves 1999; Wilcove 1999); Woodroffe *et al.*, Chapter 1).

Environmentalists today look back on these militaristic, morally charged campaigns in horror. Their calls to restore and protect wildlife are inspired by an increased appreciation of non-materialist values of wildlife. Now wildlife managers must respond to two seemingly contradictory mandates. Part of the public (mainly urbanites) demands wildlife be protected from people, and part of the public (mainly agriculturalists and livestock producers) demands people be protected from wildlife.

People and Wildlife: Conflict or Coexistence? eds. Rosie Woodroffe, Simon Thirgood and Alan Rabinowitz. Published by Cambridge University Press.

In this chapter, we consider the role of lethal control in fostering coexistence between people and wildlife. Despite the devastating history of many lethal control programmes, removal may have a legitimate role in wildlife conservation. First, well-managed lethal control has the potential to reduce threats to human lives and livelihoods without entailing serious extinction risks. Second, removing wildlife may placate local citizens and deter them from illicit killing of wildlife. Similarly, if the removal strategy channels benefits to local citizens (e.g. they obtain meat or hunting revenue) it may build local support for conservation efforts. Third, the elimination of some problem wildlife may select for conspecifcs that avoid humans and their property, thereby exerting directional selection for a wilder population of that species (Jorgensen *et al.* 1978; Treves 2002; R. Woodroffe and L. G. Frank unpubl. data). However, all of these conjectures must be rigorously evaluated lest lethal control do more harm than good. Indeed, lethal control programmes must be undertaken with care given the technical challenges surrounding the number and type of animals killed, as well as political and moral issues concerning who is allowed to kill animals and how.

Here we evaluate different forms of lethal control and their effects on long-term coexistence of wildlife and people. If lethal control is to foster coexistence of people and wildlife, it must reduce the impact of wildlife on people or raise public tolerance for damage without a significant reduction in the viability of wildlife populations. Thus, we consider three criteria for evaluating lethal control:

(1) Effectiveness in reducing future threats to human lives and livelihoods.
(2) Impact on the viability of wildlife populations.
(3) Public acceptance and stakeholder participation.

For simplicity we focus primarily on large mammals (>2 kg) but we extract general principles for the management of conflict with other taxa. We also consider translocation as a control method that is intended to be more humane but nonetheless leads to animals being lost from a population.

DEFINING TYPES OF REMOVAL PROGRAMMES

In the broadest sense, lethal control could include human activities that only incidentally diminish wildlife populations, such as habitat conversion, pollution or invasive species. Although these incidental sources of mortality ultimately constitute the greatest threat to the planet's wildlife, we choose to focus on deliberate efforts to reduce or remove wildlife to protect human lives and livelihoods. These can be substantial. For example, between 1996 and 2002 the US agency responsible for control of wildlife damage killed 15 260 640 wild vertebrates or 2.18 million animals in the average year (US Department of Agriculture 2005).

Deliberate removal programmes vary according to the proportion of animals removed and the selectivity used to remove individuals. Here we array the programmes into four overlapping classes and briefly discuss the most common motivations behind their use with examples of their application.

Eradication campaigns aim to extirpate problem wildlife from entire regions by all means available. Depending on the intensity of effort and the resilience of the target species, extirpation campaigns may produce local, regional or global extinctions. Powerful factors may motivate people to eradicate wildlife. For example, the elimination of bison from the American plains was fuelled by profit motives and the desire to subjugate native Americans, as much as the desire to protect agriculture (Isenberg 2000). Similarly, the value of ivory and skins promoted wildlife removal in the name of 'protecting natives' and 'opening agricultural land' in British-held East Africa (Beard 1963; Naughton-Treves 1999; Treves and Naughton-Treves 1999). Large carnivores have often been singled out for eradication due to the perceived and real risks they present to livestock and people (Woodroffe 2000) and their symbolic association with 'untamed wilderness' (Lopez 1978). To this day, colonists at the agricultural frontier in the Peruvian Amazon eliminate carnivores as *cazeria sanitaria* ('hunting to clean the forest'), in their eyes a first step toward economic progress (Naughton-Treves *et al.* 2003a). Today there are few country-wide deliberate eradication campaigns. Existing eradication programmes are generally more localized and might form part of a broader policy of coexistence in other areas (Linnell *et al.*, Chapter 10).

Culling programmes aim to reduce subpopulations of problem wildlife around sites of anticipated conflict (Blackwell *et al.* 2000; Hoare 2001; Cope *et al.*, Chapter 11) under the assumption that reducing wildlife populations will reduce conflicts. Culling encompasses the killing of wildlife in a specific area (but not its entire range), prior to or in the absence of specific, recent complaints about wildlife. Typically, the methods, actors and locations of culling are prescribed. Examples of culling programmes include the aerial shooting of coyotes prior to the release of sheep into summer grazing areas in the western USA (Wagner and Conover 1999) and the proactive removal of European badgers to avoid transmission of tuberculosis to cattle in the UK (case study in Box 6.1).

Government-sponsored culling engages trained agents to kill wildlife in specified areas, but private citizens also cull on private land. A good example

Box 6.1. Lethal control of European badgers in the UK

Bovine tuberculosis (TB) is a serious disease of cattle which can be transmitted to people. During the 1930s over 2500 people died each year from this disease in Great Britain alone. While TB is no longer a major threat to human health in Britain, over 1000 cattle outbreaks were confirmed in 2002, entailing substantial economic losses to farmers and government.

European badgers were first implicated in transmitting TB to cattle in the early 1970s: badger control, carried out by government staff, has been a mainstay of British TB policy ever since. This approach remains highly controversial: TB incidence in cattle has risen steadily since the mid-1980s, leading welfare lobbyists to argue that badger control is ineffective and should be discontinued, and farming groups to argue that control has not been sufficiently vigorous and should be extended (Woodroffe *et al.* 2002). In fact, the effectiveness of badger control in controlling cattle TB is not yet fully known (Krebs *et al.* 1997).

In 1998 the British government – guided by a committee of independent scientists – started a large-scale field experiment to evaluate badger population control as a coMponent of TB policy. The trial was carried out in areas with the highest cattle TB risks and involved three treatments: proactive culling (reduction of badger densities to very low levels across wide areas), reactive culling (control targeted at particular badger social groups only when the farms they occupied experienced TB outbreaks), and badger population monitoring with no culling. An alternate reactive strategy, which attempted to identify and remove only infected badgers, was rejected because diagnostic tests could only identify 41% of truly infected badgers (Woodroffe *et al.* 1999). Each treatment was replicated 10 times in 100-km^2 trial areas, to cover a total of 3000 km^2. The trial was designed on such a large scale because, although TB is a serious economic problem, in statistical terms outbreaks occur rather rarely, requiring that a large number of farms be included to provide statistical power sufficient to measure the effects of culling with the required precision.

Proactive culling has a *population impact*: badger densities are markedly reduced in proactive areas (Le Fevre *et al.* 2003). The viability of the national badger population will not be influenced by the trial, but there would be major regional impacts were this approach to be adopted as national policy. Opinion surveys indicate that proactive culling of badgers is unlikely to prove *publicly acceptable* (White and Whiting 2000), and government ministers have already stated that they are unlikely to accept widespread culling as a future policy; the treatment is included in the trial largely for the epidemiological data it provides (Woodroffe *et al.* 2002).

Differences between treatments in the incidence of cattle TB provide a measure of the *effectiveness* of culling. Unexpectedly, reactive culling has been associated with a significant increase in cattle TB (Donnelly *et al.* 2003); hence this was dismissed as a future policy. This finding suggests that past culling policies may have been equally ineffective at controlling cattle TB, and also casts doubt on claims (Eves 1999) that near-elimination of badgers effectively reduces cattle TB, which are based on comparison of elimination areas with areas where localised culling of badgers occurred (and where cattle TB may thus have been inflated) (Donnelly *et al.* 2003).

This research programme illustrates the scale (3000 km^2) and cost (about $12 million annually) of study needed to evaluate the impact of lethal control on conflicts that, while important, may in fact occur comparatively rarely.

is the widespread practice of mammalian predator control on private land managed for game-bird hunting in many European countries (Reynolds and Tapper 1996). Local populations of red fox, stoat, weasel and other relatively common small carnivores are reduced through trapping, snaring and shooting by professional gamekeepers.

Public hunts – in contrast to eradication – often include regulations governing the actors, location, timing or method of killing animals, in addition to limits on the number and type of animals that can be killed. In contrast to government-sponsored culling programmes, private citizens usually pay or volunteer to remove wildlife usually without reference to the location of past conflicts (Sagør *et al.* 1997; Sunde *et al.* 1998). Among the motivations for public hunting, some promote them as conflict mitigation strategies under the assumption that reducing populations of problem wildlife will reduce threats to human safety, economy or recreation. Public hunting is also promoted as a way to build a constituency for unpopular species by giving them value as game, food, fibre, etc. (Hamilton 1981; Linnell *et al.* 2001a; Leader-Williams and Hutton, Chapter 9, Cope *et al.*, Chapter 11).

Selective removal of wildlife is aimed specifically at the individuals suspected to have damaged property. Hence the location, methods and target are specified narrowly – which usually means that only trained authorities kill wildlife. Selective removal differs from culling in targeting fewer individuals and being reactive rather than pre-emptive: no animals are killed unless damage has occurred. The assumption underlying selective removal is that conflicts will diminish when problem individual animals are removed. Selective control is most often employed by governments to manage problems with rare or endangered wildlife. Examples include the removal of wolves radio-located near livestock kills (Bangs *et al.*, Chapter 21), and the issuance of kill permits to private livestock producers in areas that have had 20 or more depredations by lynx (Angst 2001). Selective removal can include translocation from sites of past human–wildlife conflict (Jorgensen *et al.* 1978; Linnell *et al.* 1997; Hoare 2001; Bradley 2004; Bradley *et al.* in press).

EFFECTIVENESS OF LETHAL CONTROL IN REDUCING FUTURE THREATS TO HUMAN LIVES AND LIVELIHOODS

The main justification for lethal control, and removal in all its forms, is conflict prevention and the underlying assumption is that conflict declines when wild animals are removed. There is no doubt that eradication campaigns can drastically reduce losses – at least those caused by the targeted species. The absence of wolf predation on Scottish sheep illustrates how eradication benefited agriculture. However, eradication can have unpredictable consequences. Reducing the density of top predators may cascade through ecosystems with meso-predators increasing in density, which can have unpredictable consequences for prey populations, conflict rates and the services ecosystems provide to humans (Reynolds and Tapper 1996; Estes *et al.* 1998; Terborgh *et al.* 2002). Well-studied examples of this occurring in conflict situations include the increased predation on wildfowl by skunks in the Prairie Pothole region of Canada after the eradication of red fox and coyotes (Greenwood *et al.* 1995), increased predation on rabbits by mongooses in southern Spain following the removal of the Iberian lynx (Palomares *et al.* 1995), and increasing levels of bush pig and baboon crop-raiding associated with the widespread removal of lions and leopards across Uganda (Naughton-Treves 1999). In short, eradication of one predator species may have the opposite result from that intended if a smaller predator at higher density takes its place. For example, the extirpation of wolves from all but a few tiny areas of the USA probably reduced conflicts overall for cattle and other large livestock, but conflicts with coyotes and other smaller carnivores remained frequent or have increased for smaller livestock such as sheep (Newby and Brown 1958; Taylor *et al.* 1979; Pearson and Caroline 1981). In sum, eradication of one species of problem wildlife can have unpredictable effects in the long term but certainly will reduce that species' threats to human life and livelihood. However, eradication of any problem species is clearly in conflict with efforts to promote coexistence of people and wildlife.

The effectiveness of culling programmes, public hunts and selective removal methods is far less clear because they have rarely been properly evaluated. This is particularly the case for large mammals because of the extensive spatial and temporal scales required for meaningful comparisons between different control techniques (Box 6.1). Less rigorous before-and-after comparisons indicate that the removal of large mammals has a mixed record of success in preventing future conflicts (Allen and Sparkes 2001; Hoare 2001; Osborn and Parker 2003). In Table 6.1, we review a handful of systematic studies from North America and Europe that assessed various removal programmes in preventing economic losses to carnivores.

The data in Table 6.1 suggest that removal of carnivores tends to achieve only temporary reduction in conflict if immigrants can rapidly fill the vacancies left after removals. This is consistent with findings for non-carnivores (e.g. moles: Edwards *et al.* 1999; elephants: Hoare 2001; Osborn and Parker 2003). Wolf translocation operations of the US Fish and Wildlife Service illustrate this point (Bangs *et al.* 1998; Bradley 2004; Bradley *et al.* in

Table 6.1. *Systematic studies of removal to prevent human–carnivore conflict*

Carnivore, country	Source	Type of removal	Conclusions
European badgers, Ireland	Eves 1999	Eradication	Tuberculosis in cattle declined more in a badger eradication area than in a surrounding 'reference' area where more selective lethal control was enacted (see Box 6.1 and below).
Brown bears, Norway	Sagør *et al.* 1997	Public hunt	No detectable reduction in sheep losses the following year because of recolonization and renewed depredations.
Wolverines, Norway	Landa *et al.* 1999	Public hunt	Lamb losses declined for one year, ewe losses did not change. Recruitment and recolonization led to renewed depredations.
Cougars, USA	Evans 1983	Culling	No effect on endangered prey species survival following removal of cougars.
Coyotes, USA	Conner *et al.* 1998	Culling	Non-selective removal in and around one farm did not reduce sheep losses in subsequent years.
Red foxes, UK	Reynolds *et al.* 1993	Culling	Reduced game-bird predation for less than one year because removed individuals were replaced in the same season.
Wolves, Canada	Bjorge and Gunson 1985	Culling/targeted lethal control	Cattle losses declined for two years, followed by recolonization and renewed depredations.
European badgers, Britain	Donnelly *et al.* 2003	Targeted lethal control	Tuberculosis in cattle increased in nine areas where targeted lethal control of badgers occurred, relative to matched areas without lethal control.
Wolves, Canada	Tompa 1983	Targeted lethal control	Following complaints of harassment, lethal control prevented further conflict for more than a year in 13.5% of cases. Following livestock loss, lethal control prevented further conflicts for more than one year in 34% of cases.
Wolves, USA	Bradley 2004; Bradley *et al.* in press	Targeted lethal control	Removal of depredating packs increased the interval between successive depredations by 270 days on average. However, remaining individuals or translocated packs depredated again within a year after 23 (68%) of the 34 removals. When entire packs were removed, recolonizing wolves usually (six of seven cases) also caused depredations (after 99 to 383 days).
Wolves, USA	Fritts *et al.* 1992	Targeted lethal control	Where wolves were removed 34% of farms had another depredation within one year whereas 23% of farms with verified depredations yet without wolf removal had another depredation within one year.

press; Bangs *et al.*, Chapter 21). In the Greater Yellowstone Area, 10 wolf packs were entirely removed following depredations. Recolonization of vacant habitat occurred in seven (70%) of these instances. Six new wolf packs recolonized within one year of the previous pack's removal and one recolonized five years later. Six recolonizing packs killed livestock, five of which preyed upon livestock in the ranches that had been previously affected (Bradley 2004; Bradley *et al.* in press). Data from Wisconsin are virtually identical for one cattle farm suffering chronic losses that had at least three wolf packs removed by translocation (Wisconsin Department of Natural Resources, unpubl. data). Such recolonization might be a good sign for population viability because it reflects resilient recovery following removals but recolonization does not bode well for prevention of conflicts. Recurrence of conflict despite wildlife removal has led some to conclude that the problem lies with husbandry as much as the wildlife (Stahl and Vandel 2001; Bradley 2004; Wydeven *et al.* 2004). Whether these findings hold for non-carnivores and other forms of property remains to be seen.

Table 6.1 may overestimate the effectiveness of culling programmes, public hunts and selective removal in preventing future damage. Without experimental controls, we cannot distinguish property loss followed by removal of wildlife from an isolated incident of property loss that would not have been repeated regardless of control action. Studies of radio-collared carnivores and longitudinal data on livestock operations both indicate that isolated incidents without repeat are common (Jorgensen 1979; Tompa 1983; Angst 2001; Stahl and Vandel 2001; Treves *et al.* 2002; Oakleaf *et al.* 2003; Bradley 2004; Wydeven *et al.* 2004; Bradley *et al.* in press). For example, Tompa (1983) described 49 cases of livestock predation by wolves where lethal control was denied for various reasons. In 39 (80%) of these cases, problems with wolves did not persist beyond one year. Some such cases may reflect unreported removal by the property owners, but others may reflect isolated events by transient animals or single incidents by resident animals triggered by brief changes in the relative availability of wild food.

Our review underscores the need for more experimental studies to understand the true effectiveness of control operations as part of species conservation programmes (Box 6.1). Properly designed experiments are badly needed to evaluate removal operations for large mammals in particular, because worldwide these are among the most endangered species and come into conflict with people commonly (Treves and Karanth 2003). To date such experiments have largely been restricted to small carnivores and predatory birds (Reynolds and Tapper 1996).

Population control of small carnivores is a common technique in game management in Europe and to a lesser extent in North America (Reynolds *et al.* 1993; Reynolds and Tapper 1996). We feel this deserves attention here because people often claim ownership of wild game and therefore predators trigger human–wildlife conflict by our definition when they prey on the contested wild game (e.g. Thirgood and Redpath, Chapter 12, Miquelle *et al.*, Chapter 19). The effectiveness of removal of predators as a game management tool has received considerable attention. The classic study is that of Marcstrom and colleagues (1988) who experimentally removed red fox and pine martens from islands in the Gulf of Bothnia, Sweden. The study was rigorously replicated and included switching of experimental treatments. During years with predator removal, densities of capercaillie and willow grouse were 1.7 times higher than in years without predator removal. A similar study was conducted in farmland in southern England (Tapper *et al.* 1996). In this case, experimental removal of red foxes and corvids increased spring densities of grey partridge 2.5 times and autumn densities 3.5 times. Cote and Sutherland (1997) reviewed 20 published studies of such predator removal programmes in a meta-analysis of their effectiveness to enhance or protect game-bird populations. Removing predators (either mammalian or avian) had a large positive effect on hatching success of the target bird species, with removal areas showing higher hatching success, on average, than 75% of the control areas. Similarly, predator removal significantly increased post-breeding population sizes (autumn densities) of the target bird species. The effect of predator removal on breeding population size (spring densities) was not significant, however, with studies differing widely in their reported effects. Predator removal may therefore fulfil a requirement of game management, which is to enhance harvestable post-breeding populations, but it is much less consistent in achieving an aim of conservation managers, which is to maintain or enhance breeding population size. Indeed these different objectives of game managers and conservation managers go some way to explain the different attitudes and interpretations of predator control programmes (Newton 1998).

An intriguing question is whether the greater success described above of removal of small predators to protect wild game-bird populations relative to the poorer record for removal of large predators to protect property (Table 6.1) tells us something important about the control of wildlife damage or whether it simply reflects different measures of success. With livestock, a handful of depredation events may be considered failure because no one measures success of predator control by how many cattle survive each year, which is precisely how they measure success in terms of game-bird management. Programmes that seek to protect wild prey may achieve some success with each predator removed because virtually all individual predators pose a threat (to their wild prey or the game claimed as property of humans). In short, there is little need for selective removal when all targets of removal pose a threat. However, programmes to protect livestock typically confront a minority of the predator population (see below), hence selective techniques are needed to generate the same incremental improvement in prey survival. Inaccurate removal of non-culprits may even yield unpredictable effects if culprits benefit from the removal of non-culprits (e.g. opening territorial vacancies).

Public hunts are least well represented in Table 6.1. As an ancillary motivation for public hunts, conflict prevention has not been studied as well. However, the recurrent justification of hunting as a conflict-reduction strategy merits more attention (Howard 1988; Linnell *et al.* 2001a; Knight 2003).

Without careful research on public hunts, it will be hard for managers to overcome several challenges that face public hunts as conflict-prevention strategies. For one, hunters are often unable or unwilling to target those individuals likely to participate in conflicts (Faraizl and Stiver 1996; Jackson and Nowell 1996; Sunde *et al.* 1998). For example, safari hunters participating in Zimbabwe's CAMPFIRE programme (see Leader-Williams and Hutton, Chapter 9) prefer to hunt mature bull elephants amidst wild habitat than to shoot younger animals amidst maize fields. As a result, licenses to hunt crop-raiding elephants are offered at a discount (Murombedzi 1992). Second, private hunters may be less well trained or use less effective killing methods than professional wildlife removal agents, resulting in higher frequencies of injured animals; injured animals can cause more problems than healthy ones, at least in some carnivores (Rabinowitz 1986; Linnell *et al.* 1999). Third, hunting may itself precipitate conflict by increasing the likelihood of encounters between wildlife and people or their valuable hunting dogs (Aune 1991; Treves and Naughton-Treves 1999; Treves *et al.* 2002; Wydeven *et al.* 2004). Finally, some carnivore ecologists speculate that heavily hunted populations generate more conflict, because their age structure shifts towards younger, inexperienced predators, which may turn to predictable but risky foods like livestock (Haber 1996; Conner *et al.* 1998). The potential problems described above should be taken into account in designing public hunts to prevent human–wildlife conflicts. Systematic applied research on this topic will be a welcome contribution.

Our examination of culling programmes and public hunts above prompts us to ask whether the short-lived effects of removal operations on large carnivores (Table 6.1) could be due to occasional or frequent removal of the wrong animals. The literature is unanimous that the majority of individual carnivores in a population will not kill livestock despite having access. This is well illustrated by work at the Hopland Sheep Research Station in

California (Conner *et al.* 1998; Knowlton *et al.* 1999; Sacks *et al.* 1999a, b; Blejwas *et al.* 2002). Breeding pairs of coyotes are responsible for the vast majority of incidents of predation on sheep and they kill sheep only within or on the periphery of their territories. Removal of one or both members of a breeding pair or destruction of litters reduced or eliminated livestock losses. Although new coyotes did eventually immigrate into the vacant territory, selectively killing only the breeding coyotes during the lambing season was an effective way of reducing lamb losses. Killing other coyotes was not. Studies of radio-collared pumas, wolves, lynx and grizzly bears corroborate that not all carnivores with access to domestic animals will prey on them. Some individual carnivores avoid humans and their property, others remain nearby without causing problems, and a subset causes damage (Andelt and Gipson 1979; Jorgensen 1979; Suminski 1982; Mace and Waller 1996; Bangs and Shivik 2001; Stahl and Vandel 2001; Treves *et al.* 2002; Bradley 2004; Wydeven *et al.* 2004). Similar analysis of crop-raiders and other sorts of problem wildlife would be valuable.

Non-target animals often fall victim to control operations. We estimated the proportion of non-target carnivores killed to prevent conflicts, from a handful of studies that used different methods (Table 6.2). Between 11% and 71% of the carnivores killed in control operations bore no evidence of involvement in conflicts. We caution against uncritical use of these data, because absence of evidence for an individual animal's involvement in conflict cannot fully exonerate it. The estimates in Table 6.2 therefore probably reflect maximum error estimates in some of the studies. Nevertheless, rigorous research by Sacks and colleagues (1999a) suggests the numbers are not unduly inflated (see also Box 6.1). Table 6.2 suggests removal of animals around the damaged property shortly after the damage is inflicted is the most accurate technique for the taxa examined, compared with removal later and far from the damage location (see also Bjorge and Gunson 1985).

There may be several reasons why non-target animals are killed in control operations. Habitual culprits are often hard to capture as their experiences with humans make them wary of human scent and devices (Corbett 1954; Turnbull-Kemp 1967; Conner *et al.* 1998; Sacks *et al.* 1999a, b). Yet one of the most common and effective removal techniques is to shoot, trap or poison animals that return to the damaged resource. For example, ranchers in Kenya shoot suspected culprit lions by concealing themselves in blinds at the sites of fresh livestock kills (Frank *et al.*, Chapter 18), and a similar approach is sometimes taken to shoot or trap livestock-killing wolves in the USA (Minnesota Department of Natural Resources 2001; Wisconsin Department of Natural Resources 2002; Bangs *et al.*, Chapter 21). These

Table 6.2. *Accuracy of lethal control in carnivore depredation management*

Carnivore species	Control method	Probable culprits among those removed	Source of evidence
Black and grizzly bears *Ursus americanus*, *U. arctos*	Trapping	30% ($n = 60$)	Horstman and Gunson (1982): estimated from necropsy, cessation of depredations and evidence at kill sites.
Coyote *Canis latrans*	Trapping	11–64% ($n = 113$)	Gipson (1975): estimated from necropsy of stomach contents; percentage varies with type of agricultural loss.
Coyote *Canis latrans*	Trapping, snaring, shooting, explosives, denning	55–71% ($n = 42$)	Sacks *et al.* (1999a: Table 1): estimated from age class of killed animals; lower bound assumes pups cause no depredations, upper bound assumes neither pups nor yearlings cause depredations for all methods of control.
Coyote *Canis latrans*	Aerial shooting	45% ($n = 11$)	Connolly and O'Gara (1987): estimated from the proportion of individuals killed that lacked a marker dye experimentally introduced into sheep.
African lion *Panthera leo*	Shooting over a livestock kill	70% ($n = 20$)	Frank *et al.*, Chapter 18: estimated from the proportion of lions shot that were too young to kill for themselves.
European badger *Meles meles*	Cage trapping and shooting	18.7% ($n = 18{,}141$)	Krebs *et al.* (1997): the proportion of TB-infected badgers that were killed on farms which had experienced TB outbreaks in cattle.

approaches can be selective for the culprit(s), but the selectivity would be expected to decline under several conditions. First, the bait should not be left out too long lest non-target animals be attracted (Ratnaswamy *et al.* 1997). Trappers and other control agents sometimes leave out carcasses or attractive baits for days or even weeks (Jorgensen *et al.* 1978; Horstman and Gunson 1982; Shivik and Gruver 2002; Nemtzov 2003). Second, non-target mortality will increase when using baits if wildlife have become habituated to scavenging from human refuse. The improper disposal of garbage and carcasses in area is believed to create problem animals (Andelt and Gipson 1979; Jorgensen 1979; Mech *et al.* 2000; Rajpurohit and Krausman 2000). Non-target mortality is expected to increase in species without strict territorial defence of space or resources. Among carnivores, individuals that played no part in killing wild prey and other species may be drawn to kills even in territorial animals (Frank *et al.* 2003; Shivik *et al.* 2003; Smith *et al.* 2003). Finally, non-target mortality may increase when several related taxa are difficult to distinguish from sign at kills, or when culprits are transients.

In summary, the short-lived effectiveness of culling programmes and selective lethal control seems to reflect recolonization of territories left vacant after removal, and high rates of removal of non-target animals.

IMPACT OF LETHAL CONTROL ON THE VIABILITY OF WILDLIFE POPULATIONS

While eradication campaigns are specifically designed to cause local extinction, other forms of removal are expected to have less of an impact on population viability. It is beyond the scope of this chapter to provide a thorough evaluation of wildlife population dynamics under different removal programmes. From our review of the literature, it appears the culling programmes and selective removals are both assumed to have little or no impact on wildlife populations. This is rarely examined systematically however (but see Blackwell *et al.* 2000; Cope *et al.*, Chapter 11).

Culling by government agents/programmes would seem to offer control over the number of wildlife removed. With prudent management and a careful balance between human needs and wildlife habitats, expert culling programmes have the potential to reduce wildlife densities in high-conflict areas without causing regional extinction. However, the government must receive incentives that promote wildlife population sustainability, rather than gain from their destruction. For example, the value of leopard skins and elephant ivory to the Ugandan colonial authorities of the twentieth century promoted widespread, energetic culling far beyond the needs of agricultural protection (Naughton-Treves 1999; Treves and Naughton-Treves 1999). Also, governments must control other sources of wildlife mortality lest government culling be additive with private, illicit killing and together undermine wildlife population persistence. In some cases where private individuals are involved in culling, the culling is intentionally or unintentionally extended to protected species (Goldstein 1991; Gonzalez-Fernandez 1995; Nemtzov 2003). For example, consider the killing and nest destruction of hen harriers and peregrine falcons on moorland managed for red grouse hunting in the UK (Thirgood *et al.* 2000b); Thirgood and Redpath, Chapter 12). The illegal killing of raptors to reduce their impact on game-bird populations is one of the main factors limiting raptor distribution and abundance throughout Europe (Valkama *et al.* 2004).

Public hunts are usually monitored better than culling or selective removal programmes although doubts have been raised about several issues. Setting hunting quotas based on previous years' harvests or previous years' conflict rates may not correlate well with population levels (Bennett 1998; Sunde *et al.* 1998; Landa *et al.* 1999; Logan and Sweanor 2001). The governance of hunting on communal lands may promote corruption and greed which may foster unsustainable hunting levels (Du Toit 2002; Virtanen 2003). Legal but poorly regulated hunting in multiple-use areas of the tropics can quickly extirpate large-bodied vertebrates from wide areas (Naughton-Treves *et al.* 2003a). Finally, the additive effects of public hunting and private removal of agricultural pests may elevate human causes of wildlife mortality to unsustainable levels unbeknownst to managers (Jorgensen *et al.* 1978). On the other hand, public hunts can contribute to the management of wildlife populations both directly via mortality and indirectly by generating revenue or scientific information to help manage wildlife populations (Stowell and Willging 1992; Faraizl and Stiver 1996; Nelson 1997; Andersone and Ozolins 2000).

Selective removal would appear to have a smaller population impact than any of the preceding removal strategies. First, the minimum number of animals is removed from the population. For example, India has preserved the last Asian lions and the largest population of tigers – despite a human population approaching 1 billion – by enforcing the protection of reserves and using lethal control only when problem wildlife become habitual threats to human life and property (Karanth 2002; Karanth and Madhusudan 2002). Second, culprits are eliminated from the gene pool while non-culprits are left in place to reproduce and spread their (learned or innate) avoidance of humans and their property, which could reduce future conflicts and removals (Jorgensen *et al.* 1978; Treves 2002; R. Woodroffe and L. G. Frank unpubl. data).

PUBLIC ACCEPTANCE OF LETHAL CONTROL

Making global conclusions about public opinion regarding lethal control is an overwhelming task given the diverse forms of human–wildlife conflict and the dramatic differences between and within societies regarding the acceptability of killing animals. Moreover, attitudes toward wild animals (and killing them) are value-laden and formed early in life (Kellert 1991). With these caveats in mind, we do discern some general trends in public acceptance of lethal control.

One way to understand varying acceptance to lethal control is to array people's values along a continuum with strong 'wildlife protection' on one end and strong 'wildlife use' on the other (Manfredo and Dayer in press). People whose values lie at the protection end of the continuum believe that wildlife have rights similar to humans and generally oppose lethal control, as an unethical and cruel endeavour (Berg 1998). At the other end of the spectrum are people who believe wildlife should be used for human benefit, and embrace hunting (Howard 1988). Protectionist values tend to be found in urban populations more than rural while the opposite is true for use values (Kellert 1991; Wells *et al.* 1999). This divergence produces the fundamental tension for lethal control programmes: the rural citizens who are themselves more likely to experience conflict with wildlife are more likely to welcome lethal control, while urban populations with lower vulnerability but contributing more tax revenue tend to object to it (Manfredo *et al.* 1998; Reiter *et al.* 1999; Naughton-Treves *et al.* 2003b). Individual exceptions abound in all studies. Moreover, the specifics of the conflict will shape public approval for management. Table 6.3 describes how attributes of the wildlife and the context of the conflict can shape attitudes toward lethal control.

Campaigns to eradicate regional populations of native wildlife have largely been discontinued because of changing public attitudes to wildlife conservation and animal welfare (but see Reading *et al.*, Chapter 13). Few citizens want to see the complete eradication of a species, even if they are suffering losses, whether they are ranchers in Wisconsin, USA or western Ugandan farmers (Hill 1998; Naughton-Treves *et al.* 2003b).

Public acceptance of culling and hunting as a management tool varies greatly between cultures. Some advocates of management by hunting and culling argue that theirs is an efficient and humane population-control technique (Shelton 1973; Howard 1988). Yet tolerance for hunting and culling is generally diminishing in developed countries such as the USA and UK (Suminski 1982; Evans 1983; Harbo and Dean 1983; Shaw *et al.* 1988; Bennett 1998; Cope *et al.*, Chapter 11).

Table 6.3. *Factors shaping approval for lethal control*

Factor shaping acceptance	Acceptance less likely	Acceptance more likely
Where animal is killed	Public land	Private land
How animal is killed	Poison, snares, kill traps	Sharp-shooters, live traps followed by euthanasia
Type of threat by animal	Nuisance	Attacks human
Who kills animal	Commercial hunter	Government agent
Cost of damage by animal	Low	High
Perceived attributes of animal		
Aggressiveness	Peaceful (dove, cranes)	Fierce, cunning (coyote, fox)
Intelligence	Low (rodent)	High (chimpanzee)
Appearance	Beautiful (swan), neotenous (big eyes, round head, cute), human-like (monkey)	Ugly (crow), alien (snake)
Abundance	Scarce	Superabundant
Sociality	Strong bonds (elephant)	Loners (wolf)
Reproductive status	Lactating female	Lone male
Health status	Prime or young in age	Ill, injured, decrepit

Attitudes to government culling vary greatly, and in part reflect public attitudes towards government itself. In developing nations, rural, small-scale agriculturalists and other stakeholders may welcome government interventions to control wildlife even if conflict rates remain the same (Bell 1984a; Hoare 2001). This may promote coexistence of wildlife and people if satisfaction with government culling reduces illicit killing of wildlife. By contrast, in some affluent communities of the USA, people have objected to the use of their taxes to remove wildlife, particularly if removal was perceived to have been carried out in response to political pressure by industrial interests (Torres *et al.* 1996; Fox 2001). Similarly, public attitudes to private culling vary tremendously and often reflect attitudes to game management or sport hunting itself. For example, the UK-based Royal Society for the Protection of Birds (RSPB) is Europe's largest non-governmental conservation organization with more than 1 million members. In contrast, the Game Conservancy Trust (GCT), a UK non-governmental conservation organization having strong associations with game management and sport hunting has approximately 24 000 members. Whilst it is certainly an oversimplification to suggest that these membership figures reflect the attitudes of the UK general public to protection versus use of wildlife, one can say that the use of lethal control in game management is not widely supported.

Public hunts are argued to improve tolerance for potentially dangerous wildlife like carnivores because hunters gain a sense of ownership of the wildlife (Linnell *et al.* 2001a). For example, the public in Wisconsin, USA tolerate large populations of species designated as game, such as white-tailed deer and black bears, despite millions of dollars in annual property damage and occasional human injury and death (Stowell and Willging 1992; Nelson 1997). By contrast, tolerance for wolves, a non-game species that causes less damage and does not threaten people, is far lower (Naughton-Treves *et al.* 2003b). Presumably, such tolerance reflects a sense of ownership and self-determination; hunters may accept wildlife on their land if they can use them or participate in their management, but not those species strictly protected by the government. Hunter tolerance is important because it is often hunters who encounter wildlife while armed in remote areas and can therefore subvert wildlife protections afforded by law without great fear of prosecution.

Different types of hunting face differing levels of public support. For example, approximately 75% of rural Wisconsin residents are hunters (Naughton-Treves *et al.* 2003b) and a recent ballot initiative made hunting, fishing and trapping a state constitutional right. But proposals for crane-hunting to control crop damage, and wolf-hunting to control livestock damage produced public outcry. In short, public hunts may be acceptable but the methods must be considered carefully if one goal is public acceptance of removal as a control strategy. Promoting public hunts may also be unrealistic for certain flagship or totem species. For example, Native American groups in Wisconsin oppose any form of removal of wolves because the species has symbolic significance to them. There are similar feelings among Japanese hunters about killing monkeys, serow and bears (Knight 2003).

Although selective removal of culprits may seem to be the form of lethal control most likely to receive public acceptance, some animal-welfare groups remain opposed to any lethal control. Animal-welfare advocates argue that livestock husbandry is as important as predator removal but receives far less attention (Berg 1998). For example, the US Department of Agriculture's refusal to protect sheep operations with non-lethal techniques before initiating lethal control of coyotes led local authorities in Marin County, California to seek a private contractor willing to use non-lethal strategies (Fox 2001). Although an unusual case, this illustrates how a non-responsive agency can have its lethal control programme terminated regardless of effectiveness. At the opposite extreme, some groups remain opposed to problem wildlife conservation efforts no matter how responsive and accurate the removal programme. Although the US Fish and Wildlife Service has removed problem wolves from the Greater Yellowstone Area, USA, in a highly selective manner and losses to wolves have been lower than expected (Thompson 1993; Bangs *et al.* 1998; Bangs *et al.*, Chapter 21), some key stakeholders in the livestock industry remain implacably hostile to the wolf population and continue to seek wolf extirpation. In some cases, selective lethal control can frustrate both agriculturists and conservationists because it is reactive rather than preventive; both property and wildlife are lost. However, from a pragmatic standpoint, refinements to lethal control may meet less resistance from rural or agricultural interests and wildlife managers than efforts to change to non-lethal techniques. From this perspective, improvements in the accuracy of selective lethal control or improved hunting regulations represent a compromise position that may be increasingly attractive to wildlife managers in coming years (Box 6.2).

CONCLUSIONS

Arguing that lethal control is a legitimate strategy to promote wildlife conservation is difficult given the historical record of militaristic campaigns across the globe to eradicate species in the name of progress. Efforts to poison, shoot, trap or otherwise eliminate all inconvenient or threatening species were often as much about territorial conquest and the subjugation of nature (and indigenous people) as about protecting property such as crops and livestock. This grim history demands a conservative approach to lethal control today. Our review of the benefits and risks of contemporary lethal control programmes suggests that lethal control is a legitimate part of wildlife management and as such can play a role in conservation. The more difficult questions lie in who should be allowed to kill which animals and under what circumstances. We rest our review on two arguments:

(1) When highly endangered species kill livestock or take human lives, the best form of lethal control is highly accurate, selective removal of 'problem' animals by formally appointed and trained agents. Although killing a problem animal may temporarily placate local complainants, it does nothing to instil ownership or a sense of responsibility for the species among rural citizens who will probably continue to resent the presence of 'the government's animals' on their land in

Box 6.2. Improving the accuracy of selective removal

The main impediments to precise removal of culprits are technical and economic ones. Culprits are difficult to identify because humans can rarely observe conflicts or distinguish culprits from their conspecifics (Osborn and Parker 2003). Necropsy has been the main source of indirect evidence to implicate carnivores in livestock depredations (Gipson 1975; Andelt and Gipson 1979; Horstman and Gunson 1982). Post-mortem evidence remains important in evaluating selective lethal control (see also Box 6.1), but it is obviously too late to exonerate a non-culprit.

There have been two classes of approaches to improving the accuracy of selective lethal control. One is to develop new methods or refine existing methods for selectively killing suspect animals. The other is to assess the evidence against individual suspects before they are killed.

Improving selectivity

For years, researchers have explored the use of toxic chemicals to eliminate culprits at the site of conflict (Ratnaswamy *et al.* 1997; Mason *et al.* 2001). Unintended mortality of non-target animals and learned avoidance have haunted such endeavours. However, the development of livestock-protection devices loaded with toxic chemicals may selectively target problem carnivores, if these behave in predictable ways. For example, Burns and colleagues (Burns *et al.* 1991, 1996) demonstrated that coyotes were killed quickly and effectively when they delivered their stereotypical throat bite to sheep wearing collars loaded with toxin. Highly specific devices like these do not completely eliminate unintended damage to non-target wildlife because of leakage from punctured, defective or mishandled collars and scavenging of the carnivores that succumbed to the toxin. However, these side effects seem minimal. On the negative side, it is not clear whether neophobic animals commonly avoid the collars, or if such devices can work against other taxa than coyotes. Also the considerable cost of such devices almost certainly precludes their use in less-developed countries without considerable external donor support.

Highly focussed studies of the behaviour of problem animals and their conspecifics have revealed ways to improve selectivity of lethal control. Sacks and colleagues (Sacks *et al.* 1999a) contrasted the age classes of coyotes killed by various methods. Based on their work and that of colleagues (cited in the text), they concluded that shooting breeding pairs near dens during the pup-rearing season would be the most selective method of lethal control. Highly specific recommendations like these underscore the need for well-informed, trained professionals conducting selective lethal control.

Implicating and exonerating culprits via indirect evidence

Culprits may be identifiable by scent or other trace evidence. Scent dogs are used routinely to track mountain lions for hunting as well as depredation control. Proponents argue that these hounds are extremely discriminating and will bypass the trail of non-target animals (Suminski 1982; A. A. Smith *et al.* 2001). The technique may hold promise, particularly for wildlife at low population densities and for wildlife authorities with limited resources. Alternatively, captured wildlife may retain evidence of feeding on the human property. Remains and odours on the body of the wild animal may be useful in discriminating those having damaged human property from those that have not. Currently, rapid DNA fingerprinting assays are unavailable but this is likely to change given the advantages such tests would provide in human law enforcement. By contrast, examination of stomach contents and other tell-tale remains collected from live-trapped animals is well within current technical capabilities of developing countries – without killing the subject first.

Improving selective lethal control holds promise but it is questionable if this intensive level of individual wildlife management is economical except in situations that involve very valuable animals, such as endangered species.

the absence of substantial economic benefits from the animal. In short, selective removal of problem animals by government agents may be necessary to protect wildlife from extinction via widespread, illicit retaliation. The accuracy of removal becomes critical for populations near extinction so that non-culprits are left in place to reproduce (Box 6.2). Such may be the case presently for managing the roughly 300 lions persisting in India (Chellam and Johnsingh 1993), and for wild dogs recovering in Kenya (R. Woodroffe unpubl. data). This type of selective removal *was* important for protecting the recovering population of wolves in Wisconsin (Treves *et al.* 2002). However, as the population of an endangered species recovers and expands its range, more flexible, participatory types of control can be implemented.

(2) Public hunts are more participatory and cost-effective than selective removal by government agents when 'problem' species are numerous and widespread. But two cautionary lessons emerge from our review: (a) public hunts are more effective in improving public tolerance of the species (and support for the agency charged with its management) than in preventing damage caused by the species, and (b) regulated harvests may alienate urban constituents who place higher value on non-consumptive use of wildlife.

Of course there are myriad options lying between highly selective removal programmes and large-scale public hunts. Judging which form of removal to promote is challenging given the myriad ecological and socio-political factors in play. Social and ecological science expertise will be needed. Detailed demographic, ecological or forensic analyses may be required to judge the effectiveness and impact on wildlife populations of one control programme over another. Approval for management and tolerance for conflicts must be surveyed. The relationship between the control method and illicit killing by stakeholders must also be considered and quantified. All of these data and the technical skills to analyse them and make appropriate management recommendations will be lacking in many conflict situations. Even if armed with rich scientific data, policy-makers must judge broad public approval for alternative removal programmes. Without such approval, wildlife managers may lose full, flexible control.

No single prescription will be appropriate for all conflict situations. Instead, the entire constellation of political, economic and aesthetic demands of affected human populations should dictate local and regional solutions (Treves and Karanth 2003). Therefore design of a control programme requires stakeholder input, and consideration of the material and non-material values of the wildlife, stakeholders' perceptions of government intervention, views of the human role in nature, and rarity of the species in question.

Given uncertainty about stochastic causes of mortality in most large animal populations, we suspect that erring on the side of caution is the best way to maintain wildlife population viability for certain species. The prospects for coexistence of wildlife and people have improved in many parts of the world where wildlife eradication campaigns have been replaced with efforts to promote coexistence. Achieving this coexistence will entail technological innovation, including developing better non-lethal deterrent methods, more accurate identification of problem animals and conflict sites, and improved monitoring of the impacts of control programmes. It will also require negotiation to reach a compromise between people who demand the removal of all inconvenient or threatening species and those who demand protection for every wild animal.

ACKNOWLEDGMENTS

We thank Rosie Woodroffe, Simon Thirgood, Luke Hunter and one anonymous reviewer for their detailed and helpful contributions to this chapter. AT was supported by the Wildlife Conservation Society during manuscript preparation. LN-T was supported by the Center for Applied Biodiversity Science–Conservation International and the University of Wisconsin–Madison. All opinions expressed in the chapter are only the authors' and we take responsibility for all errors.