8-1-2000

ECONOMICS OF PREDATION MANAGEMENT IN RELATION TO AGRICULTURE, WILDLIFE, AND HUMAN HEALTH AND SAFETY

Michael J. Bodenchuk
USDA-APHIS, michael.j.bodenchuk@usda.gov

J. Russell Mason

William C. Pitt

ECONOMICS OF PREDATION MANAGEMENT IN RELATION TO AGRICULTURE, WILDLIFE, AND HUMAN HEALTH AND SAFETY

MICHAEL J. BODENCHUK, J. RUSSELL MASON AND WILLIAM C. PITT

Abstract: Predation management is controversial and much recent debate has focused on the cost of management efforts. This manuscript considers the cost of predators to agriculture, big game or threatened and endangered species management, and human health and safety. Subsequently, the cost of efforts to manage predation in these contexts is discussed, and benefit:cost ratios are calculated. When properly applied, predation management shows benefit:cost ratios of between 3:1 to 27:1 for agriculture and 2:1 to 22:1 for wildlife protection. For human health and safety, benefit:cost ratios are more difficult to calculate, but we argue that benefits outweigh costs in many different areas. We conclude that in terms of benefit:cost returns on investment, predation management is an extremely efficient means of protecting livestock, wildlife species of concern, and human health and safety.

Key Words: benefit:cost ratio, big game, endangered species, human health and safety, livestock, predator management, upland birds, waterfowl.

Predation management,[1] and in particular, the application of lethal methods, is increasingly controversial (Knowlton et al. 1999). Especially among urban and suburban human populations (Mankin et al. 1999), nonlethal methods are preferred, and the protection of wildlife resources (big game, threatened or endangered species) or human health or safety, receive greater popular support than the protection of agricultural resources (Messmer et al. 1999). Much of the recent debate has centered on the cost of management efforts. At issue is whether economic costs exceed the benefits of predation management to society. Opponents have historically portrayed predation management as an expensive, ineffective, and thus, unwarranted activity performed for the benefit of a few livestock producers in the American West (Caine et al. 1972). Proponents argue that efforts are cost effective and essential for agricultural operations, and, in addition, some propose that predator management for livestock protection can benefit big game as well as threatened and endangered species (Smith et al. 1986, Reynolds and Tapper 1996, Hecht and Nickerson 1999). Exploring the relative merit of these views is difficult for a variety of reasons. First, losses prevented by management actions are difficult to estimate (Knowlton et al. 1999). Second, arguments are complicated because reports of livestock predation rates in the absence of management actions are rare. Despite speculation to the contrary (Wilkinson 1996), the available evidence suggests that members of coyote populations not subjected to management are as likely to kill livestock as members of coyote populations subjected to control (DeLorenzo and Howard 1976, McAdoo and Klebenow 1978, Windberg et al. 1997, Bromley 2000). Other factors that complicate discussion of the economics of predation management include different assumptions concerning stock inventories, inclusion or exclusion of pre-docking lamb losses, use of different assumptions and procedures in compiling loss data, and different monetary values assigned to animals lost (Knowlton et al. 1999).

In the discussion below, we single out coyote (*Canis latrans*) predation management whenever possible, because most of the controversy to date surrounding predation management has involved this species, and because coyotes are responsible for most predation loss (Knowlton et al. 1999). We examine the direct benefits and costs of predation management and also attempt to examine indirect costs incurred by livestock producers, rural communities, and consumers. These indirect costs include the costs associated with increased husbandry practices, stock replacements, contributions to control agencies, and increased prices resulting from reduced supplies (Connolly 1992a).

DEFINITIONS OF LOSS

What constitutes wildlife damage, like what constitutes wildlife and wilderness in general is inherently subjective (Nash 1967). So too are the thresholds of loss that various groups are willing to accept. Not surprisingly, what constitutes acceptable loss to a rancher is very different from what constitutes acceptable loss to other members of the public (Mech 1996, Reiter et al. 1999). For this reason alone, we think it is critical to provide an operational definition of loss that can be used as the basis for subsequent discussions. One possible definition would be to confine loss to instances of confirmed predation (dead animals found and predation confirmed by forensic examination). We reject this definition because we think it severely underestimates loss. Confirming predation is extremely difficult

[1] The term "predation management" is used in this manuscript because predator populations are not managed and the focus of management programs is on minimizing the effects of predation with nonlethal and lethal methods.

in many instances (Connolly 1992a). A second possibility would be to use the operational definition of confirmed loss: predation confirmation by a Wildlife Services (WS) biologist at a specific location. These simple definitions of loss ignore the costs incurred by producers to reduce predation risk, e.g., the purchase, training, and maintenance of guard animals, fencing, herders, shed-lambing, repellent devices, and contributions to private or public predation management programs (Littauer et al. 1986, National Agricultural Statistics Service 1999). These additional costs are significant and can be equivalent to or exceed the cost of predation, *per se*. For example, in 1981, the indirect cost of predation management in Wyoming was estimated to be US$2,639,900; reported losses to Wyoming producers that year totaled US$2,979,970 (Jahnke et al. 1987). Thus, we provide confirmed loss estimates and indirect costs when possible.

In addition to the prevention of agricultural loss, predation management activities can provide other substantial benefits in other circumstances not typically considered in economic evaluations of management activities. For example, predation management is critical to rabies suppression efforts in Texas (Finley 1998), important for the protection of game when populations are reduced in relation to available habitat (e.g., Rubin et al. 1998), and essential for the successful restoration of threatened and endangered species (Ratnaswamy and Warren 1998). Accordingly, the present discussion considers the benefits of predation management in relation to the direct and indirect economic loss to agriculture, human health and safety, and wildlife resources.

AGRICULTURAL PROTECTION

Direct Costs of Predation

The National Agricultural Statistics Service (1999) surveyed livestock producers associated with the USDA-APHIS Wildlife Services program in 1998. These producers represent a cross-section of livestock operators primarily in the 13 states of the WS western region, with a bias towards individuals with larger herds. WS cooperators, all with predation management programs in place, reported that predators killed approximately 22,600 cattle and calves, 144,000 sheep and lambs and 35,000 goats and kids. The estimated market value of these losses was in excess of US$17.4 million.[2] Although opponents of predation management frequently claim that self-reported losses are overestimates (C. Fox, Animal Protection Institute, statement to the National Wildlife Services Advisory Committee, 2000), the available evidence suggests otherwise. Connolly (1992a) reported that surveys of livestock producers tend to under-report loss, because reports emphasize confirmed kills. Furthermore, the National Agricultural Statistics Service survey data typically report lower losses than other national estimates (Connolly 1992b).

Sheep. – Predation is the leading cause of sheep and lamb mortality (National Agricultural Statistics Service 1999). For the discussion below, predation rates for domestic sheep are estimated from research on predator impacts in the absence of control (Table 1). The average annual rate of predation is 5.7% for adult sheep (range 1.4 to 8.1%) and 17.5% for lambs (range 6.3 to 29.3%). These rates are considerably higher than predation rates when predation management programs are used (National Agricultural Statistics Service 1999). In 8 studies where management was practiced, the average loss was 3.6% (range 1.1 to 6.5%). Based on the National Agricultural Statistics Service (1999) report, predation losses averaged 1.6% of adult sheep and 6.0% of the calculated lamb crop when predation management programs were in place.

Goats. – Meat goat production is growing, particularly in Texas and other areas of the Southwest. In general, goats are highly preferred prey by coyotes, to the extent that some authors have suggested using goats wearing livestock protection collars in flocks of sheep to target predation and increase control method efficiencies (F. Knowlton, personal communication). In a 2-year study of goat production in the absence of predation management, Guthery and Beasom (1978) reported that 49% of adult goats and 64% (range 33 to 95%) of goat kids were killed by predators. Shelton and Wade (1979) reported 100% of all kids and lambs were killed by predators during four short term fencing tests in Texas. Overall, predation rates on goats in these studies of loss in the absence of management exceeded 50%. With predation management in place, WS cooperators reported 12% of goats and kids killed by predators (National

[2] This estimated value is only approximate, because the value of livestock fluctuates with daily fluctuations in market values. For example, the loss of a pregnant ewe is not simply the loss of that animal, but also the loss of a lamb needed for replacement.

Table 1. Predator losses in the absence of a predation management program.

Source	Location	Year	Sheep lost %	Lambs lost %
Henne (1977)	Montana	1974	7.5	29.3
Munoz (1977)	Montana	1975	8.1	24.4
McAdoo and Klebenow (1978)	California	1976	1.4	6.3
DeLorenzo and Howard (1976)	New Mexico	1974	not reported	12.1
DeLorenzo and Howard (1976)	New Mexico	1975	not reported	15.6

Agricultural Statistics Service 1999). Of these, 42% were killed by coyotes. In the one study (Scrivner and Conner 1984) that compared costs and returns of Angora goat production with and without coyote predation (not with and without coyote management), predation reduced gross revenues for nanny, nanny and wether, and wether goat operations by 22.2% (Scrivner and Conner 1984), 14.3% (Scrivner and Conner 1984) and 13.5% (Scrivner and Conner 1984), respectively. In the same study, operational costs were increased by 32.8% (Scrivner and Conner 1984) 17.7% (Scrivner and Conner 1984) and 16.5% (Scrivner and Conner 1984) when predation was an issue.

Cattle. – Loss to coyotes is generally restricted to calves during the first several months of life. Occasionally, adult cows are killed while giving birth, when movements are restricted. Nonetheless, the National Agricultural Statistics Service (1999) estimates that coyotes account for 70.1% of cattle losses to predation. Using the Management Information System database, Utah Wildlife Services (1996a, 1996b) estimated that calf loss in the absence of predation management was 3.6%. However, interpretation of this loss rate is confounded since predation management to protect sheep was occurring in the same area. More broadly, the U.S. Department of Interior (1978) reported that 85% of cattle producers in the southwest lost no calves to coyotes, 13% had losses of < 5% and that 2% of producers had losses > 5%. Because the majority of producers experiencing no loss were probably small operations (Knowlton et al. 1999), we think that it is reasonable to assume that the number of cattle actually lost to predation is somewhat larger than these percentages suggest.

As for sheep and goats (Guthery and Beasom 1978), losses for cattle are substantially lower when predation management programs are in place. Using the Management Information System database, Utah Wildlife Services estimates that calf losses in the presence of management average 0.6%. New Mexico Wildlife Services estimates losses under similar circumstances to average 1.1%. The National Agricultural Statistics Service (1999) reports that 20,139 calves were lost by producers in 1998 with management programs in place. For Wildlife Services cooperators, predation rates on range calves prior to management activities averaged 3%, whereas predation rates in the presence of management average < 0.8% of the calculated calf crop (National Agricultural Statistics Service 1999).

Direct Benefits of Agricultural Protection

The National Agricultural Statistics Service (1999) surveyed livestock producers who used WS to manage predation and we calculated livestock (adult sheep and lambs, goats and kids, calves) savings attributed to this management program (Table 2). The market value[3] of individual animals does not take into account the potential for market price fluctuations that result from a variety of factors, including increased supply due to protection of livestock from predators. The total value of livestock saved, calculated by assuming a baseline of livestock killed in the absence of predator management, minus the number killed with management, multiplied by the market value of the livestock is US$62,606,770. This amount is impressive, but also, it is conservative, as it does not consider ancillary benefits of management actions to other livestock (e.g., poultry, pigs, adult cattle) present where management programs are in place.

Indirect Benefits of Agricultural Protection

The marketing of additional animals (i.e., those animals saved as a result of predation management) benefits many segments of the rural economy, not just individuals involved in direct production. Jahnke et al. (1987) report a 3x economic (output) multiplier effect for the benefits of predation management in Wyoming. Because rangeland livestock production in Wyoming is likely more important to the economy of that state than it is to other regions of the West, this multiplier is probably close to an upper limit. Despite this possibility, regardless of the multiplier used, our point is that the economic effects of livestock predation

[3] We used the market value of livestock to estimate the economic value because most of the costs incurred by rangeland operations are fixed and paid prior to the grazing season. The majority of predator losses occur with rangeland operations in the western United States. For example, the cost of forage and trucking for a lamb killed early is the same as the cost of forage for a lamb killed late. Thus, the market value does directly represent loss of profit.

Table 2. Savings attributed to a predation management program, calculated from statistics compiled by the National Agricultural Statistics Service (1999), who surveyed livestock producers using USDA-APHIS-Wildlife Services (WS). Note that percentages in columns 3 and 4 are rounded.

Class of livestock & market value (US$)	No. protected	No. potential loss (%)	No. reported loss (%)	No. saved	Market value saved US$
Calves (425)	2,562,823	76,885 (3)	20,139 (1)	56,746	24,117,050
Adult sheep (180)	2,018,440	115,051 (6)	33,044 (2)	82,007	14,761,260
Lambs (85)	1,856,965	324,969 (18)	111,133 (6)	213,836	18,176,060
Goats (1976)	292,151	146,075 (50)	35,027 (12)	111,048	5,552,400

and predation management extend beyond the ranch gate to other sectors of the rural economy. Applying Jahnke's effect to the total value of livestock saved by WS efforts in the western region (US$62,606,770), the upper value of predation management to businesses not involved in direct agricultural production would be US$187,820,310. The gross total benefit to all segments of the economy would be US$250,427,080.

Costs of Predation Management for Agricultural Protection

Costs of predation management include the cost of services and appropriated dollars for direct management activities and the indirect cost of investments by producers for additional production efforts (cost of additional replacement animals, extra labor, fencing, guard animals, etc.). Indirect costs are difficult to assess and vary considerably, depending on producer tolerance for loss, effectiveness (including cost-effectiveness) of methods to reduce predation problems, and suitability of the operation to adjustments in production.[4] Despite these inherent difficulties, several authors have attempted to quantify the indirect costs of predation management. Jahnke, et al. (1987) estimated that the cost of replacement animals and other indirect expenses were 162% of the cost for direct predation management activities. Littauer et al. (1986) reported that producer implemented (indirect) costs for predation management in New Mexico, including contributions to a cooperative predation management effort, averaged US$1,468/producer (range US$1,000 to US$25,600). Overall, Littauer et al. (1986) estimated that indirect expenses to producers, combined with costs for direct management activities were US$1.8 million. Losses for the same year were valued at US$3.5 million; accordingly, indirect cost contributions to predation management activities were 34% of the total cost to the livestock industry.

[4] For example, changing the timing of birth may decrease the risk of predation, but weather and/or a lack of off-season marketing opportunities may cancel the financial benefit of this option.

Direct Costs

The true cost of predation management is difficult to extract from WS annual tables. Although most of the livestock protection activity reported in these tables involves predation management, activity summaries also include bird damage management activities in feedlots. For this reason, estimates of the cost of predation management for this analysis are high.

In addition to federal appropriations, direct management programs in nearly every state involve cooperative funding from state and private sources (including contributions by producers). Table 3 details federal expenditures and cooperative dollars for livestock protection in states with operational WS programs in 1998. Costs include supervisory time and expenses, administrative costs, data management, and all program costs.

Coyote damage management costs are a subset of total livestock protection costs. Total costs could include predation losses to mountain lions (*Felis concolor*), bears (*Ursus americanus*), bobcats (*Lynx*

Table 3. Federal expenditures and cooperative dollars for livestock protection in states with operational Wildlife Services programs in 1998.

State	Federal US$	Cooperative US$	Total US$
Arizona	135,078	196,311	331,389
California	929,545	1,079,020	2,008,565
Colorado	669,891	278,630	948,521
Idaho	824,681	394,191	1,218,872
Montana	906,103	1,148,404	2,054,507
Nebraska	101,959	83,090	185,049
Kansas	29,684		29,684
Nevada	681,211	548,413	1,229,624
New Mexico	1,098,438	850,378	1,948,814
North Dakota	115,899	172,967	288,866
Oklahoma	195,905	294,945	490,850
Oregon	398,801	338,092	736,893
Texas	1,454,369	4,331,153	5,785,522
Utah	479,063	657,101	1,136,164
Washington	27,373	49,596	76,969
Wyoming	882,366	649,498	1,531,864
West region subtotal	8,930,366	11,071,787	20,002,153
Minnesota	200,811		200,811
Virginia	52,856	56,238	109,094
West Virginia	107,830	60,000	167,830
Wisconsin	7,106	17,972	25,078
East region subtotal	368,603	134,210	502,813
Total	9,298,969	11,205,997	20,504,966

rufus), red fox (*Vulpes vulpes*), wolves (*Canis lupis*), and golden eagles (*Aquila chrysaetos*) as well. Regardless, defensible estimates of the direct cost of coyote management can be calculated from the percentage of total livestock losses attributed to coyotes, or by the percentage of coyotes in the total take data of the WS annual tables. For those states with multiple predators, approximately 65% of the total predator losses can be attributed to coyotes (losses to red fox, bears, lions, and wolves account for most of the remainder). In addition, coyotes represented 90 to 95% of the total animals removed to resolve damage complaints.

Cost Efficiency of Agricultural Protection

Despite the fact that we have included all livestock protection dollars in our argument to identify the maximum cost incurred by producers, the benefit:cost ratio in 1998 (market value of all livestock saved:cost of all livestock protection programs) was 3.06:1. The benefit:cost ratio considering only federal appropriations (market value of all livestock saved:cost of WS livestock protection programs) was 6.75:1. The benefit:cost ratio considering total economic savings, including the nonagricultural multiplier,[5] and total expenditures was 12.2:1. The benefit:cost ratio considering just federal expenditures and total savings was 27:1.

WILDLIFE PROTECTION

Predation is a naturally occurring phenomenon. There is abundant evidence that predator and prey numbers fluctuate in healthy ecosystems and that the number of either is unlikely to become so low or so high as to warrant concern (Errington 1967). However, there also are many instances in which ecosystem health has been negatively affected by weather, fire, human disturbance, removal of top predators, introduction of exotic flora or fauna, etc. In these circumstances, predators may have significant negative impacts on prey (Hecht and Nickerson 1999) and populations of the latter may be driven sufficiently low to draw the attention of managers, and ultimately, the expenditure of public and private funds. One tool that can be implemented to benefit threatened prey species and to improve the recruitment of younger individuals into the population is predation management.

Economic Value of Wildlife Resources

Wildlife has intrinsic value (in terms of its role in natural systems) and an extrinsic value (in terms of dollar values assessed by wildlife management agencies). This extrinsic value can be calculated from the hunting license fees, habitat protection and restoration stamps, and non-consumptive uses of wildlife (e.g., viewing or photography). In addition, for many common game species, state departments of fisheries and wildlife have established economic values, based on estimates of contributions to the economy by individual animals of the species. These economic values serve as the basis for civil financial penalties assessed as mitigation for illegal poaching or wildlife kills that result from environmental contamination (e.g., New Mexico state statute 17.2.26; Idaho state statute 36-1404). In many cases, civil values for trophy wildlife greatly exceed the minimal civil values established. Table 4 provides sample civil values assessed as penalties for illegal take of game species in western states.

Table 4. Range of civil penalties assessed for the illegal take of wildlife.

Species	Range of civil values US$	Weighted average US$
Mule deer	250 - 450	350
Pronghorn	250 - 450	400
Bighorn sheep	700 - 2000	1,312
Wild turkey	150 - 250	183
Upland game birds	10 - 50	26

Values for threatened or endangered species have been judged "incalculable" (*Tennessee Valley Authority vs. Hill*, US Supreme Court 1978). Nonetheless, estimates of minimum value can be calculated from the funds expended for restoration. These include the costs of captive breeding projects, refuge expenditures for the protection of the species, and funds spent by the public on mitigation projects. When these costs are divided by the number of individuals in a threatened or endangered population, a conservative cost of these wildlife species can be computed. Table 5 lists 1995 expenditures for several endangered species, the population size of each species, and the estimated value of each individual animal.

Table 5. 1995 expenditures for several endangered species, the population size of each species, and the estimated value of each individual animal.

Species	Expenditures in 1995 US$	No. individuals in the wild*	Value of each US$
Black-footed ferret	2,913,220	100	29,132
San Joaquin kit fox	739,960	6,000	123
Utah prairie dog	87,320	2,500	35
Red wolf	1,013,800	80	12,672
MS sandhill crane	148,200	115	1,289

* Estimates for some species may be unreliable, but we attempted to err on the high side to provide a minimum value per individual.

[5] The Jahnke et al. (1987) multiplier is included for illustrative purposes to highlight the potential effect of predator losses on rural economies.

Costs and Benefits of Wildlife Protection

Predation management actions are implemented when ungulate fawn mortality to predators is high, or in some cases, as part of restoration efforts when predation threatens project success. In general, predation on adult ungulates does not significantly affect populations even though healthy young animals as well as the sick and old are routinely killed (Gese and Grothe 1995).

Management to improve fawn survival. – Both mule deer (*Odocoileus hemionus*) and pronghorn (*Antelocapra americanus*) fawn survival can be increased by management actions that decrease predation by coyotes (Knowlton 1976, Hailey 1979). For the latter, predation of unprotected fawns can approach 90% although factors such as alternative prey, age structure of the coyote population and synchrony of fawning all play a role (Byers 1997, Dunbar et al. 1999).

When predation management programs are implemented, pronghorn fawn survival and the recruitment of young individuals into the adult population can increase dramatically. Smith et al. (1986) noted that predation management could result in 100% annual increases in population size. In general, management activities that remove coyotes after breeding territories are established but prior to fawning can double fawning success.

Similarly, mule deer fawn survival can be increased when coyote populations are seasonally suppressed in fawning habitat. In Utah, coyote predation management was applied to deer hunt units where populations were depressed (<50% of herd objectives specified by the Utah Department of Wildlife Resources), fawn recruitment was low (<50 fawns:100 does) and the population trend was stable to declining (Utah Division of Wildlife Resources 1996). In 1 such unit, fawn survival increased from 9% to 42% when predation management was implemented. In another, fawn survival increased from 30.75 fawns:100 does to 51:100. In a third, fawn survival increased from 50:100 to 64:100 as a result of coyote management efforts.

Management to protect endangered species. – Bighorn sheep (*Ovis canadensis*) are affected by lions throughout their range. In California, lion predation has resulted in the emergency listing of this species to allow for lion predation management. Restoration of bighorn sheep in Utah has been limited by lion predation, and removal of lions is believed to be instrumental in the success of restored populations (Utah Division of Wildlife Resources 1996).

Black-footed ferret (*Mustela nigripes*) populations are severely impacted by coyote predation, especially following restoration efforts (Utah Division of Wildlife Resources 1995). In studies of restoration success in South Dakota, 30-day survival rates averaged 31% in the absence of predation management, but 67.5% with predation management in place. Based upon an introduction of 50 ferrets, the difference in survival with and without predation management, and using an average individual value of US$29,132 (Table 5), 18 ferrets would be saved with predation management producing US$524,376 in financial benefit. Perhaps more significantly, since nearly all of the ferret survival occurred in the presence of predation management, the success of the entire restoration effort arguably could be said to hinge on the application of this one management tool.

Management to protect upland birds and nesting waterfowl. – Upland game bird populations may be affected by predation, including direct predation of chicks and adults as well as nest predation. Again, while predation may be a natural phenomenon, several species have been shown to be negatively impacted. In 1 population of sage grouse in Utah, annual adult mortality due to predation (primarily non-native red fox) was 82% without fox control in place while only 33% with fox control (Bunnell and Flinders 1999). Grouse nests are also predated upon. Ten of 19 (53%) sage grouse nests on the Parker Mountain in Utah were destroyed by ravens (T. A. Messmer, personal communication). In an artificial nest predation study in an Idaho sage grouse habitat, 28% of the nests placed in a predator control area were destroyed while 98% were destroyed in an adjacent no control area (Collinge and Maycock 2000).

In 2 study sites in southern Utah, pheasant (*Phasianus colchicus*) populations doubled in treatment (predator removal) areas relative to nearby no-treatment areas. In northern Utah, a similar study increased pheasant populations in areas with good pheasant habitat, but an overall increase was not noted (Frey et al. 2000). The conditional nature of the northern Utah result was attributed to the small size of the study plots involved, and the amount of pheasant habitat available for treatment.

Production by nesting waterfowl also can be improved by predation management. Adult survival during the nesting season also can be improved. Red fox alone are reported to kill 18% of the nesting hen mallards in North Dakota annually and kill an estimated 900,000 adult ducks (predominantly hens) each year in the prairie pothole region. In a predator removal demonstration project, nest success in the treatment (predator removal) site was 71% while nest success on the no-treatment site was 14%. The difference was compounded by the treatment site containing 166% more nests than the no-treatment site, which could indicate that predation management can lead to increased productivity due to nest site selection by duck pairs as well as decreasing actual predation. Numerically, 178 nests successfully hatched on the treatment site, compared to only 21 nests on the no-treatment site, an 847% increase in total nest productivity. Cost for the treatment was US$2/acre, assuming the benefits extended only to the treatment site itself. If the benefit of predator removal extended outside of the treatment area 2 miles, costs dropped to US$0.48/acre (Jones 1994).

Case Studies of Big Game Protection

The present discussion focuses on the cost of conventional predation management and the effect applications of these methods have on wildlife numbers. Much of the best available data have been generated in Utah; a series of case studies is presented below. Each of the areas discussed is a big game management unit that was selected by the Utah Division of Wildlife Resources for predation management activity. Selection highlights an important caveat that, although previously stated, is worth reiteration here. Specifically, the timing of predation management, habitat characteristics, game abundance relative to carrying capacity, and a variety of other factors can and do influence game populations. Like any wildlife management tool, managers must select methods carefully so that the critical features limiting recruitment are addressed.

Henry Mountains mule deer. – Using aerial hunting of coyotes from fixed and rotary wing aircraft and coyote removals by ground personnel, the cost of fawn protection from coyotes was US$6.96 per square mile treated in 1997 and US$8.69 per square mile in 1998. Overall, the cumulative cost for 2 years of fawn protection in this unit was US$15,841. Recruitment was improved substantially; herd size increased by 600 animals, reversing a 5-year decline (Bodenchuk 1999). The civil value assigned to mule deer is US$300. Accordingly, the net benefit for 2 years work was US$180,000, permitting calculation of a benefit:cost ratio of 11.4:1.

Bookcliffs mule deer. – Intensive aerial hunting of coyotes on fawning grounds cost US$11,100 in 1997, or US$66.87 per square mile. Recruitment improved substantially, and herd size increased by 667 animals (Bodenchuk 1999). Accordingly, the net benefit was US$200,100. The benefit:cost ratio for this project area was 18:1.

Pahvant mule deer. – Using aerial hunting and coyote removals by ground personnel, three years of deer fawn protection cost US$27,480 and resulted in an estimated increase of 2,073 fawns worth US$621,900 (Bodenchuk 1999). The benefit:cost ratio of this project was 22.6:1.

Pronghorn. – Pronghorn protection has been extensively evaluated (much more so than mule deer) and is nearly always considered to be cost beneficial. For example, Smith et al. (1986) evaluated the benefit: cost of predation management using the cost of pronghorn permits plus estimated hunter expenditures. A management schedule that involved the removal of territorial coyotes every other year yielded the greatest return, a benefit:cost ratio of 1.92:1. Depending on herd size, Smith et al. (1986) argued that benefits in the range of between 2:1 and 3:1 could be expected.

Overall, then, the range of benefit:cost ratios for predation management to protect wildlife ranged between 2:1 and 22.6:1. In FY 1998, Wildlife Services programs in the western region spent US$2,936,068 (federal and cooperative combined) on this activity. Accordingly, the benefits of Wildlife Services predation management to protect wildlife ranged between US$5,872,136 and US$66,355,137.

Incidental Benefits of Predation Management for Livestock Protection to Wildlife

The examples above lead to the conclusion that predation management can be a beneficial wildlife management tool when selectively and strategically applied. Since wildlife in crisis often co-exist with livestock in many areas of the West, predation management for livestock protection may have significant consequences for wildlife species in the treatment areas. The degree of incidental benefit may depend on the timing and intensity of management efforts. Several case studies follow to illustrate this point.

In Utah, 5 deer management units received intensive coyote control for domestic sheep grazing on summer range (fawning range for the deer). Despite a severe winter loss in 1992-93, these units averaged 74.4% of the Utah Division of Wildlife Resource's deer herd objective in 1995, an average increase in herd size of 6.4% over 1994 numbers. Three other deer management units received intensive coyote control for winter sheep grazing (winter range for the deer herd) and in 1995 averaged 50.3% of the objective and were increased at an average of 2.3% over 1994 numbers. Finally, 9 deer units received no predation management efforts by WS during the period. These units averaged 39.7% of the objective and were decreased at an average of 1.1% from 1994 numbers.

In Texas, intensive coyote control for sheep and goat protection may be one cause of high deer survival and densities on the Edwards Plateau. Whether these densities are biologically good or bad depends on the degree to which deer management is concurrently applied. Unchecked deer populations overuse the available forage and that in turn may argue against predation management in certain areas. This final point highlights the fact that predation management can have negative effects on other species of wildlife (Kie et al. 1979).

HUMAN HEALTH AND SAFETY

Predation management can decrease the risk of attacks and disease transmission from coyotes. Management for these purposes, regardless of the species involved, invariably receives strong support from the public (Manfredo et al. 1998, Reiter et al. 1999). Although the likelihood of a human being attacked or killed by a coyote is low, the annual number of attacks is higher for coyotes than most large mammals, such as bears (Carbyn 1989, Conover et al. 1995). Although there are no national statistics for coyotes, on average they attack 1.3 people each year in Los Angeles, California alone (Howell 1982). More commonly, coyotes attack domestic cats or dogs. This represents an additional loss and the potential for disease transmission.

Rabies is the most prevalent disease for which coyotes are vectors. Predation management programs are critical for the management of this disease, and management activities have had marked effects on the potential incidence of this disease. In particular, Texas has had an extensive rabies control program since 1995 (Finley 1998). The number of post-exposure vaccinations for coyote rabies in South Texas has declined from 166 reported in 1994 to 8 in 1999, and zero during 2000 (Fearneyhough, personal communication). The current cost for the post-exposure series of rabies antibody injections is US$960.00 per series. In addition, rabid coyotes bite livestock resulting in transmission of the disease. The prevalence of canine rabies in livestock is poorly documented; however, in Mexico, where numbers of cases are routinely recorded > 2,300 cattle were killed by wildlife rabies in a recent outbreak (Associated Press, 2000).

WS management activities for human health protection generally occur before human lives are lost, and not taking action is never a legally or morally available option. We think it is sufficient to argue that the medical and social costs of predator management are as easily justified as management programs to control other wildlife-vectored diseases that could significantly affect human populations (e.g., West Nile Virus, plague, etc.).

GENERAL DISCUSSION

Predation management is controversial, and its implementation is sometimes unpleasant, especially when compared with positive management actions such as habitat restoration (Hecht and Nickerson 1999). In the past, debate has focused on the choice of methods, whether or not toxicants should be used, and other issues connected by a greater or lesser degree to biological considerations (Leopold et al. 1964, Cain 1972, Wagner 1988). More recently, however, the debate has focused less on issues of ecological harm or humaneness of method, and more on questions concerning the economics of predation management. Critics have charged that costs exceed benefits and that federal funds are being spent to subsidize a small number of livestock producers.

Instead, our review of the available evidence suggests that livestock protection activities are economical, with benefit:cost ratios ranging from 3:1 to 27:1. Likewise, predation management activities to protect wildlife show benefit:cost ratios ranging from 2:1 to 22:1. Activities performed to protect human health and safety undoubtedly show the greatest return on investment, although they are perhaps impossible to quantify.

It is important to note that the present discussion has focused on the application of nonlethal and lethal methods by WS personnel and the use of nonlethal (indirect) methods by others, mainly livestock producers. In the future, additional nonlethal methods are increasingly likely to be considered for application by WS personnel. These alternatives may be considerably more expensive than current lethal strategies (Knowlton et al. 1999, Bromley 2000). Accordingly, benefit:cost ratios for predation management will likely decline with increasing costs of management (Fall and Jackson 1998). Whether or not these ratios diminish sufficiently to warrant concern may be one of the factors to consider when deciding if alternative methods can be practically implemented and for what purposes (e.g., livestock protection versus protection of threatened and endangered species).

Overall, we conclude that properly applied predation management, shows large benefits in comparison with the costs incurred. Benefits may be even more substantial when only the federal contribution to these activities is considered. For these reasons, we encourage biologists to apply their training and best instincts to the art of management. This requires courage and conviction as well as understanding, for as others have noted before us:

> "Opponents of predator management often sensationalize it. For many wildlife biologists and wildlands managers, especially those working in close proximity to urban and suburban communities, predator management frequently alienates customary supporters. The fact remains, however, that predation is a critical threat to many threatened, endangered, and locally rare species. Willingness of land managers to implement predator management, sometimes including lethal removal, may be the make-or-break factor that determines whether all other protection efforts for some vulnerable species will ultimately succeed or fail (Hecht and Nickerson 1999)."

ACKNOWLEDGMENTS

We would like to thank USDA economists Alice Wywialowski and Janet Grimes, Utah State University economist Nicole Haynes, Michael Fall and several anonymous reviewers for providing editorial suggestions and comments on earlier manuscript drafts.

LITERATURE CITED

Associated Press. 2000. Vampire bats plague Mexican livestock; rabies cases soar. Livestock Weekly: April 2000.

Bodenchuk, M. J. 1999. Cost-effectiveness letter to Utah Division of Wildlife Resources, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services, Utah State Office. Salt Lake City, Utah, USA.

Bromley, C. 2000. Sterilization as a method of reducing coyote predation on domestic sheep. Thesis, Utah State University, Logan, USA.

Bunnell, K. D., and J. T. Flinders. 1999. Restoration of sage grouse in Strawberry Valley, UT 1998-99. Report to Utah Reclamation Mitigation and Conservation Commission, Brigham Young University, Provo, Utah, USA.

Byers, J. A. 1997. American pronghorn. University of Chicago Press, Chicago, Illinois, USA.

Caine, S. A., J. A. Kadlec, D. L. Allen, R. A. Cooley, M. C. Hornocker, A. S. Leopold, and F. H. Wagner. 1972. Predator control 1971/Report to the Council on Environmental Quality and the Department of the Interior by the Advisory Committee on Predator Control. Council on Environmental Quality and the U.S. Department of the Interior, Washington, D.C., USA.

Carbyn, L. N. 1989. Coyote attacks on children in western North America. Wildlife Society Bulletin 17(4):444-446.

Collinge, M. D., and C. L. Maycock. 2000. Artificial nest study to assess potential threats to sage grouse in Owyhee County and to assess potential benefits of predator control. USDA-APHIS-Wildlife Services Project Report, Idaho State Wildlife Services office, Boise, Idaho, USA.

Connolly, G. E. 1992a. Coyote damage to livestock and other resources. Pages 161-169 *in* A. H. Boer, editor. Ecology and management of the eastern coyote. University of New Brunswick, Fredrickton, Canada.

Connolly, G. E. 1992b. Sheep and goat losses to predators in the United States. Proceedings of the Eastern Wildlife Damage Control Conference 5:75-82.

Conover, M. R., W. C. Pitt, K. K. Kessler, T. J. Dubow, and W. A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildlife Society Bulletin 23(3): 407-414.

DeLorenzo, D. G., and V. W. Howard, jr. 1976. Evaluation of sheep losses on a range lambing operation without predator control in southeastern New Mexico. Final report to the U.S. Fish and Wildlife Service, Denver Wildlife Research Center. New Mexico State University, Las Cruces, USA.

Dunbar, M. R, R. Velarde, M. A. Gregg, and M. Bray. 1999. Health evaluation of a pronghorn antelope population in Oregon. Journal of Wildlife Diseases 35:496-510.

Errington, P. L. 1967. Of predation and life. Iowa State University Press, Ames, USA.

Fall, M. W., and W. B. Jackson. 1998. A new vertebrate pest control? An introduction. International Biodeterioration and Biodegradation 42:85-91.

Finley, D. 1998. Mad dogs: The new rabies plague. Texas A&M University Press, College Station, USA.

Frey, S. N., M. R. Conover, and T. A. Messmer. 2000. Pheasant recruitment study final report. Jack H. Berryman Institute, Department of Fisheries and Wildlife, Utah State University, Logan, USA.

Gese, E. M., and S. Grothe. 1995. Analysis of coyote predation on deer and elk during winter in Yellowstone National Park, Wyoming. American Midland Naturalist 133:36-43.

Guthery, F. S., and S. L. Bessom. 1978. Effects of predator control on Angora goat survival in South Texas. Journal of Range Management 31:168-173.

Hailey, T. L. 1979. A handbook for pronghorn antelope management in Texas. FA Report Series No. 20, Texas Parks and Wildlife Department, Austin, USA.

Hecht, A., and P. R. Nickerson. 1999. The need for predator management in conservation of some vulnerable species. Endangered Species Update 16:114-118.

Henne, D. R. 1977. Domestic sheep mortality on a western Montana ranch. Pages 133-149 *in* R. L. Phillips and C. Jonkel, editors. Proceedings of the 1975 Predator Symposium. Forest Conservation Experiment Station, University of Montana, Missoula, USA.

Howell, R. 1982. The urban coyote problem in Los Angeles County. Proceedings of the Vertebrate Pest Conference 10:21-22.

Jahnke, L., C. Philips, S. H. Anderson, and L. L. McDonald. 1987. A methodology for identifying sources of indirect costs of predation control: a study of Wyoming sheep producers. Pages 159-169, *in* S. A. Shumake and R. W. Bullard, editors. Vertebrate Pest Control and Management Materials. Volume 5. ASTM STP 974, American Society for Testing and Materials, Philadelphia, Pennsylvania, USA.

Jones, L. 1994. Background, summary and press release on Delta Waterfowl's Pilot Predator Research Project. Delta Waterfowl, Bismarck, North Dakota, USA.

Kie, J. G., M. White, and F. F. Knowlton. 1979. Effects of coyote predation on population dynamics of white-tailed deer. Pages 65-82 *in* D. L. Drawe, editor. Proceedings of the First Welder Wildlife Symposium, Corpus Christi, Texas, USA.

Knowlton, F. F. 1976. Potential influence of coyotes on mule deer populations. Pages 111-118 *in* G. W. Workman and J. B. Low, editors. Mule Deer Decline in the West: A Symposium. Utah State University and Utah Agricultural Experiment Station, Logan, USA.

Knowlton, F. F., E. M. Gese, and M. M. Jaeger. 1999 Coyote depredation control: an interface between biology and management. Journal of Range Management 52:398-412.

Leopold, A. S., S. A. Cain, C. M. Cottani, I. N. Gabrielson, and T. L. Kimball. 1964. Predator and rodent control in the United States. Transactions of the North American Wildlife and Natural Resources Conference 29:27-49.

Littauer, G. A., R. J. White, and D. C. Hall. 1986. Private costs of predator control in New Mexico in 1983. Proceedings of the Vertebrate Pest Conference 12:330-335.

Manfredo, M. J., H. C. Zinn, L. Sikorowski, and J. Jones. 1998. Public acceptance of mountain lion management: a case study of Denver, Colorado, and nearby foothills areas. Wildlife Society Bulletin 26:964-970.

Mankin, P. C., R. E. Warner, and W. L. Anderson. 1999. Wildlife and the Illinois public: a benchmark study of attitudes and perceptions. Wildlife Society Bulletin 27:465-472.

McAdoo, J. K., and D. A. Klebenow. 1978. Predation on range sheep with no predator control. Journal of Range Management 31(2): 111-114.

Mech, L. D. 1996. A new era for carnivore conservation. Wildlife Society Bulletin 24:397-401.

Menzel, K. 1992. Nebraska pronghorn fawn rates. Report provided to USDA-APHIS-WS. Nebraska Game and Parks Commission, Lincoln, USA.

Messmer, T. A. In press. Predator Management for ring-necked pheasant protection report to the Utah Division of Wildlife Resources, Utah State University, Logan, USA.

Messmer, T. A., M. W. Brunson, D. Reiter, and D-G, Hewitt. 1999. United States public attitudes regarding predators and their management to enhance avian recruitment. Wildlife Society Bulletin 27: 75-85.

Munoz, J. R. 1977. Cause of sheep mortality at the Cook Ranch, Florence, Montana, 1975-1976. Thesis, University of Montana, Missoula, USA.

Nash, R. 1967. Wilderness and the American Mind. Yale University Press, New Haven, Connecticut.

Nass, R. D. 1980. Efficacy of predator damage control programs. Proceedings of the Vertebrate Pest Conference 9:205-208.

National Agricultural Statistics Service. 1999. 1999 livestock wildlife damage survey results, U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services.

Ratnaswamy, M. J. , and R. J. Warren. 1998. Removing raccoons to protect sea turtle nests: are there implications for ecosystem management? Wildlife Society Bulletin 26:846-850.

Reiter, D. K., M. W. Brunson, and R. H. Schmidt. 1999. Public attitudes towards wildlife damage management and policy. Wildlife Society Bulletin 27:746-758.

Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. Mammal Review 26:127-156.

Rubin, E. S., W. M. Boyce, M. C. Jorgensen, S. G. Torres, C. L. Hayes, C. S. O'Brien, and D. A. Jessup. 1998. Distribution and abundance of bighorn sheep in the Peninsular Ranges, California. Wildlife Society Bulletin 26:539-551.

Scrivner, J. H., and J. R. Conner. 1984. Costs and returns of Angora goat enterprises with and without coyote predation. Journal of Range Management 37:166-171.

Shelton, M., and D. Wade. 1979. Predatory losses – a serious livestock problem. Animal Industry Today. Jan-Feb: 4-9.

Smith, R. H., D. J. Neff, and N. G. Woolsey. 1986. Pronghorn response to coyote control – a benefit:cost analysis. Wildlife Society Bulletin 14:226-231.

Wagner, F. H. 1988. Predator control and the sheep industry. Regina Books, Claremont, California, USA.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services. 1996(a). Wildlife damage management in the southern Utah ADC District- Environmental Assessment. ADC Utah State Office, Salt Lake City, USA.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services. 1996(b). Wildlife damage management in the northern Utah ADC District. Environmental Assessment. ADC Utah State Office, Salt Lake City, USA.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services. 1999. Environmental assessment monitoring report. USDA-APHIS-WS, New Mexico State Office, Albuquerque, USA.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Wildlife Services. 2000. Environmental assessment monitoring report. USDA-APHIS-Wildlife Services, Utah State Office, Salt Lake City, USA.

U.S. Department of Interior. 1978. Predator damage in the West: a study of coyote management alternatives. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Utah Division of Wildlife Resources. 1995. Cooperative plan for the reintroduction and management of black-footed ferrets in Coyote Basin, Uintah County, Utah, Utah Division of Wildlife Resources, Salt Lake City, USA.

Utah Division of Wildlife Resources. 1996. Managing predatory wildlife species. Policy No. W1AG-4, Utah Division of Wildlife Resources, Salt Lake City, USA.

Wagner, F. H. 1988. Predator control and the sheep industry: the role of science in policy formation. Iowa State University Press, Ames, USA.

Wilkinson, T. 1996. Why won't ADC stop its predator war? Defenders 71:6-13.

Windberg, L. A., F. F. Knowlton, S. M. Ebbert, and B. T. Kelly. 1997. Aspects of coyote predation on angora goats. Journal of Range Management 50(3): 226-230.