Wilderness Discount on Livestock Compensation Costs for Imperiled Gray Wolf *Canis lupus*

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Abstract—There is evidence that Wilderness reduces costs for livestock depredations caused by the endangered and threatened gray wolf (*Canis lupus*) in the northern Rockies and upper Midwest, U.S.A. From 1995 to 2004, direct costs for compensation in the northern Rockies came to only 47 to 78 percent of losses anticipated at wolf reintroduction and projected from non-wilderness habitat. Compensation was lowest in the wilderness-rich, central Idaho recovery area ($69/wolf/year), more than doubling in greater Yellowstone ($160/wolf/year) where private ranches commingle with extensive grazing leases on public land. Per capita compensation in northern Minnesota and Michigan was 5 percent to 14 percent of costs in wilderness-deficient northern Wisconsin ($163/wolf/year). Globally, compensation for carnivore depredations tends to be higher where wild lands are scarce, but husbandry practices and grazing subsidies confound the discount in some regions. Nevertheless, a wilderness discount reduces some costs of (and may mitigate cultural resistance to) conservation programs aimed at restoring large predators.

Predation on domestic livestock often thwarts coexistence between people and large carnivores (Espuno and others 2004; Ogada and others 2003). Those enduring losses from predators tend to retaliate, with resultant non-targeted killing acting as temporary appeasement (Mishra and others 2003) rather than long-term prevention (Linnell and others 1999; Musiani and others 2005; Stahl and others 2001). Local communities sometimes become reluctant to support extant carnivore populations, much less recovery programs to increase predator range and numbers (Breitenmoser 1998; Ericsson and Heberlein 2003; Lohr and others 1994).

Resistance to carnivores is linked with rural pastoralist and farming occupations where economic risk from lost livestock is greatest (Andersone and Ozolinš 2004; Meadow and others 2005; Skogen and Krange 2003; Williams and others 2002). Domestic livestock may form up to 87 percent of diet in certain gray wolf *Canis lupus* populations (Álvares 2004), so isolating carnivores from economic damage contributes to resolutions to the depredation problem (Treves and Karanth 2002). Wild lands present one opportunity to accomplish this objective.

Wilderness improves conservation prospects for wide-ranging carnivores (Breitenmoser 1998; Kerley and others 2002). When carnivores with large area requirements become isolated by habitat loss and fragmentation (Kramer-Schadt and others 2004), certain species come to rely on remote lands for meeting key habitat needs (Hendee and Mattson 2002; Noss and others 1996). In exceptional cases wilderness may serve as the last refuge for entire groups of predators (Mittermeir and others 2003). For yet other species, wild lands act to reduce the competition between wildlife and human interests (Wright and Garrett 2000).

Modest attention has been levied at various ecological roles wild lands play in fostering wildlife and biodiversity conservation (for example, Crist and others 2005; Hendee and Mattson 2002). In contrast, here we analyze the costs of compensating livestock losses across certain wilderness gradients in order to evaluate a cultural dimension of supporting imperiled species. We compare unit costs of livestock depredations by gray wolf: (1) within the northern Rockies, U.S.A., (2) within the upper Midwest, U.S.A., and (3) between these two North American regions and other selected global sites and carnivore species. Extent of wild lands was examined as a factor that might influence geographic variation in the per capita compensation cost for these large carnivores.

Geographic and Cultural Contexts for Wolf Predation on Livestock

By "wilderness" we refer to large, undisturbed natural areas with relatively low human population densities. For example, the northern Rockies constitute one of 24 global wilderness

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ecoregions distinguished by large minimum size (greater than 10,000 km^2 or 3,861 square miles), low human density (less than 5 people/km^2), and extensive natural habitat—at least 70 percent of historical extent (Mittermeier and others 2003). Wolf populations have increased and expanded their range within both study areas examined here (for example, fig. 1).

Northern Rockies

Wolves include populations that are both naturally colonized (northwest Montana: endangered status under the Endangered Species Act [ESA]) and deliberately reintroduced (elsewhere: non-essential experimental 10-j status under the ESA) (Bangs and others 1998). Wolves now inhabit primarily forested montane habitat in the Rockies. Extensive public land holdings (including wilderness) and abundant native ungulate prey (for example, elk *Cervus elaphus*, deer *Odocoileus hemionus* and *O. virginianus*, bison *Bison bison*, moose *Alces alces*) factored strongly into selecting this region for reintroduction (U.S. Fish and Wildlife Service 1994).

Greater Yellowstone. Land ownership in the 14.5 million ha (35,830,281 acres) greater Yellowstone recovery area is mostly federal public (60 percent) versus about one-third private (31 percent). In the center is the 1.4 million ha (3,459,475 acres) Yellowstone National Park, with 192,000 ha (474,442 acres) of other national park lands nearby, plus a complex of six national forests (Gallatin, Custer, Shoshone, Bridger-Teton, Targhee, Caribou). These national forests contain 12 federally designated wilderness areas totaling 3.75 million ha (9,266,452 acres).

As of 2004, 280 active commercial cattle and 74 active commercial sheep allotments were permitted in these six national forests. From June through October approximately 146,000 cattle/calves and 265,000 sheep graze on 14 percent to more than 70 percent of land area, totaling approximately 1.6 million ha (3,953,686 acres) (U.S. Fish and Wildlife Service 1994). Grazing allotments occur both within and outside designated wilderness areas. Although many wolves remain inside livestock-free Yellowstone National Park, some of these packs dispersed and additional packs were established outside the park where they prey on livestock (Bangs and others 1998).

Central Idaho. In a 10-county recovery area of 9.2 million ha (22,733,695 acres) land ownership is mostly federal public (67 percent). The recovery area contains 5.4 million contiguous hectares (13,343,691 contiguous acres) in nine national forests (Bitterroot, Boise, Challis, Clearwater, Nez Perce, Payette, Sawtooth, Salmon, and Panhandle). In or near these national forests, several wilderness areas and inventoried roadless areas cover almost 3.8 million ha (9,390,005 acres).

On the order of 385,000 cattle and more than 100,000 sheep are present during spring in this recovery area (U.S. Fish and Wildlife Service 1994). In summer, some 43,000 cattle and nearly all Idaho sheep are moved to 1.75 million ha (4,324,344 acres) of public land grazing allotments on primarily those national forests without extensive federal wilderness. Some sheep and cattle from outside the state are also moved to summer grazing allotments. Over half of wolf packs in central Idaho have livestock in and near their territories (Bangs and others 1998).

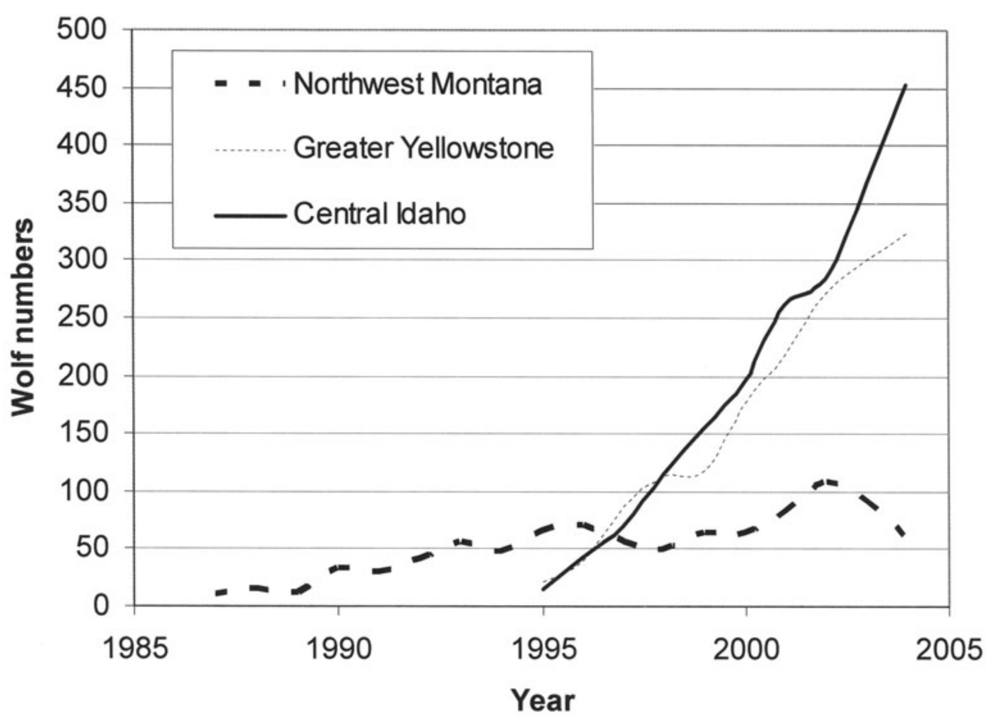

Figure 1—Gray wolf populations increased in three recovery areas, northern Rockies, U.S.A., 1995–2004.

Northwest Montana–This recovery area contains Glacier National Park (628,000 ha or 1,551,822 acres) plus 1.1 million ha (2,718,151 acres) of designated wilderness. Three contiguous wilderness areas (Great Bear, Bob Marshall, and Scapegoat) total 925,000 ha (2,285,725 acres). As in both central Idaho and Greater Yellowstone, sheep and cattle are grazed on grazing allotments inside both national forest and wilderness boundaries. Extensive private land holdings are also prevalent, however, especially between the Idaho border and Glacier National Park.

Upper Midwest

Gray wolves occupy mixed hardwood-conifer forest and forest/agricultural edge in Minnesota (ESA status: were threatened), central and northern Wisconsin and the upper peninsula (UP) of Michigan (ESA status: were endangered in both states). Relative to the northern Rockies, this region is more highly managed, in mixed ownership (Mladenoff and others 1999), heavily roaded (Saunders and others 2002), and less than 20 percent of land cover is in undeveloped native condition (Radeloff and others 2005).

Minnesota. A 7.8 million ha (19,274,220 acres) core range is inhabited by some 3,020 (90 percent confidence interval: 2,301—3,708) gray wolves in northern reaches of the state. Minnesota contains about 4.8 million ha (11,861,058 acres) of public land, including 2.2 million ha (5,436,318 acres) of national forest, 440,000 ha (1,087,264 acres) of designated wilderness, 25,000 ha (61,776 acres) of inventoried roadless area, and 57,000 ha (140,850 acres) of national park lands. Much of this public land base is contiguous, especially in northeastern Minnesota where Boundary Waters Canoe Area Wilderness adjoins several large state forests. Some 10,000 to 15,000 farms occur mostly on southern and western edges of the wolf range (Fritts 1982). At least 90 percent of farms have some livestock. From May to October livestock graze free in open pastures and woodlands.

Wisconsin. About 425 wolves occupy northern parts of the state. Like Minnesota, wolf range contains a mixture of publicly and privately owned forests, agricultural areas, and rural housing (Treves and others 2004). However, at only 2.5 million ha (6,177,635 acres), total public land area is less than in Minnesota. Beef cattle and other livestock operations in Wisconsin are often situated in forest pastures or adjacent to forested lands, thereby predisposing livestock to risk of wolf predation. In general, favorable wolf habitat in Wisconsin is smaller and more fragmented than in Michigan and Minnesota (Mladenoff and others 1999).

Michigan. Some 360 wolves have recolonized all northern counties except Keweenaw in the UP. High prey and low road and human densities create more than 29,000 km^2 (11,197 square miles) of suitable habitat in the UP (Mladenoff and others 1995). Compared to Wisconsin, livestock operations in northern Michigan are sparse and the proportion of wild land is high. More than 70 percent of the UP where wolves occur is in public ownership; these holdings tend to form large blocks of consolidated habitat with little intermingling with farms.

Structure of Compensation Programs

Northern Rockies

In 1987, Defenders of Wildlife initiated the first privately funded livestock compensation program to reimburse owners for losses while also protecting wolves. Compensation follows a complaint verified by U.S. Department of Agriculture (USDA)—Animal and Plant Health Inspection Service (APHIS)-Wildlife Services (WS)—or other officials who determine whether wolves killed or maimed one or more domestic animals. A depredation event consists of one or more individual livestock taken on the same date in the same location, and generally believed to have resulted from the same wolf or wolf pack. In general, verification includes either observing wounded animals or remains of animals killed. This compensation pays 100 percent of current market value for adult livestock, or the projected market value of livestock below marketable age for confirmed losses (up to $2,000 per animal). The fund pays 50 percent of the value for probable losses.

Upper Midwest

Wolf depredation claims in Minnesota are handled by either a Department of Natural Resources Conservation officer or county extension educator and a county extension agent determines the market value for the livestock lost. In Wisconsin, USDA-WS professionals conduct and verify depredation investigations. Investigations in Michigan are verified jointly by a conservation officer and district wildlife biologist in the Michigan Department of Natural Resources (MIDNR).

Once a loss is verified as wolf caused, the economic value of the loss is determined and a compensation payment is made within a reasonable time period. All compensation programs typically follow the same pattern: notification—verification—compensation. Verified depredations in the three states are compensated at fair market value for livestock animals.

In Minnesota, the state's Department of Agriculture reimburses livestock owners for verified confirmed wolf attacks. Wisconsin Department of Natural Resources administers payments for missing, probable and confirmed losses. These payments are generated from the endangered resources voluntary payments fund and a percentage of endangered resources license payments. In Michigan, the Michigan Department of Agriculture pays for confirmed and probable livestock losses for the livestock's current market value at the time it was killed. A supplemental fund administered by the International Wolf Center in Minnesota is used to increase the compensation payment to the full market value. The Wisconsin compensation program offers compensation payments for missing, confirmed and probable losses of hunting dogs, pets, and livestock guarding dogs, but these animals are not compensated by the programs administered in Minnesota and Michigan.

Analytical Approach and Sources of Data

Unit costs

Total reimbursed costs for livestock depredation vary as a function of wolf population size (Haney and others 2005), so we employed unit cost for comparing relative costs within and between regions. Unit cost was based on total compensation for all verified claims for all lost livestock prorated over the number of wolves counted within a particular region (U.S. Fish and Wildlife Service and others 2005). Unit cost was expressed in per capita terms, that is, in dollars per wolf per year. Costs for depredation events were assigned by depredation date rather than payment date.

For regions outside the northern Rockies, we took annual compensation payments attributed to wolves and divided them by the corresponding estimated wolf population size. Global regions from which we could find data for both variables included Israel (Gilady 2000), Spain (Blanco 2001), and Italy (Ciucci 2000).

Accuracy of wolf population counts varies across most regions: Minnesota's estimates for wolves are an order of magnitude less precise than those in Wisconsin and Michigan. Across the northern Rockies, wolf numbers are also estimated although the counts are typically reported with greater putative accuracy than in the upper Midwest.

Realized and Projected Compensation Costs

Projected costs in the northern Rockies were computed by prorating costs over average and maximum rates of wolf depredation anticipated in the original environmental impact statement (under Alternative 4—deliberate reintroduction) calculated prior to reintroduction (U.S. Fish and Wildlife Service 1994). These projected rates were expressed as number of cattle and sheep killed as a function of wolf population size (per 100 wolves).

For national forests surrounding greater Yellowstone, projected rates were an average of 8 (1 to 13 range) cattle and 68 sheep (38 to 110 range) per 100 wolves per year (U.S. Fish and Wildlife Service 1994). For central Idaho, projected rates were an average of 8 (1 to 17 range) cattle and 40 sheep (32 to 92 range) per 100 wolves per year (U.S. Fish and Wildlife Service 1994). Importantly, these projected rates were derived from North American regions adjacent to but containing less wild land habitat than found in the northern Rockies.

For the northern Rockies as a whole, average and maximum (upper range) rates were combined to obtain total livestock expected to be lost to wolves each year. Projected costs were then computed by multiplying number of livestock by the relevant fair market values for individual sheep and cattle, then summed over the three recovery areas. Despite few livestock other than sheep and cattle killed by wolves (table 1), realized costs in our analyses nevertheless included compensation for all domestic animals.

Wild Land Extent

For each state, we used total area (in hectares) and proportion (in percent) of the land base in public ownership (federal, state, local, and tribal governments). Likewise, we used national forest area, inventoried roadless area (http://roadless.fs.fed.us/), national park area, and designated wilderness area (http://www.wilderness.net/index.cfm) to compare unit costs. Finally, we used various combinations of the more restricted land designations (national park, inventoried roadless, and designated wilderness) to compare unit costs across regions.

Patterns in Compensation Costs

Northern Rockies

From 1995 to 2004, Defenders of Wildlife paid $470,187.55 in verified claims for 1,884 livestock lost to 442 events of wolf depredation across all three northern Rockies recovery areas (table 1). Costs translated to a region-wide average of $108.41 per wolf per year. The greatest total cost for verified claims was in greater Yellowstone (56.7 percent), followed by central Idaho (28.6 percent) and northwest Montana (14.7 percent). After adjustments for wolf population size, unit costs were lowest in central Idaho ($68.72/wolf/year), higher in northwest Montana ($97.37/wolf/year), and peaked in greater Yellowstone ($159.72/wolf/year).

Wilderness extent strongly influenced unit cost in the northern Rockies. Costs were inversely and monotonically related to the amount of public land, national forest, inventoried roadless area, designated wilderness, national park plus national forest area, and national park plus inventoried roadless area (table 2; fig. 2). Also, costs were lowest in the state (Idaho) with the greatest proportion of land in public ownership.

Table 1—Types and numbers of livestock and other domestic animals for which verified claims of depredation by gray wolf *Canis lupus* were recorded 1995–2004, northern Rockies, U.S.A. (Defenders of Wildlife).

Region	Cattle	Sheep	Guard and herding dogs	Horses, donkeys, and mules	Llamas	Goats	Total number of livestock and other animals	Total payments
Central Idaho	120	553	4	0	0	0	677	$134,552.30
Northwest Montana	91	140	1	1	7	0	240	$69,227.31
Greater Yellowstone	224	703	20	8	0	12	967	$266,407.94
Total	435	1,396	25	9	7	12	1,884	$470,187.55

Table 2—Unit costs of wolf depredation on domestic livestock in the United States decline with increasing wilderness area and other selected proxies for extent of wild lands (monotonic relationships between cost and wildland extent in **bold**; threshold relationships with underline).

Region	Long-term unit cost(s)[a]	Public land	Public land area	National forest area	National forest inventoried roadless area	National park area	Designated wilderness	National park plus national forest area	National park plus inventoried roadless area	National park plus designated wilderness
		Percent	ha							
Wisconsin	$168.03	17.8	2,504,772	818,682	27,923	**29,421**	17,987	848,103	**57,344**	47,408
Minnesota	$22.71	23.5	4,846,130	2,212,345	25,091	**57,304**	439,876	2,269,648	**82,394**	497,180
Michigan	$7.91	28.1	4,140,720	1,981,066	6,475	**255,803**	37,832	2,236,869	**262,278**	293,635
Greater Yellowstone	$159.72	55.9	**14,069,682**	**3,926,924**	**1,318,067**	1,024,518	**1,259,076**	**4,951,442**	**2,342,585**	2,283,594
Northwest Montana	$97.37	37.5	**14,127,674**	**7,731,268**	**2,588,785**	494,245	**1,393,354**	**8,225,512**	**3,083,029**	1,887,598
Central Idaho	$68.72	70.4	**15,081,886**	**8,770,869**	**3,772,495**	40,145	**1,621,061**	**8,811,014**	**3,812,640**	1,661,206

[a] Per wolf per year; based on yearly unit costs weighted by the annual wolf population size and computed over 10 (Greater Yellowstone, Northwest Montana, Central Idaho), 9 (Michigan, Wisconsin), and 4 years (Minnesota).

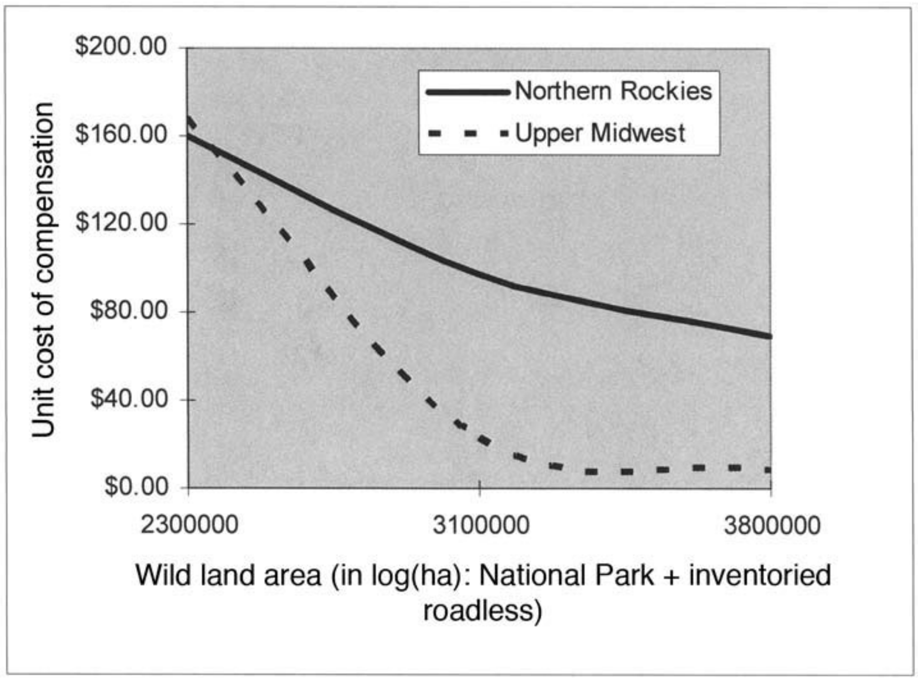

Figure 2— Unit costs of compensating for livestock lost to wolves were related to wild land extent by both monotonic and threshold functions.

Upper Midwest

Between 1996 and 2004, three upper Midwest states paid at least $902,483.41 in claims for livestock and other domestic animals lost to wolf depredation. In Michigan, $15,566.00 in total compensation was paid out between 1998 and 2004. A total of $380,518.18 was paid out in Wisconsin between 1996 and 2004. In Minnesota, $506,399.23 in total claims went for lost livestock between 1996 and 2003. Over the period 1996 to 2004, compensation costs for the upper Midwest as a whole came to an average of $43.47/wolf/year.

Adjusted for wolf population size, unit costs were lowest in Michigan ($7.91/wolf/year), with higher unit costs in Minnesota ($22.71/wolf/year; 90 percent confidence interval: $17.39—$28.11). Unit costs in Wisconsin were $168.03/wolf/year, higher even than in greater Yellowstone, the most expensive recovery area in the northern Rockies (table 2). Some portion of this great difference in per capita costs is likely to have stemmed from the more generous criteria used in Wisconsin's compensation program versus the other two upper Midwest states.

Regional differences in unit cost were nevertheless robust to influences from other variables. Unit costs for compensation varied annually. However, this source of variation was substantially less than that attributed to region, so is not treated here. Also, unit cost was not particularly sensitive to variation in wolf population size. For example, a more than 1,000 individual range in the estimate of Minnesota wolf population leads to only an $11 dollar range in unit cost.

As in the northern Rockies, compensation varied as a function of wild land extent. Unit costs in all three upper Midwest states were inversely monotonic when contrasted with national park area, and with national park plus inventoried roadless area (table 2). Unit costs were very high in Wisconsin, the state with the smallest proportion of public land, least total public land area, least national forest area, least designated wilderness, least national park plus national forest area, and least national park and designated wilderness area combined.

In general, functions between unit cost and wilderness extent were more complex in upper Midwest states (table 2). A monotonic decrease of unit cost with increasing wilderness was not evident for all wild land proxies from this region. Nevertheless, national park plus inventoried roadless area displayed a consistent inverse relationship with unit costs within each of the North American regions studied here. In addition, a threshold relationship (fig. 2) better described the function of unit costs with several wilderness proxies in the upper Midwest (table 2).

Cost Savings Over Original Projections

Average projected costs for compensated livestock lost to wolves in the northern Rockies ranged from a low of approximately $12,700.00 in 1995 to a high of $115,850.00 in 2004. Maximum projected costs ranged from a low of around $21,200.00 in 1995 to a high of $193,270.00 in 2004. Realized compensation costs ranged from a low of only $1,630.00 in 1995 to a high of $138,162.87 in 2004. Realized costs for compensation usually but not always increased monotonically year over year, roughly in line with the annual wolf population size for the northern Rockies as a whole.

During the first decade of wolf recovery (fig. 1), realized costs never exceeded maximum projected costs (fig. 3). In only two out of ten years (1997 and 2004) did realized costs exceed average projected costs. Cumulative costs for compensation over the entire decade thus came to only 47 percent and 78 percent of maximum and average projections, respectively (table 3).

Contrasts With Other Regions and Species

Compared to certain global regions where uninhabited habitat for carnivores is scarce, North American compensation in the range of $40 to $170 per wolf per year is a relative bargain. Compensation for livestock lost to a small population of wolves (*C. l. pallipes*) in the Golan of Israel came to at

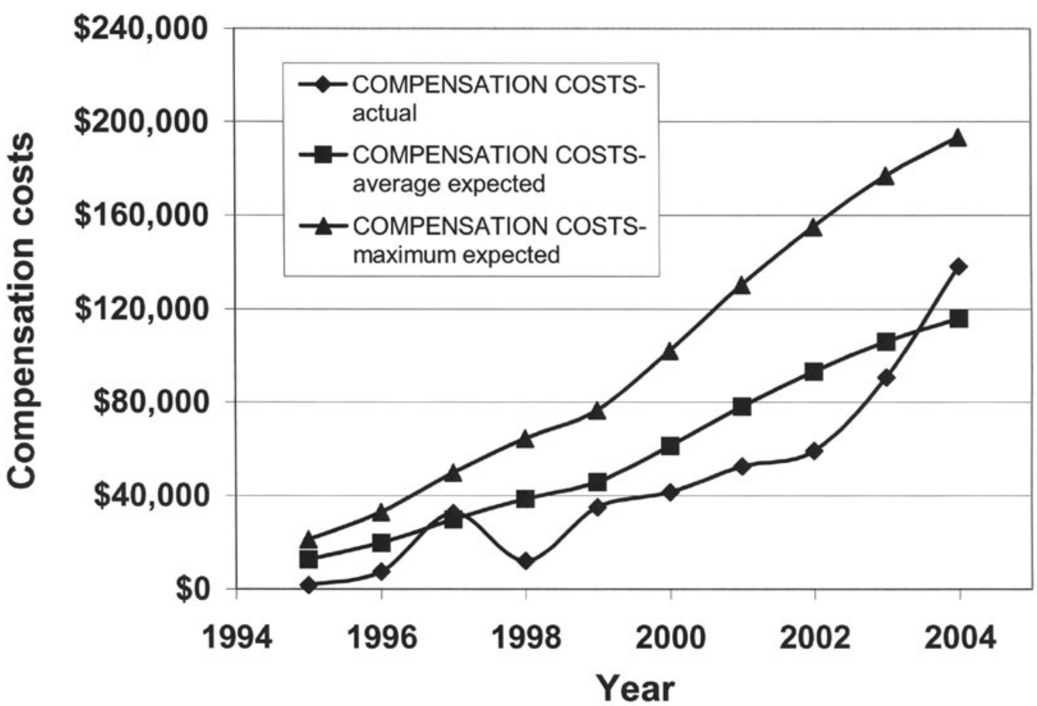

Figure 3—Realized costs (1995–2004) for verified depredations caused by gray wolf on domestic livestock, northern Rockies, U.S.A., trended lower than projections of compensation made prior to reintroduction.

Table 3—Cumulative depredations and compensation costs attributed to wolf depredations in the northern Rockies, 1995–2004.

Region	Realized	Average projected [a]	Maximum projected[a]
Central Idaho			
Sheep	553	783 (71%)	1,801 (31%)
Cattle	120	157 (76%)	333 (36%)
Greater Yellowstone			
Sheep	703	1,134 (62%)	1,835 (38%)
Cattle	224	133 (168%)	217 (103%)
Total costs	$470,187.55	$600,665.63 (78%)	$1,002,084.67 (47%)

[a] Percentages in parentheses indicate the ratio of realized to projected depredations and compensation as estimated by rates used in the environmental impact statement prior to wolf reintroduction.

least $1,400.00 per wolf per year (Gilady 2000). In Spain, the cost of compensation varied, ranging from $330 to $500 per wolf per year (Blanco 2001). In certain localized landscapes, however, per capita costs in Spain climb to as much as $1,375 per wolf per year. In Italy, where wolves number 400 to 600 animals, $2 million in annual compensation (Ciucci 2000) translates to per capita costs of $3,300-$5,000 per wolf per year.

Similarly, compensation for wolf depredation in North America is inexpensive compared to certain other predator species and regions. Costs of wild dog (*Lycaon pictus*) depredation were $389 per dog per year where wild prey occurred at low densities outside protected areas in Kenya (Woodroffe and others 2005), rising to $1,042 per dog per year on some private ranchlands in South Africa (Swarner 2004). Per capita costs for lion (*Panthera leo*) depredation on livestock adjacent to a national park in Kenya came to $290 per lion per year (Patterson and others 2004).

Wilderness and Carnivore Conservation

Wilderness as Wolf Habitat

Vast wilderness meets the viability needs of carnivores having large-area requirements (Kerley and others 2002; Noss and others 1996). Wolves avoid heavy traffic (Theuerkauf and others 2003) and high road densities (Mladenoff and others 1999; Thurber and others 1994; Whittington and others 2005), thereby increasing survival absent this human contact (Mech and others 1988; Wydeven and others 2001).

Native prey also contributes to wolf survival in protected areas (Apollonio and others 2004). Where human-caused mortality is low, prey abundance accounts for as much as 70 percent of wolf population size (Fuller 1989). By affording native ungulates usually selected by carnivores (Merrigi and Lovari 1996; Polisar and others 2003), wild lands reduce predation pressure on domestic livestock (Sidorovich and others 2003; Woodroffe and others 2005). Both North American regions studied here offer abundant ungulate prey to wolves, thereby lowering the risk of livestock depredations (table 3).

A discount is distinct from attributes normally described for wild landscapes. If coexistence with carnivores is achieved via reduced depredation costs on wild lands (Conforti and de Azevedo 2003), it broadens the vision for optimal conservation landscapes for large carnivores. For example, the discount could inform spatially explicit models used to assess feasibility for wolf restoration (Carroll and others 2003; Mladenoff and Sickley 1998; Ratti and others 2004). Such modeling would improve evaluation of whether protected areas merely achieve minimum area thresholds (Haney and others 2000; Landry and others 2001). Indeed, a discount can be used to identify landscapes where carnivores are 'cheapest' to recover (Woodroffe and others 2005). If compensation is constrained, the discount might be used to link affordability with viability in order to identify recovery sites for achieving a suitable meta-population at least cost (Lindsey and others 2005c). Such interdisciplinary applications will greatly improve effectiveness of carnivore conservation efforts (Clark and others 1996; Musiani and Pacquet 2004).

The discount we describe here is compromised if compensation enables inefficient and subsidized livestock husbandry (Bulte and Rondeau 2005). The wilderness discount was also conspicuous where topography, ecosystem type, and livestock practices were broadly similar. Differences in husbandry practices and subsidized grazing may confound a discount because proximity to buildings, herd size, livestock breed, degree of shepherding, and means of livestock carcass disposal all greatly influence local carnivore depredations (Espuno and others 2004; Fritts 1982; Mech and others 2000; Odden and others 2002).

Negligent husbandry practices may actually eliminate the discount; compensation within certain agricultural areas of Spain was one-tenth of that in preserved lands due to lax shepherding (Blanco 2001). Subsidized grazing may explain the doubling in per capita compensation for wolf depredations observed between the two North American regions studied here. The large Rockies wilderness should have had compensation outlays well below those paid in the more developed upper Midwest. But livestock in the Rockies have free rein in very remote settings, in close proximity to wild ungulate herds normally targeted by wolves. We believe per capita costs for wolf depredation in the upper Midwest were also comparatively low because farms there are smaller, livestock do not roam far unattended, and wild prey (forest-inhabiting deer) and domestic livestock may be more spatially segregated (for example, see Treves and others 2004).

In summary, several unique attributes of wilderness enhance wolf conservation. Some of these are biophysical in nature, others are socioeconomic in origin and consequence. Wolf packs (and presumably their economic impacts) appear to be localized at the wild land interface in the broader northern Rockies region. Yet wolves were once more common in prairies well outside the montane wilderness they currently occupy (Riley and others 2004). These observations thus reinforce a wilderness-associated rather than wilderness-dependent habitat affinity for this carnivore (Hendee and Mattson 2002).

Costing Wolf Recovery

Compensation: Direct and Indirect Costs. Direct costs of livestock losses from carnivore depredation are straightforward to derive, a prime motive in limiting our analyses to this category of direct costs. Unit cost provides a convenient metric for comparing cost effectiveness among sites (Lindsey and others 2005c), across years and regions, and between different predator species.

Importantly, due to unsubmitted claims, low rates of carcass detection (Oakleaf and others 2003), and other factors, expenses we report here may underestimate total direct costs. Conversely, Fritts (1982) found that wolf-livestock depredations are exaggerated, kills by other carnivores (especially coyote *Canis latrans*) misattributed to wolves, and non-existent missing animals (especially calves, lambs) falsely blamed on wolves. Under closer scrutiny, wolves may account for only 20–50 percent of depredations for which they are held liable (Zimen and Boitani 1979). Such biases would tend to inflate estimation of these direct costs.

Compensation includes several indirect outlays, including expenditures to verify, pay, and archive claims. For the two North American regions studied here, at least one to three full-time equivalent agency and non-profit staffers are required to administer a compensation trust and the accompanying claims process. Such indirect costs are likely to be non-trivial. A comprehensive estimate of all costs linked to compensation programs for wolves seems a ripe topic for analysis, as has been recently completed for wild dogs in Africa (Lindsey and others 2005c).

Few studies combined all expenditures to estimate total cost of maintaining carnivore populations from the perspective of livestock depredations (Main and others 1999). In Wisconsin, wolf control doubles expenditures for direct compensation (Treves and others 2002). Between 1979 and 1989, realized direct costs for livestock losses in Minnesota were about one-third the cost of controlling problem wolves, or about one-fourth the total cost estimated for that state's compensation program (Mech 1999). This translates to annual unit cost of $71 per wolf realized in the core wilderness range compared to $197/wolf/year projected in more agricultural areas into which wolves were forecasted to expand.

Due to regional differences in wolf management, and in breeds and value of livestock taken, this ratio is unreliable for figuring program costs elsewhere. Mech's projections for Minnesota overestimated true expenditures in the direct cost category: $75,000 to $182,000 per year was anticipated for the period 1999 to 2005 whereas costs really came to $53,000 to $84,000 per year. Direct unit costs in Minnesota actually declined on a per capita basis from a high of $29.29/wolf/year in 1998 to just $17.83/wolf/year in 2003. Our study nevertheless confirms and extends the wilderness effect on per capita livestock compensation anticipated by Mech (1999).

Other Recovery Program Costs. Livestock compensation is only part of the expenditures needed to recover endangered carnivores. Other costs that we did not treat are nevertheless linked to livestock depredations: translocation or lethal control of wolves (Mech 1999), repellents to reduce livestock losses (Musiani and others 2003; Shivik and others 2003), aversive conditioning of wolves (Schultz and others 2005), and so on. Livestock operators may incur extra costs for vigilance, and to prepare and submit claims. In central Europe, shepherding is eight times more expensive than direct losses (Promberger and Mertens 2001). Once such costs are synthesized, a fuller comparison to benefits will produce robust estimates for gauging net economic impact of carnivore presence (Duffield 1992; Lindsey and others 2005a).

Compensation Discount as a Wilderness Amenity

Either benefit creation or cost reduction can improve social acceptance of carnivores (Lindsey and others 2005b). But is a decrease in predator compensation costs a novel category of economic benefits derived from wilderness? We briefly review types of wilderness benefits (Morton 1999) to understand if direct or indirect benefits are obtained. We did not consider the non-use category (Krutilla 1967; Loomis and White 1996), as neither compensation nor wolf recovery costs are off-site in nature.

Direct uses include recreation that generates market activity via direct expenditures and multiplier effects in the regional economy (Lutz and others 2000; Rudzitis and Johnson 2000); education; and scientific research (Loomis and Richardson 2001). Direct use benefits include earnings from recreational expenditures and consumer surplus of recreationists, as well as the harder to quantify benefits derived from education, and scientific research. Wilderness and other protected areas supply amenity values to nearby residents through open space and scenic views, at times with faster economic growth, greater diversification, and lower unemployment (see Duffy-Deno 1998; Rasker and Hackman 1996). Amenity values in turn foster real estate premiums adjacent to protected lands (McConnell and Walls 2005). A wilderness discount for compensation does not seem to qualify as a direct use benefit.

Indirect uses of wilderness include ecosystem services that facilitate human production of goods and services (Balmford and others 2002). Hydrological and nutrient cycles, soil formation, erosion control, pollination, habitat for fish and game, food and water for livestock, and climate regulation are a few examples. We believe that lower compensation costs are an ecosystem service—essentially, native prey on wild lands buffer economic loss of livestock to carnivore predation. In the northern Rockies, this benefit manifests despite extensive use of subsidized grazing on public lands. Given how challenging it remains to describe and quantify ecosystem values generally (National Research Council 2004), it is hardly surprising that this novel wilderness discount has heretofore escaped attention.

Wilderness in the northern Rockies supplies a variety of benefits to regional economies (Rasker and Hackman 1996). Our results show wilderness also reduces economic costs incurred by society due to carnivore presence. We conclude that this benefit provides strong additional incentive to conserve both large predators and wilderness habitats.

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