POLICY PERSPECTIVE

License to Kill: Reforming Federal Wildlife Control to Restore Biodiversity and Ecosystem Function

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Abstract

For more than 100 years, the US government has conducted lethal control of native wildlife, to benefit livestock producers and to enhance game populations, especially in the western states. Since 2000, Wildlife Services (WS), an agency of the US Department of Agriculture, has killed 2 million native mammals, predominantly 20 species of carnivores, beavers, and several species of ground-dwelling squirrels, but also many nontarget species. Many are important species in their native ecosystems (e.g., ecosystem engineers such as prairie dogs and beavers, and apex predators such as gray wolves). Reducing their populations, locally or globally, risks cascading negative consequences including impoverishment of biodiversity, loss of resilience to biotic invasions, destabilization of populations at lower trophic levels, and loss of many ecosystem services that benefit human society directly and indirectly. Lethal predator control is not effective at reducing depredation in the long term. Instead, we recommend that WS and its government partners involved in wildlife conflict management emphasize training livestock producers in methods of nonlethal control, with sparing use of lethal control by methods that are species-specific, and cease all lethal control in federal wilderness areas and for the purpose of enhancing populations of common game species.

Introduction

Utilitarian valuation of wildlife—including large carnivores—in Western societies increasingly is being replaced with noncommodity valuation (Schwartz *et al.* 2003; Treves & Karanth 2003; Loomis 2012). In the United States, this has led to growing public support for preservation of our diverse native fauna and naturally functioning native ecosystems, particularly in the larger landscapes of western public lands (Bengtson *et al.* 1999). More than 70 million Americans spend $55 billion and generate over $100 billion in total economic activity on nonconsumptive uses of wildlife in native habitats, especially on federal public lands (Leonard 2008; USFWS 2012a).

At the same time, leading ecologists have concluded that many of the world's pandemics, irruptions of undesirable species and collapses of desirable ones, and destabilization of ecosystems, resulting in lost ecosystem services, have been caused by the loss of apex predators (Estes *et al.* 2011) and of important small native herbivores (Delibes-Mateos *et al.* 2011). Still, the US government spends tens of millions of dollars annually killing predators and other mammals and birds that private agribusiness regards as pests (WS 2012a).

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Table 1 Federally threatened (T), endangered (E), and ESA petitioned (P)[a] mammals killed by Wildlife Services (1990–2011)

Species	States Where Killed	Year (# Killed)	TOTAL
NRM gray wolf (*Canis lupus*) (E)[b]	ID, MT, WY	1996 (6), 1997 (10), 1998 (15), 1999 (16), 2000 (25), 2001 (13), 2002 (42), 2003 (49), 2004 (75), 2005 (77), 2006 (129), 2007 (178), 2008 (210), 2009 (255), 2010 (262), 2011 (154)	**1,516**
Western Great Lakes gray wolf (*Canis lupus*) (T)[c]	MI, MN, WI, ND	1990 (94), 1991 (70), 1992 (114), 1993 (141), 1994 (165), 1995 (85), 1996 (134), 1997 (212), 1998 (168), 1999 (157), 2000 (149), 2001 (105), 2002 (152), 2003 (138), 2004 (115), 2005 (175), 2006 (149), 2007 (162), 2008 (186), 2009 (223), 2010 (190), 2011 (211)	**3,295**
Mexican gray wolf (*C. lupus baileyi*) (E)	AZ, NM	2004 (1), 2005 (1), 2006(3), 2007 (4)	**9**
Island gray fox (*Urocyon littoralis*) (E)[d,e]	CA	1990 (2), 1998 (2), 1999 (13)	**17**
San Joaquin kit fox (*Vulpes macrotis mutica*) (E)[f]	CA	1990 (1)	**1**
Louisiana black bear (*Ursus americanus luteolus*) (T)	LA	1990 (2), 1995 (1), 1999 (2), 2002 (1)	**6**
Grizzly bear (*Ursus arctos horribilis*) (T)	MT, WY	1990 (9), 1997 (1), 1999 (2), 2000 (1), 2001 (1), 2002 (2), 2003 (3), 2005 (2), 2010 (2)	**23**
Canada lynx (*Lynx canadensis*) (T)	UT	1990 (1)	**1**
Wolverine (*Gulo gulo*) (P)	ID	2010 (1)	**1**
Black-tailed prairie dog (P) (*Cynomys ludovicianus*)	CO, KS, ND, NE, NM, MT, OK, TX, WY	1990 (54), 1991 (354), 1992 (408), 1993 (220), 1994 (256), 1995 (391), 1996 (1,302), 1997 (696), 1998 (833), 1999 (321), 2000 (43), 2001 (19), 2002 (337), 2003 (52), 2004 (53), 2005 (88), 2006 (961), 2007 (1,132), 2008 (3,537), 2009 (10,533), 2010 (20,515), 2011 (16,277)	**58,382**
Black-tailed prairie dog- Burrow/Den[g] (P) (*Cynomys ludovicianus*)	CO, NE, OK, WY	2007 (18), 2008 (12), 2009 (13,252), 2010 (24,204), 2011(15,821)	**53,307**
Gunnison's prairie dog (P) (*Cynomys gunnisoni*)	AZ[h], CO, NM	1996 (57), 1997 (16), 1998 (108), 1999 (101), 2000 (755), 2001 (58), 2005 (30), 2006 (259), 2007 (11), 2008 (72), 2009 (387), 2010 (394), 2011 (808)	**3,056**
Gunnison's prairie dog- Burrow/Den[g] (P) (*Cynomys gunnisoni*)	CO	2009 (625), 2010 (5,918), 2011 (4,775)	**11,318**
White-tailed prairie dog (P) (*Cynomys leucurus*)	CO, NM, UT, WY	1996 (4), 1997 (120), 1999 (72), 2001 (1), 2004 (2022), 2005 (3), 2006 (317), 2007 (94)	
		2008 (116), 2009 (1,694), 2010 (1), 2011 (4)	**4,448**
White-tailed prairie dog- Burrow/Den[g] (P) (*Cynomys leucurus*)	CO	2009 (1,950), 2010 (59), 2011 (4)	**2,013**

[a]Four species were candidates for ESA listing as either T or E at some time during the period, following citizen petitions to the US Fish and Wildlife Service (USFWS); of these, wolverine in its entire range and Gunnison's prairie dog in parts of CO and NM were found by USFWS to be warranted for listing but precluded by higher priority species; subsequently and as of this writing USFWS, under court order, is reevaluating the entire Gunnison's prairie dog species for listing; black-tailed prairie dog and white-tailed prairie dog were found not warranted for listing in 2009 and 2010, respectively; [b]NRM gray wolf was reintroduced in 1995 and 1996 and then designated under the ESA as a nonessential experimental population; listed as T in ID and MT, and E in WY; the ID and MT wolves were delisted in 2011; [c]Western Great Lakes gray wolf was listed as T in MN and E in MI and WI; delisted in Mar 2007, reversed in Sept 2008, delisted again in Jan 2012; [d]four of six subspecies listed as Endangered under the ESA; IUCN lists entire species as critically endangered; increased take in 1999 partly due to depredation on endangered shrike *Lanius ludovicianus anthonyi;* [e]lumped into "gray foxes" by WS since 2000; [f]lumped into "kit foxes" by WS since 2000; [g]listed as "Removed/Destroyed" by WS; [h]listed as "Prairie-Dog, z-(Other)" by Wildlife Services, included in Gunnison's category here based on geographic range of *Cynomys* in Arizona.

With 10 name changes and several department transfers during its 126-year legacy of animal control, the stated purpose of Wildlife Services (WS, an agency of the US Department of Agriculture's [USDA] Animal and Plant Health Inspection Services [APHIS]) is "to provide Federal leadership and expertise to resolve wildlife conflicts to allow people and wildlife to coexist" and more specifically to "apply the integrated wildlife damage management (WDM) approach to provide technical assistance and direct management operations" (WS 2012a). Yet, since 2000, WS has killed—intentionally and unintentionally—2 million native mammals (WS 2012a), including 12 taxa of federally endangered, threatened or "candidate" mammals (Table 1), numerous state-protected mammals (Table 2), and 15 million native birds including—unintentionally—protected golden eagles (*Aquila chrysaetos*) and bald eagles (*Haliaeetus leucocephalus*) (Knudson 2012a; WS 2012a; WS unpubl. data); WS unintentionally killed an endangered California condor (*Gymnogyps californianus*) in 1983 (US Congress

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Table 2 State-listed threatened (T), endangered (E), and special concern (SC) mammals killed by Wildlife Services (1996–2011)[a]

Species	State	Status	Year (# taken)	TOTAL
Swift fox (*Vulpes velox*)	CO	SC	1998 (6)[b], 2001 (1), 2003 (4), 2005 (2), 2006 (6), 2010 (3)	**22**
	NE	E	2008 (2)	**2**
	WY	SC	1999(1), 2001 (1), 2002 (2), 2004 (6), 2005 (2)[c], 2006 (3), 2007 (6), 2008 (12), 2009 (5), 2010 (8), 2011 (8)	**54**
Kit fox (*Vulpes macrotis*)	UT	SC	1996 (5)[b], 1997 (4)[b], 1998 (3)[b], 1999 (4), 2000 (4), 2001 (1), 2003 (14), 2004 (3), 2005 (29), 2007 (2)	**69**
River otter (*Lontra canadensis*)	CO	T	2003 (1)	**1**
	IL	T[d]	2002 (1), 2005 (3), 2006 (4), 2007 (6)	**14**
	NE	T	2009 (1)	**1**
Black-tailed prairie dog[c] (*Cynomys ludovicianus*)	CO	SC	2000 (1), 2005 (4), 2006 (918), 2007 (1,108), 2008 (3,520), 2009 (6,042), 2010 (14,029), 2011 (8,906)	**34,258**
	MT	SC	2002 (200), 2003 (5), 2004 (3), 2009 (20), 2010 (29)	**257**
White-tailed prairie dog[c] (*Cynomys leucurus*)	UT	SC	1996 (4)[b], 1997 (120)[b], 1999 (72), 2005 (1), 2006 (317), 2007 (94), 2008 (100), 2009 (1,625)	**2,333**

[a]Reported take by WS was unintentional (nontarget) unless otherwise indicated; [b]intention of take unknown; [c]take was intentional; [d]delisted in September 2004.

1992). Vertebrates of 150 species have been killed unintentionally by WS since 2000 (Knudson 2012a; WS 2012a) by nonselective control methods including snares, leghold traps, poison-laced bait, baited explosive cyanide cartridges (M44s), and gassing of burrows and dens (Knudson 2012a; WS 2012a).

WS's National Wildlife Research Center (NWRC) conducts important research in nonlethal control, but those methods NWRC concludes are effective rarely are adopted by WS field operations, particularly on livestock grazing allotments in the West, which are heavily biased toward lethal control (GAO 1995; Niemeyer 2010); WS claims it *cannot* determine what proportion of its WDM expenditures go toward nonlethal methods (WS 2012b).

WS conducts little or no population monitoring of lethally controlled mammals nor of their alternate natural prey, no studies of whether WS control is additive with other causes of mortality, and no studies of how control affects populations of nontarget species that are unintentionally killed. Moreover, WS operations have never been the subject of an independent cost-benefit analysis, and their internal economic analyses do not adhere to guidelines used by most federal agencies, nor do they consider lost ecological or economic values of the predators themselves (Loomis 2012). In this policy perspective, we argue that the federal government's ongoing and century-old program of widespread lethal control of western predators, and of other keystone species such as prairie dogs (*Cynomys* spp.), requires cost-benefit analysis-driven reform in order to represent broader societal interests, restore biodiversity and ecosystem function, and align with current scientific knowledge on wildlife control.

The western United States possesses numerous large national parks, roughly 300 million acres of national forests and grasslands and federal public range lands, and 50 million acres of designated wilderness (Vincent 2004). Presettlement biodiversity and trophic relationships still can be represented on these significant land areas (Bailey *et al.* 1928; USDI BLM 1997). Unfortunately, many of these lands are overgrazed by livestock and by native ungulates whose predators have been depleted (Beschta *et al.* 2013). Simultaneously restoring apex predators and retiring livestock grazing on these lands hold promise for restoring western ecosystems and mitigating the likely effects of climate change (Beschta *et al.* 2013), but such restoration is inhibited in part by a legacy of predator and rodent control on these lands (GAO 1995; Estes *et al.* 2011; Davidson *et al.* 2012).

Evolution and environmental legacy of a federal wildlife control agency

Coincident with 3 million European families settling the western United States from 1865 to 1890 (Turner 1935), tens of millions of bison (*Bison bison*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and pronghorn (*Antilocapra americana*) that had populated the region were dramatically depleted by unregulated hunting, with bison nearly driven to extinction and largely replaced by domestic livestock (Isenberg 2000). Yet, mammalian carnivore populations retained much of their presettlement abundance (Kay 2007). Wolf and coyote (*C. latrans*) populations briefly thrived on bison carcasses littering the Plains; then, following the decline in their prey, these

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predators increasingly targeted domestic livestock, which elicited a campaign of large-scale predator extermination (Isenberg 2000; Robinson 2005).

After state and private bounties on predators became unreliable around 1900, livestock interests lobbied successfully for direct federal involvement in predator eradication, which began as a collaboration between USDA's Forest Service and Bureau of the Biological Survey (BBS) in the early 1900s and received direct congressional funding in 1915 (Hawthorne *et al.* 1999). Federal control of nuisance rodents soon followed, and, by 1939, government and western livestock interests cooperatively funded the Division of Predatory Animal and Rodent Control (PARC) under BBS at >$1 million (Cain *et al*. 1972; McIntyre 1982 *in* Feldman 2007).

Mass extermination of wolves and coyotes across the western United States began in the early 1900s; by the 1920s, overpopulation of rabbits induced their mass culling (600,000 rabbits were killed in 1 year in Idaho by government hunters; Hawthorne *et al.* 1999). Such lethal control mentality failed to recognize herbivore irruptions as consequences of predator release (Henke & Bryant 1999), or "trophic downgrading" (Estes *et al.* 2011). Extermination of prairie dogs—perceived as competitors with domestic livestock—also began in the early 1900s. New deal relief agencies greatly bolstered BBS/PARC's control programs; by 1936, the Civilian Conservation Corps alone had poisoned 21.5 million acres of prairie dog colonies across the western United States (Robinson 2005).

Controversial from the start: historical critiques of federal wildlife control

Early 20th century conservationists criticized federal government predator-eradication programs, after the successful extirpation of grizzly bears (*Ursus arctos horribilis*) from most of their range in the western United States, and the ongoing campaign against wolves (Robinson 2005). As early critics warned, extirpation of gray wolves from the western United States by 1930 caused interruption of natural trophic cascades, which became evident following their reintroduction to Northern Rocky Mountain (NRM) ecosystems in 1995 (Bergstrom *et al.* 2009).

Poisoning of prairie dog colonies by PARC and its successor agency Animal Damage Control (ADC, under the US Department of the Interior (USDI)) was implicated in the near extinction of the black-footed ferret (*Mustela nigripes*; Cain *et al.* 1972). The American Society of Mammalogists, repeatedly from 1924 to 2012 criticized federal wildlife control programs as overly reliant on lethal measures, driven by special interests rather than science, and causing excessive mortality of nontarget species. Over many decades, prominent conservationists, three study committees appointed by USDI, and several Government Accounting Office (GAO) reports echoed these concerns (see Supporting Information). The 1931 ADC Act (7 U.S.C. § 426) remains WS's primary enabling legislation (Robinson 2005); its provision for private cooperator funding of federal wildlife control programs creates a conflict of interest in setting WS management policy (Ketcham 2008).

Lethal control and its unintended consequences continue

Despite severe population reductions and extirpation of prairie dogs across 92–98% of their original range (Miller *et al.* 2007), there has been a resurgence of lethal control by WS, with 50,613 prairie dogs killed in 2009–2011, compared to 9960 in 2000–2008 (not counting Burrow/Den; Table 1; WS 2012a). Yet, it is questionable whether livestock directly benefit from extermination of prairie dogs, whose colonies have been shown to increase nutritional content and digestibility of forage plants, and increase live-plant to dead-plant ratio, for both bison and cattle (*Bos taurus;* Davidson *et al.* 2012). The loss of most large colony complexes of prairie dogs, partly due to continued government-funded extermination programs, has had cascading effects throughout North America's central grasslands, including declines of many other animal species that depend on prairie dogs as prey and for the unique habitats they create (Davidson *et al.* 2012; Figure 1), and the invasion of shrubs into those grasslands (Weltzin *et al.* 1997; Jones 2000). The US Fish and Wildlife Service (USFWS) program to recover endangered black-footed ferrets, almost solely dependent on prairie dogs as prey, currently is hindered by lack of reintroduction sites (Davidson *et al.* 2012).

Numbers of WS's primary mammalian targets of lethal control and certain other carnivores killed annually since 2000 has remained remarkably constant (Figure 2); data in Berger (2006) indicate a similar pattern from 1939 to 1998. Without monitoring of these populations, we do not know whether this represents a constant proportional annual mortality, but it at least implies that predator control has not effected any long-term solution to the perceived problem, and it shows there is no downward trend in lethal control, despite GAO (1995) admonishments. WS officials recently admitted that relatively few ranching operations, on an estimated 5–10% of native coyote range in the West, account for a large percentage of their annual coyote kills (Clay 2012;

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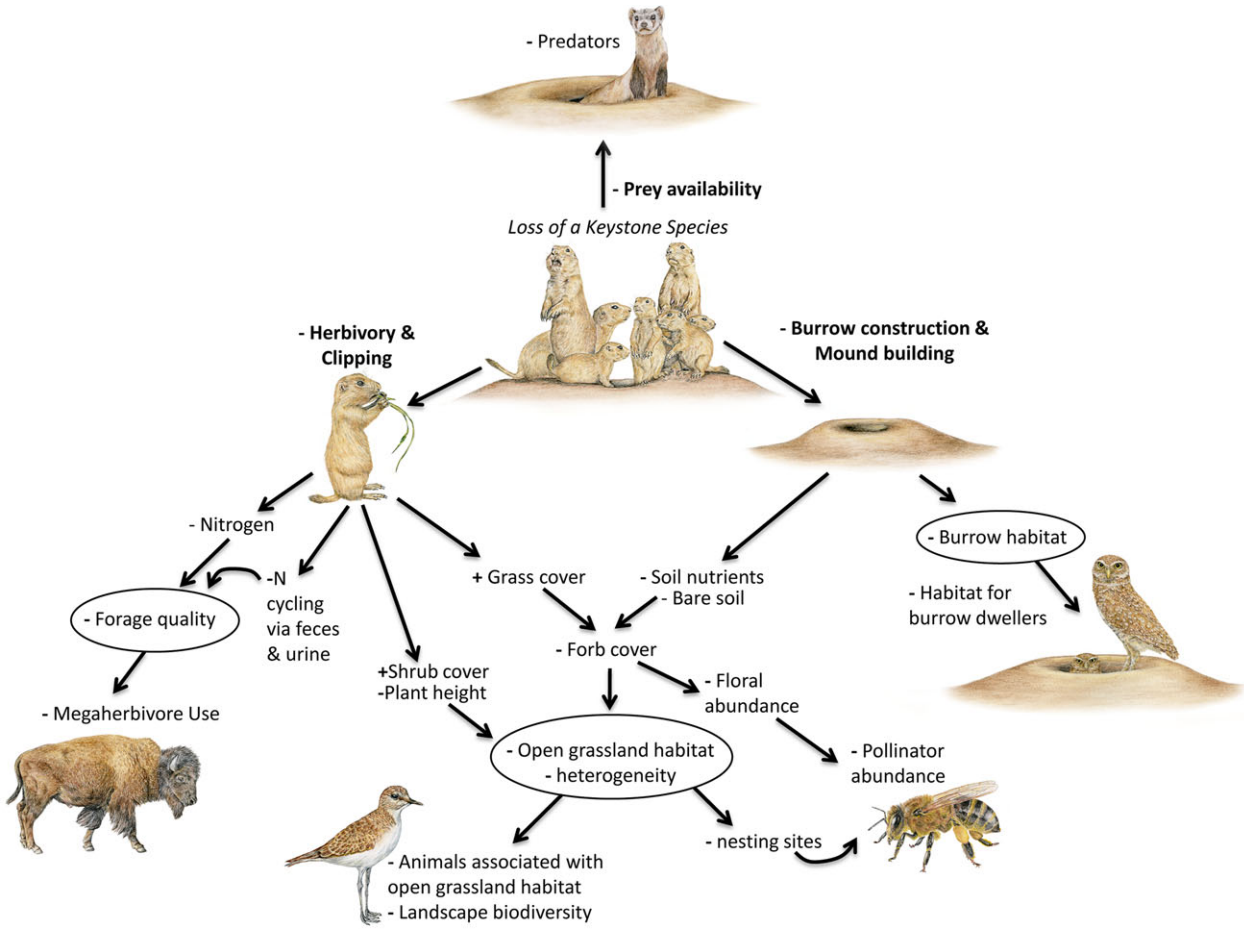

Figure 1 Conceptual diagram illustrating how the loss of a keystone species cascades throughout an ecosystem, using the black-tailed prairie dog (*Cynomys ludovicianus*) in North America's central grasslands as an example. Declines in prairie dogs result in the loss of their trophic (herbivory, prey) and ecosystem engineering (clipping, burrow construction, and mound building) effects on the grassland, with consequent declines in predators [e.g., black-footed ferrets (*Mustela nigripes*), raptors, swift and kit foxes (*Vulpes velox, V. macrotis*), coyotes (*Canis latrans*), badgers (*Taxidea taxus*)], megaherbivore activity [e.g., Bison (*Bison bison*)], invertebrate pollinators, and species that associate with the open habitats and burrows that they create [e.g., burrowing owls, (*Athene cunicularia*), mountain plovers (*Charadrius montanus*), pronghorn (*Antilocapra americana*), swift and kit foxes, cottontail rabbits (*Sylvilagus* spp.), rodents, and many species of herpetofauna and invertebrates]. Black arrows depict the effects of prairie dogs. Plus signs indicate an increase in an ecosystem property as a result of the loss of prairie dogs; minus signs indicate a decrease. Drawings are by Sharyn N. Davidson.

Knudson 2012c). State and federal managers removed 23.2% of the estimated coyote population of Wyoming in 1994–1995 (Taylor 2009). WS will not reveal exactly where coyote control occurs (WS 2012b), suggesting that localized population effects are a potential conservation concern. We acknowledge that range-wide effects likely are negligible, because coyotes have greatly expanded their range east and west during the period of WS control (Kays *et al.* 2010). Coyote removal at a local scale, however, can destabilize small-mammal communities, causing irruptions and reduced diversity (Wagner & Stoddart 1972; Henke & Bryant 1999).

Despite abundant evidence of top-down restoration of NRM ecosystems by reintroduced gray wolves (reviewed in Bergstrom *et al.* 2009), the number of wolves killed by WS has increased substantially since 2000, peaking at 480 in FY2009 (WS 2012a). Additionally, NRM wolves are now hunted in three states. Idaho and Montana killed 525 wolves—or 32% of their total population—by licensed hunting and WS control actions in 1 year, from 2009 to 2010 (Bergstrom 2011; USFWS 2012b). WS has not assessed whether their continued management kills of wolves is additive with hunting mortality and thus jeopardizes wolf recovery as a cumulative effect. Simulation modeling of NRM wolf populations indicates that this level of mortality is unsustainable, and with a likely increase in human offtake, NRM wolf populations will decline substantially (Creel & Rotella 2010).

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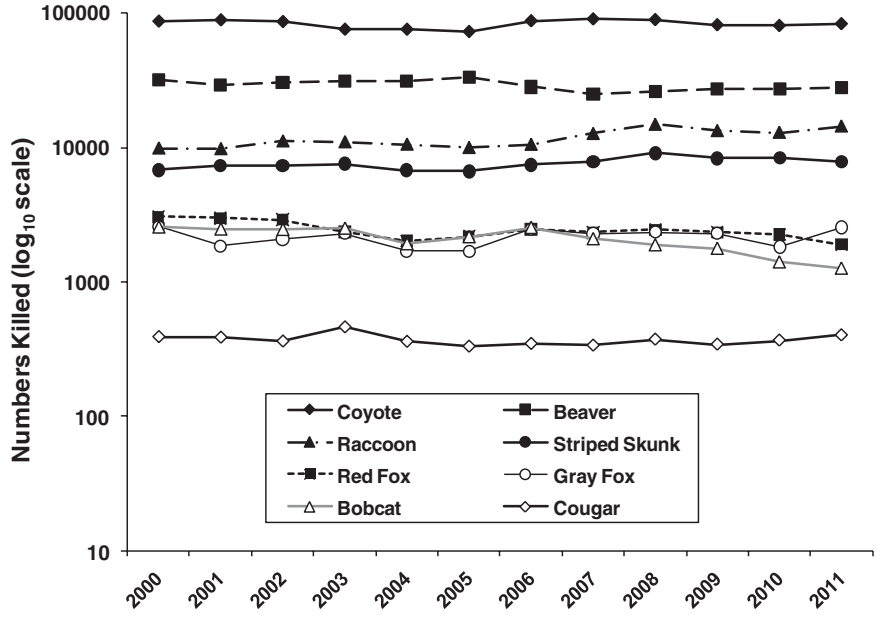

Figure 2 Numbers of the top seven species of native carnivores, plus beavers (*Castor canadensis*), killed annually by USDA-APHIS Wildlife Services from 2000 through 2011 (WS 2012a). Note: coyote (*Canis latrans*), beaver, raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*), in descending order, were the top four mammal species reported killed during the period by WS; fifth and sixth ranks, respectively, were "ground squirrels" and "prairie dogs," but several species are combined in each of those two categories.

Conversely, unmanaged populations of gray wolves in the Yellowstone ecosystem preferentially prey on old and diseased elk (Wright *et al.* 2006), so allowing wolves to establish and maintain natural pack structure could theoretically aid disease prevention in ungulate populations (Roy & Holt 2008). Reducing wolf populations increases coyote populations through "mesopredator release" and can have other unintended consequences on native ungulate populations (Berger *et al.* 2008; Prugh *et al.* 2009). For example, pronghorn fawn survival in areas with wolves was four times higher than in areas without wolves, because wolves suppressed coyotes and consequently fawn depredation (Berger *et al.* 2008). Predator control may, at least locally, decrease ecosystem resilience and lead to state shifts where invasive species become dominant (Wallach *et al.* 2010), which only increases the need for invasive control while decreasing its likelihood of success.

The legacy and legislative history of federal wildlife control reveal agriculture as its primary beneficiary, and lethal control of top carnivores and burrowing mammals such as prairie dogs particularly benefits western ranchers (see WS 2011). A relatively few influential western ranchers and major agribusiness lobbying groups, such as the American Farm Bureau, have prevented Congress from reforming WS in the past (Robinson 2005; Ketcham 2008). Nearly half of WS's annual $57 million federal allocation directly benefits already heavily taxpayer-subsidized agriculture (FY2010; WS 2012a; Ketcham 2012). This subsidy supports merely 7 million head of livestock, primarily cattle, which graze 268 million acres (>1 million km^2) of leased federal land, or 70% of the land area of 11 western states, including active allotments within 35% of the nation's wilderness areas (Fleischner 1994; 7 million head represented only 6.3% of the nation's total cattle, sheep and goats in 1994 [USDA 1999a, 1999b]). This subsidy contravenes other federal expenditures; e.g., USDI has spent over $43 million since 1974 reintroducing and conserving the gray wolf (USFWS 2011).

Cattle losses to all predators account for 5.5% of total mortality in the United States (USDA 2011) and even in the NRM wolf recovery zone, wolf predation accounts for a fraction of total predator losses (USFWS 2012b). Yet, WS increased control kills of wolves in recent years in the Wyoming recovery area, even though confirmed wolf depredations of cattle and number of packs depredating have declined steadily since 2006, while the wolf population has increased by 31% (USFWS 2012b).

In addition to increasing human-wildlife conflict, overstocking public rangelands with livestock reduces forage and habitat for small mammals (Bock *et al.* 1984; Heske & Campbell 1991) and other vertebrates (reviewed in Beschta *et al.* 2013) that are important prey of carnivores.

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Ohmart & Anderson (1986) concluded livestock grazing likely was the major factor negatively affecting wildlife populations in 11 western states. Sacks & Neal (2007) found a significant negative association between wild prey biomass and sheep predation by coyotes, suggesting that healthy and productive native small-mammal habitats act as buffers against livestock depredation by coyotes. With a declining natural prey base, predators may switch to more abundant domestic stock, prompting greater demand for lethal predator control (Knowlton *et al.* 1999). Heavy cattle grazing has significantly depressed black-tailed jackrabbit (*Lepus californicus*) density (Flinders & Hansen 1975), and when black-tailed jackrabbit populations became severely depressed, ewe and lamb depredation by coyotes increased dramatically (Stoddart *et al.* 2001).

As long as private livestock producers can externalize the costs of predator losses via government-subsidized predator control, they will have little incentive for responsible animal husbandry techniques, i.e., reduce stocking levels, clear carcasses and after-births quickly, confine herds at night or during calving/lambing, install fencing and fladry, or adopt numerous other nonlethal preventive methods to avoid depredation (Shivik *et al.* 2003). The easiest and most obvious places to reduce human-wildlife conflict are wilderness areas. As long as the practice of lethally controlling "problem animals" persists wherever livestock graze (see Linnell *et al.* 1999), livestock-free wilderness areas and national parks may provide the only refuges and source populations for most rare and endangered North American large carnivores.

Lethal wildlife control for livestock: ineffective and wasteful

In 1887, Albert Fisher, C. Hart Merriam's assistant at BBS, examined stomach contents of hawks and owls shot for $90,000 in bounties in Pennsylvania, estimating the lost value of rodent and insect control by removing these predators at $3.9 million; the direct savings in chickens was $1,875 (Robinson 2005; the federal government long ago ceased targeting avian predators for lethal control but has not altered its approach to mammalian predators). Cole (1970) estimated a 5:1 cost-benefit ratio of WS killing Arizona coyotes for livestock depredation, adding lost forage due to compensatory increases in jackrabbits to taxpayer costs for lethal control (see Wagner & Stoddart 1972; Henke & Bryant 1999).

Eradication of predators ended livestock depredation, but lethal control measures, short of eradication, appear no more effective in the long term than no lethal control at all. Three gray wolf removal studies in different decades in different areas of North America indicate that effects are short-lived, because remaining individuals and recolonizing packs just as often depredate as those removed (Treves & Naughton-Treves 2005). Coyote control usually has involved population reduction rather than selective killing (Mitchell *et al.* 2004); this can create temporary local extirpations, soon attracting immigrants that experience dramatically higher reproductive output, resulting in no long-term effect on depredation (Connolly 1978; Knowlton *et al.* 1999). Removing more than the territorial breeding pair of coyotes (which commit most depredations of sheep) from a wider zone around a depredation site may even *increase* the overall problem by allowing more breeding pairs to immigrate (Sacks *et al.* 1999). Despite considerable effort by WS at lethal coyote control in the western United States, evaluation of a 60-year data set indicated that the decline of the sheep industry in both eastern and western United States could be attributed to market trends and production costs, and that predator control (lacking in the East) did not have a significant impact on the decline (Berger 2006).

Lethal control often proceeds without certain knowledge that targeted individuals are responsible or that a depredation has occurred (as in "preventive" culling of coyotes; GAO 1990; Knudson 2012c). But the compensatory aspect of depredation control described above suggests that even highly specific lethal control methods such as poison collars (Connolly *et al.* 1978) would not be a long-term solution. Preventive, nonlethal methods, such as fencing, guard dogs, and taste aversion conditioning hold more promise for long-term reduction of depredation (Green *et al.* 1984; Gustavson & Nicholas 1987; Treves & Karanth 2003; Knudson 2012b). That the unmanaged wolf population of Yellowstone National Park has declined 40% since its peak density in 2006 and appears to have stabilized at $\leq$100 animals (Figure 3) suggests that simply ending lethal control elsewhere in the NRM could lead to, at worst, a stable rate of depredation (<5%; Bergstrom *et al.* 2009; USDA 2011), which could be decreased by aggressive application of nonlethal methods. The latest annual report for the NRM projects a declining growth rate for the wolf population as it stabilizes at a lower equilibrium in line with natural carrying capacity (USFWS 2012b). Affirming what generally is hypothesized for a territorial mammal, WS/NWRC's own research indicates that gray wolf populations are not prey-limited but rather are intrinsically density-dependent, i.e., self-regulating (Cariappa *et al.* 2011).

Even assuming scientifically supportable benefits of targeted killing of mammals by WS, 2000–2011 kill data reveal several striking examples of waste of nontarget species. Badgers are targeted in most states where they

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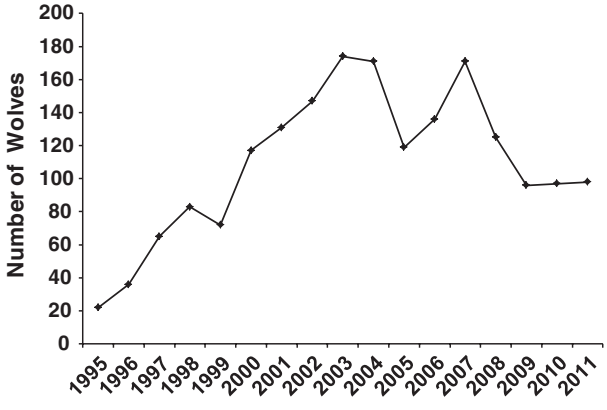

Figure 3 Annual numbers of wolves in Yellowstone National Park from initial reintroduction in 1995 and 1996 through 2011 (winter counts; data from NPS 2011; USFWS 2012b).

occur, but fully a third (>180 per year) of those killed were killed unintentionally (WS 2012a). (Hall 1930 also reported excessive nontarget killing of badgers by PARC agents). Virtually all kit foxes (*Vulpes macrotis*) and swift foxes (*V. velox*) killed (95% of 339 and 99.5% of 225, respectively) were killed unintentionally by neck snares, leghold traps, or M44s set for coyotes (WS 2012a). Ironically, swift foxes were extirpated in many areas by the 1930s as a result of nontarget mortality from federal coyote and wolf control programs (Stephens & Anderson 2005). Swift foxes were identified as the one predator ADC may have killed in FY1989 over a significant portion of its range and therefore put at risk of extinction (GAO 1990). Eighty-six percent of 82 ringtails (*Bassariscus astutus*) killed from 2000 to 2011 were killed unintentionally, as were 97.3% of 2,413 collared peccaries (*Pecari tajacu*; WS 2012a). An average of >400 river otters (*Lontra canadensis*) annually were killed unintentionally by WS, after considerable efforts by at least 21 states to reintroduce the species (Raesly 2001). Unfortunately, eyewitness accounts suggest that not all protected species unintentionally killed are being reported by WS field agents (Niemeyer 2010).

The other reason for lethal predator control

Increasing participation of WS in what was identified in its 2001 Research Needs Assessment as "the growing and expanding negative impact of predators (for example, coyotes, foxes, wolves, and raccoons) on wildlife resources (for example, deer and antelope)" highlights renewed emphasis on WS's role as promoter of particular wildlife species over others (Bruggers *et al.* 2002). This emphasis contradicts the evidence that, where apex predators have been reduced or extirpated, native ungulate populations exceed carrying capacity and are causing increasing habitat deterioration (Beschta *et al.* 2013). In its collaboration with states, WS controls wolves and other predators by aerial gunning in remote areas to reduce predation on elk (Robbins 2011; WS 2012b), especially in Idaho, despite the fact that in 2009, 26 of 29 management units in that state had elk populations at or above state management objectives (Bergstrom *et al.* 2009). Despite wolf recovery and while its aggressive wolf-reduction plan was awaiting federal approval, Wyoming had a record elk harvest in 2010 (WGFD 2013). The political power of western ranching has long been a primary determinant of WS's mammalian predator control (Robinson 2005), but conducting it for the ostensible benefit of common native game species specifically favors certain segments of the US population over others. The Wildlife Society (TWS), in its recent technical review of carnivore management, states "Although the Public Trust Doctrine for Wildlife Management clearly articulates that federal and state agencies manage wildlife for the benefit of all citizens, often the opinions of nonconsumptive users are ignored. Unbalanced information that supports the perceptions of some stakeholders over others can increase conflicts (Peek *et al.* 2012)." This seems to us to be the case when state or federal agencies conduct predator control on wilderness areas (see WS 2012b) and/or implement predator control to promote certain game species over other native wildlife. The latter arguably benefits 11.6 million people in the United States who hunt big game to the detriment of 22.5 million active wildlife watchers, whose direct expenditures are three times that of big-game hunters (USFWS 2012a). TWS goes on to say "In places where human presence and impact is minimized, wildlife populations of all species should be allowed to fluctuate with as little anthropogenic interference as possible (Peek *et al.* 2012)."

Even if enhancing wild ungulate populations were a justifiable goal, predator control is an unproven instrument for achieving it. A meta-analysis of predator-removal experiments in 113 systems found prey populations subsequently *declined* in 54 of them (Sih *et al.* 1985). In Idaho, wolf predation on elk is <10% of total elk mortality and mostly replaceable (IDFG 2007; see Wright *et al.* 2006). In a long-term, large-scale manipulative study of coyote and cougar (*Puma concolor*) removal in Idaho, the effects on mule deer abundance were marginal and short term; winter severity in the current and previous winters was the best predictor of deer population trends (Hurley *et al.* 2011). Three years of elk-calf mortality data from northern Yellowstone indicated wolves did not meet an important criterion of ability to control elk populations,

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as they were not the dominant predator on all stages of the life cycle of the prey (NRC 1997), accounting for only 14–17% of calf mortality (Barber-Meyer *et al.* 2008).

Conclusion

The continuing heavy reliance of the federal government on lethal control of native mammals is a vestige of the outmoded mentality of western expansionism, in which the goal was to "tame" the wilderness, replacing the ecosystem's primary-consumer trophic level entirely with domesticated herbivores and a few favored game species and all higher trophic levels with humans (Robinson 2005). Its survival into the 21st century defies the consensus among ecologists that significant reductions in local populations of native primary consumers and apex predators has had far-reaching consequences on primary production, nutrient flows, disease incidence, and biodiversity at all levels and at all spatial scales (Delibes-Mateos *et al.* 2011; Estes *et al.* 2011; Davidson *et al.* 2012).

Both to restore ecosystems and to serve broader societal interests in conservation, we recommend that all federal management agencies that deal with human-wildlife conflict collaborate with all stakeholders in adopting a more holistic and ecosystem-based management approach resulting in reduced reliance by WS on lethal control methods, especially on western public lands. An independent cost-benefit analysis of WS operations that includes full economic valuation of native wildlife subject to lethal control (possibly including a contingent valuation method study of public willingness to pay for predators; Loomis 2012) must be undertaken. This could include participatory intervention planning (PIP; Treves *et al.* 2009), which analyzes management options in light of cost effectiveness, sociopolitical acceptability, and species-specific efficacy. It will also necessitate that WS field operations move beyond promotion to actual implementation of "integrated WDM," in which lethal control is a last, not a first, resort. Specific measures to reduce the negative impacts of, and need for, lethal wildlife control in the western United States include: 1) retiring grazing leases on remote federal lands, especially those that are overgrazed or in wilderness areas; 2) requiring federal grazing permittees, under penalty of revocation, to employ best animal-husbandry practices fully; 3) prioritizing use of, and research and outreach on, nonlethal, preventive methods of depredation control; 4) ceasing lethal control methods that are not highly selective of the individual (and species) being targeted; 5) ending misguided efforts to enhance populations of common game species by predator control; 6) preparing an updated, peer-reviewed environmental impact statement on all WS lethal control programs, which analyzes potential direct, indirect, and cumulative effects of lethal control on populations and ecosystems in light of current science; and 7) making details of WS funding sources and budget expenditures transparent and readily available to the public.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Brief History of Expert Criticism of Federal Wildlife Control Programs

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