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ANALYSIS

# Livestock depredation by wolves and the ranching economy in the Northwestern U.S.

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ABSTRACT

Due primarily to wolf predation on livestock (depredation), some groups oppose wolf (*Canis lupus*) conservation in the Northwestern U.S., which is an objective for large sectors of the public. Livestock depredation by wolves is a cost of wolf conservation borne by livestock producers, which creates conflict between producers, wolves and organizations involved in wolf conservation and management. Compensation is the main tool used to mitigate the costs of depredation, but this tool may be limited at improving tolerance for wolves. Furthermore, livestock production may in fact provide indirectly an important benefit for wolf conservation – i.e. a positive externality, by maintaining relatively intact habitat on private lands. We analyzed some of the costs of livestock depredation by wolves to livestock producers relative to recent economic trends in the livestock production industry, specifically income generated from livestock production and trends in land and livestock value. Data were gathered from depredation investigations, from the livestock compensation program and on land and livestock price in Idaho, Montana and Wyoming, U.S.A. from 1987 to 2003 – a period during which wolves had endangered species status. We found that instigation of attacks on livestock by wolves was determined by need for food, but wolves may kill sheep in excess of food needs. Excessive killing of livestock may contribute significantly to intolerance for wolves. Livestock killed by wolves cost producers approximately $11,076.49 per year between 1987 and 2003, although costs were increasing linearly ($R^2 = 0.789$, $P < 0.001$). Each year such costs accounted for <0.01% of the annual gross income from livestock operations in the region. Thus, wolf depredation is a small economic cost to the industry, although it may be a significant cost to affected producers as these costs are not equitably distributed across the industry. Compensation for depredation was efficient when compared to other regions. Land prices increased steadily throughout the study period ($R^2 = 0.966$, $P < 0.001$), while the price of cattle decreased ($R^2 = 0.749$, $P < 0.001$). We maintain that conservation groups should consider the potential consequences of all of these economic trends. Specifically, declining cattle price and the steady increase in land price might induce conversion of agricultural land to rural-residential developments, which could negatively impact wolf conservation via large scale habitat change and increased human presence.


## 1. Introduction

Livestock production is an important economic activity in the Northwestern U.S. (Bedunah and Willard, 1987; Sarchet, 2005) yet the livestock industry is facing challenges in maintaining its economic viability (Wuerthner, 1994; Hanson et al., 2008). One particular challenge is dealing with the costs of wolf predation on livestock (i.e., depredation). Since 1987, Canadian wolves (*Canis lupus*) have recolonized regions of Northwestern Montana. In 1995, wolves were reintroduced in Yellowstone National Park and central Idaho, and since then have expanded their range into contiguous areas (Fig. 1). Many parts of the Northwestern U.S. now frequented by wolves overlap livestock production areas and consequently wolves have killed livestock. Livestock depredation by wolves is therefore a financial cost of wolf reintroduction borne by livestock producers, which creates conflict between producers, wolves and organizations involved in conservation and management that can undermine wolf conservation (Niemeyer et al., 1994; Naughton-Treves et al., 2003). Ironically, contiguous, relatively undeveloped private rangelands can provide habitat for wildlife outside of public land (Hobbs et al., 2008). Such landscapes are often necessary for conservation of wide-ranging wildlife species, particularly for large carnivores such as wolves (Woodroffe and Ginsberg, 1998; Carroll et al., 2003). In actuality, livestock production may provide indirectly an important benefit for wolf conservation – i.e. a positive externality. Externalities (see Pigou, 1932; Baumol, 1972), are the positive outcomes (benefits) or negative outcomes (costs) of an economic activity (in this particular case, livestock production) that are not reflected in the market price of the commodity (e.g., livestock). Typically, externalities influence individuals and groups that are not engaged in the economic activity. In our case, livestock production may provide a benefit to wolf conservationists, which are a large portion of the public (Kellert et al., 1996) and come from different social contexts than those engaged in

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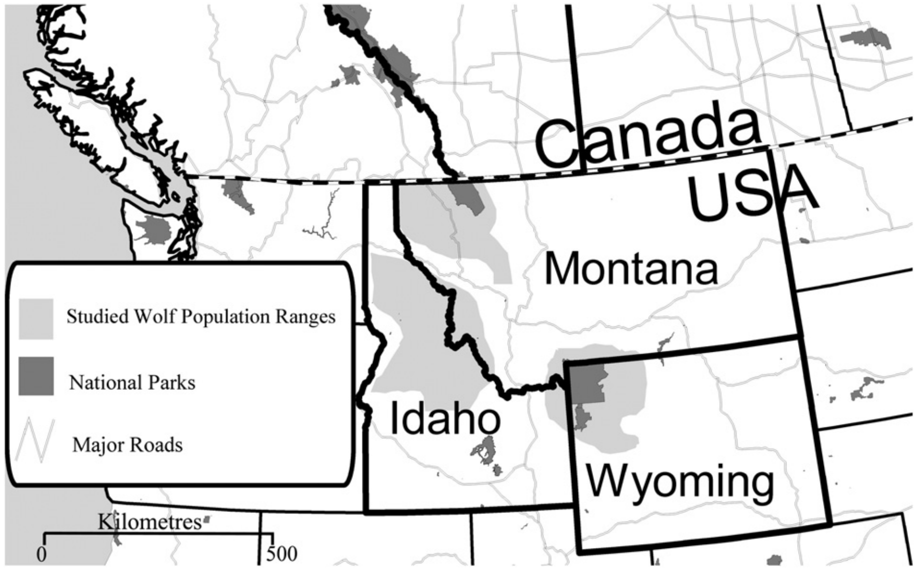


**Fig. 1.** Map of the study area in the northwestern U.S. Light gray areas within Idaho, Montana and Wyoming indicate the range of wolf populations in those states and thus the area within which livestock depredation can occur and where depredation data was collected. National parks are indicated as dark grey.

livestock production. In practice, livestock producers maintain landscapes that are important to wolves and wolves are important to other groups. In accordance with externality theory, these benefits are not reflected in the market price of livestock.

The purpose of this paper is to assess some of the economic costs of livestock depredation by wolves to livestock producers relative to recent economic trends in the livestock production industry, specifically income generated from livestock production and trends in land and livestock value. Our approach illustrates why livestock depredation by wolves is an important concern to livestock producers and how trends in various assets of livestock production, of which livestock and land value may be of paramount importance, may ultimately affect wolf conservation in agricultural areas in the Northwestern U.S.

Depredation can have significant monetary costs and cause emotional stress for individual livestock producers (Bangs et al., 1998; Bangs and Shivik, 2001; Naughton-Treves et al., 2003). Several aspects of wolf depredation damage may contribute significantly to the perception of the problem by the affected producers. For example, one perception held by livestock producers that likely contributes to conflict with wolves is that wolves kill livestock at a rate beyond that necessary to supply their immediate needs for food (i.e., "surplus killing"; Gipson et al., 1998). Surplus killing is characterized by an absence of (Kruuk, 1972), or a low level of (Short et al., 2002) utilization of the prey carcasses by the predator. If wolves engage in surplus killing of livestock they could kill a number of individuals over a short period of time, potentially contributing to increased financial costs to producers. In addition, surplus killing by wolves may significantly influence opinions of livestock producers, as well as their perception of the costs of depredation.

Surplus killing by wolves has been documented on wild prey (DelGiudice, 1998), although it is not considered common. However, surplus killing of livestock may be relatively more frequent because of poor anti-predator behaviour in domestic animals. Artificial selection has produced populations of domestic animals with reduced potential for survival in nature (Foley et al., 1971; Eibl-Eibesfeld, 1975; Wood-Gush and Duncan, 1976; Price, 1984; Mignon-Grasteau et al., 2005). In domestic livestock production, traits with economic value (e.g., faster weight gain, more wool) are favored, which diverts resources from other traits (Mignon-Grasteau et al., 2005). As a result, domestic animals typically have smaller brains and less acute sense organs than do their wild ancestors (Diamond, 2002). Furthermore, animals that are less fearful of humans are preferred, and therefore domestic animals tend to be much tamer than wild animals (Lankin, 1997; Gross, 1998). Domestic animals may therefore express a lower incidence of behaviours and morphological traits that deter predators (Johnsson et al., 2001; Mignon-Grasteau et al., 2005). We identified whether surplus killing is in fact occurring on livestock in the Northwestern U.S. to evaluate whether it should be considered when evaluating the monetary and non-monetary costs of livestock depredation by wolves.

While depredation by wolves is an important concern of livestock producers, this concern occurs within the larger economic argument: that is, livestock producers who lose livestock to wolves pay a cost (i.e., what could be viewed as a negative externality) for conserving rangelands that are critical for wolf persistence. One means to mitigate this cost is through compensation for livestock depredation. Compensation programs are designed with the objective to help producers financially and to reduce or eliminate animosity towards wolves by reimbursing livestock producers for the monetary value of livestock killed by wolves (Wagner et al., 1997; Naughton-Treves et al., 2003; Bangs et al., 2004).

Compensation has been in place in the Northwestern U.S. for the last 20 years. However, compensation programs can be controversial as they do not necessarily improve attitudes of livestock producers towards wolves (Naughton-Treves et al., 2003). In fact, in some cases compensation programs may have the opposite effect by increasing the conflict between producers and agencies. For instance programs that take a long time to reimburse producers create the impression that the agencies providing compensation do not take the problem seriously (Fourli, 1999; Montag, 2003). Nevertheless, halting compensation is not advisable due to potential backlash (Naughton-Treves et al., 2003) and compensation is proposed to continue in the Northwestern U.S. in the near future (USFWS, 2008). Therefore, the compensation program in the Northwestern U.S. should be assessed to ensure producers are promptly reimbursed.

Wildlife conservation programs that employ economic tools such as compensation must understand the economic context within which the compensated individuals' industry operates, as economic factors important to that industry may ultimately influence the success of such programs. A good example of this comes from the U.S. management of livestock depredation by coyotes (*Canis latrans*). For 80 years the U.S. government promoted and funded lethal control of coyotes as a means to improve sheep production by preventing coyote depredation of sheep (Berger, 2006). Perception was that coyote depredation was driving the decline in the sheep industry. However, governmental lethal control ultimately had no effect on the industry; rather, rising production costs and declining commodity prices reduced or eliminated the profitability of sheep production (Berger, 2006).

In the Northwestern U.S., poor profitability from livestock production could threaten the livelihood of all livestock producers, not just those experiencing depredation. This may have significant implications for not only the effectiveness of compensation programs, but for conservation of wolves on private lands. In addition, recent demand for natural amenities (e.g., recreational opportunities and viewscapes, *sensu* Hansen et al., 2002) provided by some agricultural areas has contributed to a trend in conversion of agricultural land to rural-residential (Hansen et al., 2002; Sengupta and Osgood, 2003; Brown et al., 2005; Gosnell and Travis, 2005). Conversion of agricultural lands to other land uses can dramatically alter habitat (Theobald et al., 1997; Hansen et al., 2002; Mitchell et al., 2002) in such a way that could negatively affect wildlife, wolves included. For example, fragmentation of rangeland into smaller land tenure parcels results in habitat loss as well as in diminished accessibility of resources important to wildlife (Hobbs et al., 2008).

We investigated patterns and trends in livestock depredation by wolves, compensation for depredation, and livestock and land price in Idaho, Montana and Wyoming from 1987 to 2003. This time frame represents a period under which wolves had endangered species status and were managed by the USFWS in the Northwestern U.S. More recently wolf management was transferred to state authorities (USFWS, 2008) and then transferred back to USFWS jurisdiction following a court injunction; we avoided analyses during this period of management transitions.

Our approach consisted of evaluating wolf depredation in the study area from five different perspectives. First, we described the patterns of wolf depredation on various livestock species in the Northwestern U.S. Second, we tested whether wolves killed domestic animals in excess of their food needs to address the consequential perception of "surplus killing" that is held by some livestock producers. Third, we evaluated the timing of the various steps involved in financial compensation of wolf damage and the relationship between the monetary value of domestic animals killed and the funds actually disbursed to assess the effectiveness of compensation at reimbursing producers. Fourth, we compared the annual monetary value of livestock killed by wolves to annual gross income from livestock production with the objective to place the costs of depredation within the context of economic production of the industry. Finally, we examined trends in livestock price and land price to evaluate the value of these two important assets in the study area. Our results provide a greater understanding of the economics of livestock depredation by wolves, which have implications for conservation planning in areas with significant human–wolf conflicts, in particular on private agricultural land. In the framework of externality theory, our analysis of the practice of livestock damage compensation also constitutes an important example of the costs paid by some segments of society for the benefit of conserving wildlife.

## 2. Methods

### 2.1. Study area

The study area consisted of the northwestern states of Idaho, Montana and Wyoming in the U.S.A. (Fig. 1). Parts of the study area are characterized by temperate steppe consisting of agricultural lands and grasslands interspersed with stands of *Populus spp. and Salix spp.* Forests consist of white and black spruce *Picea spp.*, subalpine fir *Abies lasiocarpa*, lodgepole pine *Pinus contorta*, trembling aspen *Populus tremuloides*, balsam poplar *P. balsamifera* and white birch *Betula platyphylla*. Several prey species for wolves are abundant in parts of the study area including bison *Bison bison*, moose *Alces alces*, elk *Cervus elaphus*, white-tailed deer *Odocoileus virginianus*, mule deer *Odocoileus hemionus*, and bighorn sheep *Ovis canadensis*. Domestic animals, particularly livestock such as cattle, sheep, and horses are also abundant.

The region contains both developed areas (e.g. towns, agricultural lands and managed forests) and public reserves (e.g. Wilderness Areas and National Parks including Glacier and Yellowstone). Major economic activities in the study area include manufacturing, mining, petroleum and natural gas extraction, and agriculture. Important agricultural crops include potatoes, hay, barley, wheat, peas, beans, and sugar beets. Tourism and the service industry is an emerging economic sector due to the amenity values in the study area. Wilderness habitats that support species such as wolves provide environmental amenities that may stimulate economic growth in the region (Rasker and Hackman, 1996). Wolf conservation in the study area may also generate income through tourism (Duffield, 1992). While wolves were released into regions where the economy was not as agriculturally based as other parts of the study area (Bangs et al., 1998), livestock production is an important economic activity on the private and public grazing lands where wolves settled. Wolf range has expanded further into livestock production areas since reintroduction and recolonization from Canada in the mid 1990s.

### 2.2. Wolf depredation and compensation data

We analyzed USFWS and United States Department of Agriculture-Wildlife Services (USDA-WS) depredation investigations in Idaho, Montana and Wyoming, from January 1987 to January 2003. The non-government organization Defenders of Wildlife collaborated with the government by funding and administering compensation for depredation. In the study area, "confirmed" damage caused by wolf depredation was refunded at full market value and "probable" damage was refunded at half market value. Investigation forms included the following information for depredation events for which wolf responsibility was "confirmed": dates for complaint, investigation, and payment to the livestock producer, amount compensated, estimated time elapsed between wolf attack and investigation, livestock species, number and age of domestic animals killed or injured, and carcass condition (i.e., level of consumption).

Using the investigation data, we analyzed the number of cattle and sheep killed per attack and the amount of consumption of each carcass by wolves. Instances in which scavengers were clearly involved (i.e., as noted by the investigator) or where depredation events were not discovered by ranchers within 24 h, as estimated by government officers during investigations, were not analyzed. The latter method was designed to minimize chances for overestimation of carcass consumption by wolves due to undetected scavengers or to decomposition (Miller et al., 1985; Hayes et al., 2000).

We calculated biomass consumed by wolves and compared it to total live weight of the carcass(es) and to the weight of parts edible by wolves. In previous studies conducted on moose (Peterson, 1977), deer (Fuller, 1989), caribou *Rangifer tarandus* (Ballard et al., 1987), and Dall sheep *Ovis dalli* (Hayes et al., 1991), an approximate proportion of 0.75 of the live weight of an ungulate was assumed edible, or found to be edible by wolves (bones without marrow, rumen contents and hide are typically not consumed). A few (less than 10%) of the investigation reports included live weight of the depredated animals. When this was not provided, we assigned depredated animals to weight classes based on their age. For cattle, animals aged >24 months were assigned 600 kg, animals aged 12–24 months were assigned 320 kg, whereas animals aged <12 months were assigned a weight depending on monthly developmental stages of the calf (Berg and Butterfield, 1976; USDA, 2003). For sheep, all animals reported as adult were assigned 57 kg, whereas animals reported as lamb were assigned 16 kg (Butterfield, 1988; USDA, 2003). Data on pack sizes were obtained from the USFWS and data on maximum food consumption per meal

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**Table 1**
Occurrences of deadly wolf attacks, numbers of domestic animals killed and consumption patterns of livestock carcasses by wolves in Idaho, Montana and Wyoming U.S. from 1987 to 2002.

| | | Kilograms consumed per attack, mean ± SD | Kilograms consumed per carcass, mean ± SD | Percent of edible parts consumed per attack, mean ± SD |
|---|---|---|---|---|
| Cattle | | | | |
| Attacks | 158 | | | |
| Animals killed | 219 | 87 ± 93 | 79 ± 89 | 40 ± 31 |
| Sheep | | | | |
| Attacks | 68 | | | |
| Animals killed | 602 | 48 ± 55 | 8 ± 8 | 18 ± 19 |
| Dogs | | | | |
| Attacks | 23 | | | |
| Animals killed | 32 | – | – | – |
| Other | | | | |
| Attacks | 4 | | | |
| Animals killed | 8 | – | – | – |
| Total | | | | |
| Attacks | 253 | | | |
| Animals killed | 861 | – | – | – |

by individual wolves were gathered from the literature (approximately 8 kg; Mech, 1970; Huggard, 1993). We used the above values to calculate the following indices for wolf consumption: biomass consumed per attack (kg), biomass consumed per domestic animal depredated (kg), and proportion of biomass consumed per attack out of total weight of all edible parts available (%). We used the Mann–Whitney *U* test (Sokal and Rohlf, 2000) to compare wolf consumption indices for cattle and sheep carcasses.

We calculated elapsed time between: (a) depredation complaints and depredation investigations to evaluate promptness of response to complaints; (b) depredation events (assessed during investigations) and complaints to evaluate promptness in response by livestock producers to the compensation program and/or producers' ability to find losses; and, (c) investigations and mailing of compensation checks to evaluate promptness of the compensation payment. We used the Kolmogorov–Smirnov test with reference to Lilliefors' probabilities (Sokal and Rohlf, 2000) to determine that the data on the yearly numbers of domestic animals killed and injured and compensation costs were normally distributed. To test correlation among yearly numbers we used Analysis of Variance (ANOVA) and least-squares simple linear regression (Sokal and Rohlf, 2000). All tests were two-tailed and the significance cut-off was $P<0.05$.

### *2.3. Estimated monetary value of livestock killed by wolves in the Northwestern U.S.*

To estimate the monetary value of cattle and sheep killed by wolves in the Northwestern U.S. each year from 1989 to 2003 we multiplied the number of livestock killed each year by the average livestock weight and price per kilogram for each livestock type: cow, steers and heifers, calves, sheep and lambs (USDA, 2008). We compared monetary value of livestock killed to annual gross income generated by cattle/calf and sheep/lamb operations as provided by the USDA (USDA, 1993, 1998, 2004a). To further evaluate the compensation program we compared the number of livestock killed to published compensation disbursements provided by Defenders of Wildlife over the same period (available from http://www.defenders.org/) using a Spearman correlation and a paired two-tailed *t*-test (Sokal and Rohlf, 2000).

### *2.4. Livestock and farm land price in Idaho, Montana and Wyoming*

From the 1990s to 2003, we assessed yearly trends in livestock and farm land prices in Idaho, Montana and Wyoming. Data on livestock prices were available for each month from the National Agricultural Statistics Service, Agricultural Statistics Board, USDA, but for analyses of trends we used figures from August of each year, as August coincides with the peak of livestock depredation by wolves in the study area (Musiani et al., 2005) and therefore we assumed most livestock producers were compensated for their losses at the August market price. Livestock market prices were calculated from the sales of livestock from producers to buyers. We obtained data on farm real estate prices for Idaho, Montana and Wyoming for 1990 and from 1994 to 2003 (USDA, 1999, 2004b). Farm real estate is defined as all land and buildings (including operator dwelling) used for agricultural production (USDA, 2004b). For comparative purposes, we adjusted all annual prices (including livestock and farm real estate) to year 2007 prices using the United States Department of Labor Consumer Price Index (CPI) inflation calculator. We calculated least-squares simple linear regressions (Sokal and Rohlf, 2000) to determine if there was a linear trend in adjusted prices for livestock and farm real estate value and we calculated the annual percent change in adjusted prices, and their standard deviations to evaluate the variability of prices throughout the study period.

## 3. Results and discussion

### *3.1. Wolves kill sheep in excess compared to other domestic animals*

In Idaho, Montana and Wyoming, U.S.A., from January 1987 to January 2003, wolves attacked cattle in 158 instances resulting in 219 individuals killed (Mean = 1.39, SD = 1.07 cattle per attack; Table 1). There were 68 instances of attacks on sheep (Fig. 2) in which wolves killed 602 individuals (Mean = 8.85, SD = 14.45 sheep per attack). The number of sheep killed per wolf attack was comparable to other studies (3–7.6 sheep per attack; Telleria and Saez-Royuela, 1989; Fritts et al., 1992; Fico et al., 1993; Ciucci and Boitani, 1998). Wolves killed more sheep than cattle per attack ($Z=9.233$, $P<0.001$). Other domestic animals, including dogs, were killed infrequently. During most wolf attacks on cattle, only one individual was killed (121 instances corresponding to 77% of attacks). Two cattle were depredated in 22 instances, three in nine instances, and between four and eight in six instances (totaling 23% of attacks with more than one cattle killed). Wolves killed one sheep per attack in 12 instances (18% of all attacks on sheep), two in 15 instances (22% of attacks), three in five instances, and between four and 98 in 36 instances (totaling 60% of all attacks on sheep with more than two sheep killed per attack).

Biomass consumed by wolves per attack was not significantly different regardless if the prey was cattle or sheep (Mean = 87 kg, SD = 93 kg and Mean = 48 kg, SD = 55 kg, respectively; $Z=1.384$, $P=0.167$; Table 1). Thus our data show that instigation of attacks was influenced by actual need for food, as generally assumed in other predation studies (Holling, 1965; Sjöberg, 1980). However, biomass consumed per individual animal depredated was higher when wolves attacked cattle than when wolves attacked sheep (Mean = 79 kg, SD = 89 kg and Mean = 8 kg, SD = 8 kg, respectively; $Z=3.490$, $P<0.001$) and relative utilization of edible parts consumed per attack was higher when wolves attacked cattle than when wolves attacked sheep (Mean = 40%, SD = 31% and Mean = 18%, SD = 19%, respectively; $Z=2.037$, $P=0.042$), i.e., more sheep was unused or “wasted” (*sensu* Kruuk, 1972). Furthermore, edible biomass of prey killed in an attack exceeded the estimated food requirements of an average wolf pack (48 kg for 6 wolves corresponding to ≤1 cattle and ≤2 sheep) more frequently for sheep than for cattle ($Z=5.336$, $P<0.001$). Compared to attacks on cattle, a higher proportion of attacks on

**Fig. 2.** Photo of two wolves feeding on a sheep carcass. This study's findings on food waste and on killing in excess of food requirements suggested that wolves conducted "excessive killing" of sheep (photo credit: Stefano Mariani, 2004).

sheep involved killing in excess of the immediate food requirements of an average pack living in the study area. The original definition of "surplus killing" (Kruuk, 1972) was the killing of prey characterized by an absence of utilization of the carcasses. According to Short et al. (2002), instances when a predator consumes only a small portion of the total edible prey clearly also indicates surplus killing. Despite the inconsistencies in the definition of surplus killing, our findings on food waste and on killing in excess of food requirements demonstrate that wolves conduct "excessive killing" (*sensu* Carbyn, 1983; Miller et al., 1985) on sheep.

While our data indicate wolves can kill sheep in excess of food requirements, further exploration of excessive killing on domestic animals might be necessary for two reasons. Firstly, we were unable to assess whether wolves would return to carcasses to consume more meat from livestock kills if human disturbance of the carcass had not occurred. Human disturbance might have happened when the rancher detected the kill and when ranchers and government personnel conducted the subsequent investigation. Human disturbance may bias our results towards concluding that excessive or surplus killing occurred when it would have not. However, humans occur throughout wolf range in the study area and arguably throughout wolf range worldwide, with a few exceptions (Fritts et al., 2003). Similar circumstances are found for various carnivore species worldwide (Treves and Karanth, 2003). Thus, human disturbance of prey consumption could be considered as a constant part of the environment; and this applies to both agricultural (as described above) and protected areas.

A second methodological bias could be due to our inability to determine the exact number of wolves that fed on an animal. As lone wolves or only a portion of the pack living in the area may have been involved, our results (which account for potential visits by a whole pack) may underestimate the total edible biomass consumed per individual. Thus, again, our results could potentially be biased toward overestimating the occurrence of excessive killing. Nevertheless, in the absence of intensive experimental manipulation, more accurate or unbiased assessments of excessive killing are not feasible.

Our data highlight the greater vulnerability of sheep to predators compared with cattle (Hell, 1993; Gipson and Paul, 1994; Ciucci and Boitani, 1998; Keeling and Gonyou, 2001) and support the importance of prey traits (Roberts, 1996; Lima, 1998; Brown, 1999; Mitchell and Lima, 2002) in influencing the outcome of wolf-livestock interactions. Livestock traits such as morphology, choice of habitat, vigilance and overall ability to defend against or escape predator attacks are influenced by animal husbandry and artificial selection (Foley et al., 1971; Eibl-Eibesfeld, 1975; Wood-Gush and Duncan, 1976; Price, 1984; Johnsson et al., 2001; Mignon-Grasteau et al., 2005). Sheep are easy prey for canids due to their small body size, low agility and lack of defense mechanisms (i.e., horns; Short et al., 2002). Flocking behavior, which is naturally exhibited by sheep and reinforced through husbandry (Keeling and Gonyou, 2001) can supply large numbers of highly concentrated, vulnerable prey during a wolf attack. Confinement of sheep at high densities in enclosures permeable to wolves but not sheep might also compel wolves to kill many sheep in a single attack (Kruuk, 1972; Stuart, 1986). In addition, all breeds of sheep group more closely together than cattle (Grandin and Deesing, 1998). Our results suggest that differences in morphology, behavior and husbandry between sheep and cattle induce different predatory behaviors by wolves, represented as excessive killing of sheep in relation to food needs of wolves.

Organizations involved in wolf conservation and/or providing depredation compensation should be aware of excessive killing of sheep by wolves. There is potential for added negative perception of wolves by sheep producers due to excessive killing. Excessive killing could result in a number of sheep killed by wolves in single attacks, with the parallel need to quickly refund the damage of such sudden losses. Compensation providers should therefore identify and regularly communicate with sheep producers within wolf range to ensure depredation events are identified and compensation is delivered promptly. In addition, when anticipating future costs of depredation it should be acknowledged that sheep may be killed in excess of what would be predicted based on normal rates of meat consumption by wolves.

### *3.2. Timing in compensation of livestock losses suggests prompt compensation*

In many parts of Europe and North America a typical means to prevent or reduce animosity of agricultural communities towards wolves is to compensate livestock producers for damage caused by wolves (Boitani, 1982; Gunson, 1983; Mech, 1995). We detected a strong relationship between yearly numbers of domestic animals killed and injured by wolves and compensation costs disbursed for damage throughout the study (linear regression, $R^2 = 0.86$, $F = 86.85$, $P < 0.001$; Fig. 3). On average, U.S. wildlife officials investigated instances of wolf depredation the same day that complaints were received (Mean = 0, SD = 1 days; range = 0–8 days). Most livestock producers contacted authorities between one and two days of estimated occurrence of death or injury to domestic animals (Mean = 1, SD = 3 days; range = 0–21 days). Compensation checks were sent to producers between 10 and 273 days after investigations, but on average within 77 days (SD = 53 days).

Our data indicate compensation is delivered promptly in our study area. Producers appear to patrol and check their properties and livestock intensively, and government investigations are timely. However, some losses might be undetected by ranchers (Oakleaf et al., 2003)

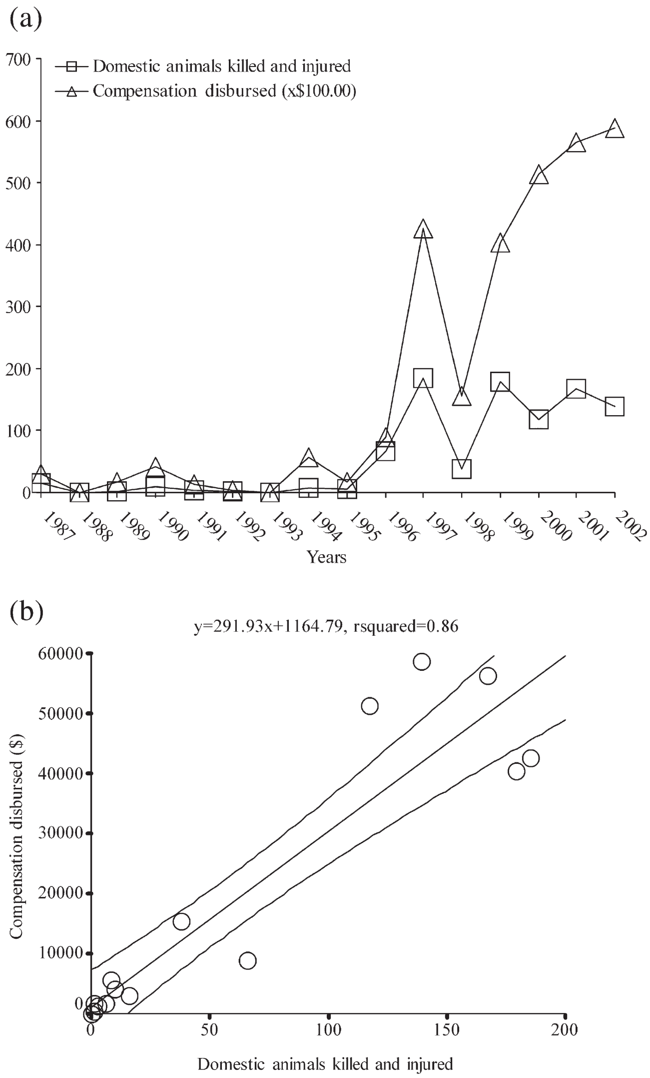


**Fig. 3.** Relationship between the number of domestic animals killed or injured by wolves and compensation disbursed for the damage in Idaho, Montana and Wyoming U.S. from 1987 to 2002. Trend in the total number of domestic animals killed and injured and compensation disbursed (a), and simple linear regression (with 95% confidence intervals) between number of animals killed and injured and compensation dollars disbursed (b).

or detected late when carcass decompositions preclude identification of the offending predator species (Bangs and Shivik, 2001). Thus, our sample, which deals only with confirmed losses due to wolves, likely overestimates promptness of detection. We found the major delay in the compensation program was in the sending of the actual compensation check – within an average of 2–3 months. However, the timing of refunding was comparable or shorter than other compensation programs for carnivore damage (Fourli, 1999). Even so, compensation programs could be improved by reducing the delay in delivering compensation money. In general, prompt payment is believed to contribute to ease public animosity (Wagner et al., 1997; Fourli, 1999). Producers invest in livestock every year and they benefit from weight gain and reproduction. Any delays in compensation result in additional losses to the producers, because of lack of such growth and reproduction in the compensation-delay period. Prompt compensation can reduce such additional losses. Furthermore, any delays in compensation would suggest to producers that the agencies providing compensation do not take the depredation problem seriously (Montag, 2003), and thus delays could undermine the effectiveness of compensation at reducing animosity towards wolves.

The positive influence of compensation programs on livestock producers' tolerance for wolves or other depredating carnivores is debatable (Naughton-Treves et al., 2003; Gusset et al., 2009). Ongoing wolf control in our study area (Bangs and Shivik, 2001; Bangs et al., 2004; USFWS, 2008) suggests that compensation has not necessarily improved tolerance of livestock producers toward wolves. There are several potential problems with compensation, including for example, disparity in the political views of agencies and livestock producers over who is responsible for damage, differences in urban and rural values and inability to address larger issues of large carnivore conservation, for example, human safety concerns (see Montag, 2003 for review). In addition, many producers believe compensation is inadequate because it does not compensate for emotional investment in livestock and because many wolf kills go uncompensated due to lack of detection or definitive evidence (Naughton-Treves et al., 2003). Furthermore, compensation does not typically account for "welfare loss" of depredation (Bostedt and Grahn, 2008), i.e., the value of an animal outside of its meat value; for example, the financial loss if the killed animal is an important breeding animal. Nevertheless, the benefits of ongoing wolf damage compensation programs appear to outweigh their costs and there cancellation is not advocated (Chambers and Whitehead, 2003; Naughton-Treves et al., 2003). Rather, organizations currently involved in compensation programs should be aware of the limitations of such programs for improving tolerance for wolves and enhancing wolf conservation.

### 3.3. *Costs of livestock depredation by wolves appear minimal at the industry scale, although significant at the ranch scale*

According to calculations based upon confirmed kills and average market price for livestock, wolves killed an average of $11,076.49 worth of livestock per year between 1987 and 2003, with a maximum of $41,230.32 in 2003 (Table 2). The estimated costs of livestock depredation increased during this period (linear regression, $R^2 = 0.789$, slope = 2445.161, $P < 0.001$; Table 2). Our estimates were correlated with published compensation disbursements provided by Defenders of Wildlife over the same period (Spearman correlation, $r = 0.986$, $P < 0.001$); however, our depredation cost estimates were lower than costs disbursed ($t = -3.101$, $P = 0.008$). These findings perhaps indicate willingness to also refund un-confirmed losses in some circumstance, with the likely aim to foster tolerance for wolves. We estimated an annual monetary value of cattle killed by wolves of $9,496.70. Sheep monetary value was approximately six times smaller

**Table 2**
Estimated value of livestock losses from wolves and, as a comparison, gross income from livestock production in Idaho, Montana and Wyoming from 1989 to 2002.

| Year | Livestock losses from wolves | | Cattle and calf operations income (Gross, × 1000) | Sheep and lamb operations income (Gross, × 1000) | Cattle and calf losses relative to income | Sheep and lamb losses relative to income |
|---|---|---|---|---|---|---|
| | Cattle | Sheep | | | | |
| 1989 | $1,632.21 | $0.00 | $2,041,756.00 | $66,696.00 | 0.0001% | <0.0001% |
| 1990 | $3,257.72 | $0.00 | $1,920,076.00 | $53,096.00 | 0.0002% | <0.0001% |
| 1991 | $1,192.86 | $47.72 | $1,976,956.00 | $55,639.00 | 0.0001% | 0.0001% |
| 1992 | $585.80 | $0.00 | $2,035,723.00 | $71,234.00 | <0.0001% | <0.0001% |
| 1993 | $0.00 | $0.00 | $2,110,752.00 | $73,988.00 | <0.0001% | <0.0001% |
| 1994 | $3,174.66 | $0.00 | $1,990,894.00 | $68,986.00 | 0.0002% | <0.0001% |
| 1995 | $1,355.84 | $0.00 | $1,820,334.00 | $85,548.00 | 0.0001% | <0.0001% |
| 1996 | $4,590.34 | $1,315.99 | $1,688,947.00 | $82,024.00 | 0.0003% | 0.0016% |
| 1997 | $10,124.73 | $5,753.82 | $2,096,127.00 | $88,774.00 | 0.0005% | 0.0065% |
| 1998 | $8,986.59 | $398.98 | $2,018,890.00 | $70,384.00 | 0.0004% | 0.0006% |
| 1999 | $14,667.43 | $3,321.93 | $2,109,207.00 | $67,290.00 | 0.0007% | 0.0049% |
| 2000 | $15,243.39 | $3,087.73 | $2,469,288.00 | $71,068.00 | 0.0006% | 0.0043% |
| 2001 | $20,833.68 | $5,269.56 | $2,662,758.00 | $56,717.00 | 0.0008% | 0.0093% |
| 2002 | $22,211.57 | $2,921.34 | $2,540,105.00 | $61,230.00 | 0.0009% | 0.0048% |
| 2003 | $34,593.68 | $6,636.64 | NA | NA | NA | NA |

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**Table 3**
Number and percentage of cattle and calf deaths due to predators and non-predator causes in Idaho, Montana and Wyoming in 2005.

| | | State | | |
|---|---|---|---|---|
| Cause of death | | Idaho | Montana | Wyoming |
| Coyotes | Cattle | – | – | 100 |
| | % Total cattle | – | – | 1 |
| | Calves | 600 | 1300 | 2100 |
| | % Total calves | 1 | 3 | 7 |
| Dogs | Cattle | – | – | – |
| | % Total cattle | – | – | – |
| | Calves | 100 | 100 | 100 |
| | % Total calves | <1 | <1 | <1 |
| Mountain lions and bobcats | Cattle | – | – | 100 |
| | % Total cattle | – | – | 1 |
| | Calves | 200 | 200 | 400 |
| | % Total calves | 0 | 0 | 1 |
| Other predators | Cattle | 400 | 200 | 300 |
| | % Total cattle | 1 | 1 | 3 |
| | Calves | 600 | 500 | 900 |
| | % Total calves | 1 | 1 | 3 |
| Total predator | Cattle | 400 | 200 | 500 |
| | % Total cattle | 1 | 1 | 5 |
| | Calves | 1500 | 2100 | 3500 |
| | % Total calves | 2 | 5 | 11 |
| Digestive problems | Cattle | 3200 | 1500 | 1200 |
| | % Total cattle | 8 | 8 | 11 |
| | Calves | 20,000 | 5500 | 5500 |
| | % Total calves | 32 | 12 | 18 |
| Respiratory problems | Cattle | 6900 | 3100 | 2700 |
| | % Total cattle | 16 | 16 | 25 |
| | Calves | 19,600 | 7800 | 6000 |
| | % Total calves | 31 | 17 | 19 |
| Metabolic problems | Cattle | 1800 | 200 | 200 |
| | % Total cattle | 4 | 1 | 2 |
| | Calves | – | 300 | – |
| | % Total calves | – | 1 | – |
| Mastitis | Cattle | 1500 | – | – |
| | % Total cattle | 4 | – | – |
| | Calves | – | – | – |
| | % Total calves | – | – | – |
| Other diseases | Cattle | 2100 | 2200 | 600 |
| | % Total cattle | 5 | 11 | 5 |
| | Calves | 2500 | 1100 | 800 |
| | % Total calves | 4 | 2 | 3 |
| Lameness/injury | Cattle | 2600 | 1000 | – |
| | % Total cattle | 6 | 5 | – |
| | Calves | 500 | 600 | – |
| | % Total calves | 1 | 1 | – |
| Weather related | Cattle | 200 | 1200 | 1000 |
| | % Total cattle | <1 | 6 | 9 |
| | Calves | 1100 | 10,200 | 6000 |
| | % Total calves | 2 | 22 | 19 |
| Calving problems | Cattle | 3300 | 1500 | 800 |
| | % Total cattle | 8 | 8 | 7 |
| | Calves | 5900 | 11,300 | 7000 |
| | % Total calves | 9 | 25 | 23 |
| Poisoning | Cattle | 500 | 800 | 800 |
| | % Total cattle | 1 | 4 | 7 |
| | Calves | 300 | 300 | 700 |
| | % Total calves | <1 | 1 | 2 |
| Theft | Cattle | 100 | – | 100 |
| | % Total cattle | <1 | – | 1 |
| | Calves | 100 | 300 | 500 |
| | % Total calves | <1 | 1 | 2 |
| Other non-predator | Cattle | 2000 | 3500 | 3100 |
| | % Total cattle | 5 | 18 | 28 |
| | Calves | 1000 | 900 | 1000 |
| | % Total calves | 2 | 2 | 3 |
| Unknown non-predator | Cattle | 17,300 | 4200 | – |
| | % Total cattle | 41 | 22 | |
| | Calves | 10,000 | 5300 | – |
| | % Total calves | 16 | 12 | |
| Total non-predator | Cattle | 41,500 | 19,200 | 10,500 |
| | % Total cattle | 99 | 99 | 95 |
| | Calves | 61,000 | 43,600 | 27,500 |
| | % Total calves | 98 | 95 | 89 |
| Total | Cattle | 41,900 | 19,400 | 11,000 |
| | Calves | 62,500 | 45,700 | 31,000 |

Other predators include wolves, grizzly bears and black bears.

($1,579.79). However, the proportion of monetary loss relative to gross income of the industry in Idaho, Montana and Wyoming was one order of magnitude smaller for cattle than for sheep (Table 2); thus, sheep producers experienced proportionally higher costs due to wolves. In either case, the monetary value of cattle and sheep killed by wolves was less than 0.01% of the total income of all producers.

To give further perspective to the depredation problem, we analyzed data gathered in Idaho, Montana and Wyoming in 2005 which documents the relative contribution of predators to cattle mortality from all causes. The number of cattle and calf losses due to the category called "other predators" (including wolves, grizzly bears and black bears) was no more than 3% of all mortality (Table 3). This result suggested that within those states with wolf populations, the total costs of cattle depredation by wolves to the industry is relatively low compared to the costs of other losses (i.e., total non-predator losses accounted for at least 89% of all losses). Unfortunately, such data was not available for sheep, nor does it describe the relative contribution of wolves compared to other predators. Although, we have no reason to believe that losses due to wolves to other livestock species would be substantially different.

Despite the relatively low cost of wolf depredation to the livestock industry, depredation could be comparatively costly at the ranch scale. In particular, individual producers that experience multiple depredations (Niemeyer et al., 1994; Naughton-Treves et al., 2003) or excessive killing (see above) may carry a higher burden of the costs. In other words, the costs of depredation are not evenly distributed across the industry (Collinge, 2008). A few attacks with significant losses of livestock may disproportionately influence intolerance for wolves, with negative effects for conservation. Research on risk perception suggests that people focus on maximal events rather than the average (Lehmkuhler et al., 2007); therefore, despite low costs to the industry, livestock producers within wolf range may focus on and be concerned about high cost of some depredation events, such as those documented in this study. Finally, costs of depredation are increasing (Table 2), which also likely concerns producers.

### *3.4. Increasing land price and decreasing cattle price may negatively impact livestock production and wolf conservation*

Land price increased in the Northwestern U.S. during the study period (Fig. 4). There was a significant increase in CPI adjusted average annual farm real estate for Idaho (linear regression, $R^2 = 0.954$, slope = 88.887, $P < 0.001$), Montana (linear regression, $R^2 = 0.876$, slope = 16.262, $P < 0.001$), and Wyoming (linear regression, $R^2 = 0.943$, slope = 19.490, $P < 0.001$), and all three states together (linear regression, $R^2 = 0.966$, slope = 41.638, $P < 0.001$). Annual rates of change were mostly positive since 1994 (Fig. 4b) with a mean value of 2.96% (SD = 1.61%), 2.20% (SD = 2.70%), 3.09% (SD = 1.25%) and 2.81% (SD = 1.13%) for Idaho, Montana and Wyoming, and all three states, respectively. The rate of change was negative in only two years (1997 and 1999), and only in Montana. Thus, land prices were generally increasing at a steady and predictable rate during the study period.

The price of cattle decreased during the study period (Fig. 5). There was a significant negative trend in the price of cows (linear regression, $R^2 = 0.749$, slope = −8.538, $P < 0.001$), steers and heifers ($R^2 = 0.436$, slope = −6.024, $P = 0.007$), and calves (linear regression, $R^2 = 0.268$,

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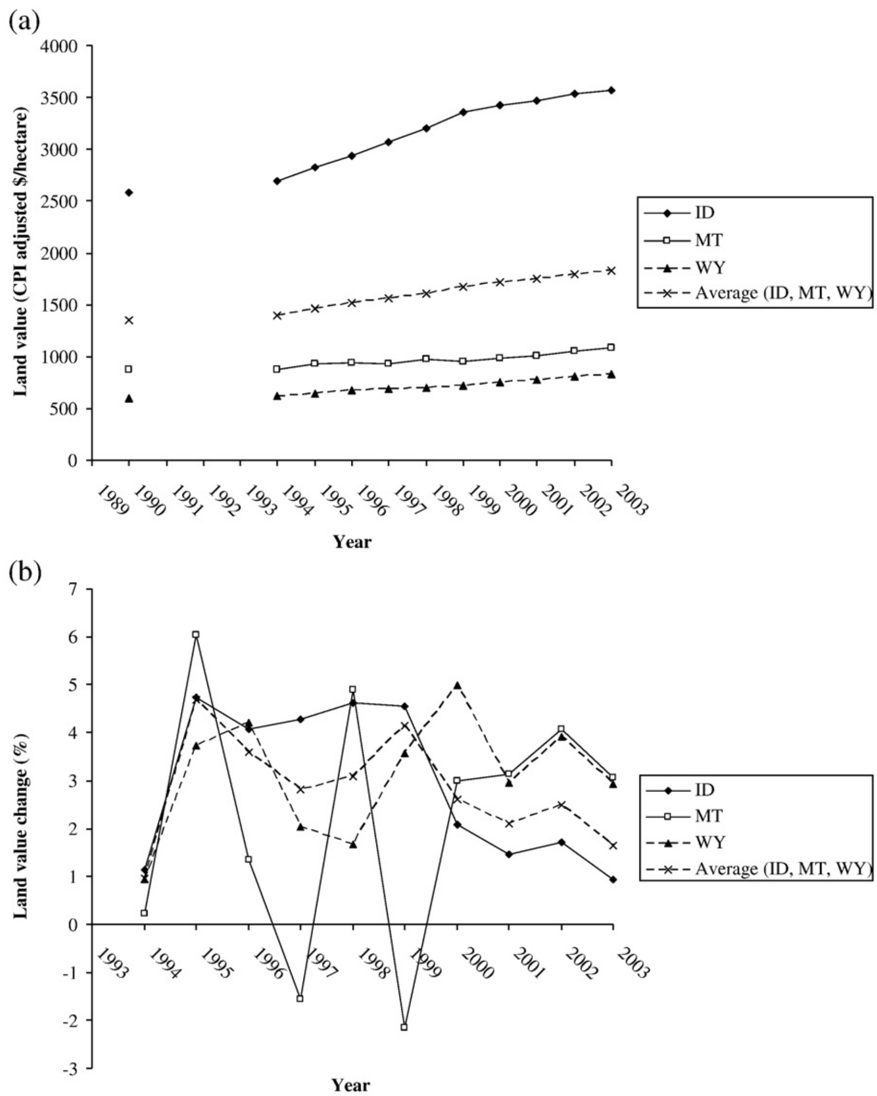


**Fig. 4.** Average 2007 Consumer Price Index (CPI) adjusted annual farm real estate value (a), and annual percent change in farm real estate value (b), for Idaho, Montana and Wyoming from 1990 to 2003. Farm real estate value (a) provided in CPI adjusted U.S. dollars per hectare. Percent change in farm real estate value (b) is the change in adjusted value from the previous year to the next year except 1994, which was interpolated assuming an equal annual change between 1990 and 1994.

slope = −7.823, $P$ = 0.048). There was no significant trend in sheep and lamb price. The average annual percent change in livestock price was −2.08% (SD = 12.63%), −0.03% (SD = 13.18%), 0.92% (SD = 20.90%), −0.67% (SD = 17.55%), and −0.24% (SD = 18.16%), for cows, steers and heifers, calves, sheep, and lambs, respectively. Contrary to land prices (Fig. 4b), changes in livestock prices varied between positive and negative values across years (Fig. 5b) and livestock prices were much more variable than land prices (i.e., they had a much larger standard deviation relative to the mean). These findings indicate volatility in the price of livestock.

Decreasing (in the case of cattle) or stagnant (in the case of sheep) trends in livestock prices coupled with increasing land prices might be of concern to groups interested in conservation of wildlife on or adjacent to agricultural lands. Throughout the U.S. and including Idaho, Montana and Wyoming, demand for agricultural land that provides natural amenities is increasing (Hansen et al., 2002; Talbert et al., 2007). In fact, agricultural lands within or adjacent to wildlife (including wolves) and wildlife habitat are in even greater demand and thus command higher prices (Duffield, 1992; Rasker and Hackman, 1996; Bastian et al., 2002). This demand for amenities has resulted in subdivision of agricultural ranchlands in favour of rural-residential development (Sengupta and Osgood, 2003; Gosnell and Travis, 2005).

### 3.5. Implications for wolf conservation planning

Compensation for livestock depredation by wolves might help those livestock producers that experience depredation offset some of the financial burden for conserving wolves; however, compensation programs as they are currently designed are inadequate for recognizing positive externalities of livestock production to wolf conservation. There are other economic tools that can recognize these externalities and thus perhaps further encourage tolerance for wolves and improve wolf conservation on agricultural lands.

Various studies highlight the importance of agricultural rangelands for wildlife conservation in Western North America (Fritts et al., 1994; Hobbs et al., 2008). Some authors object that in these areas wildlife conservation also presents challenges (see Wuerthner, 1994). For example, excessive livestock grazing can degrade habitat for wild herbivores (Milton et al., 1994) and thus potentially reduce the abundance of wild prey for wolves. In any case, conversion to rural-residential developments may be a worse alternative as it will

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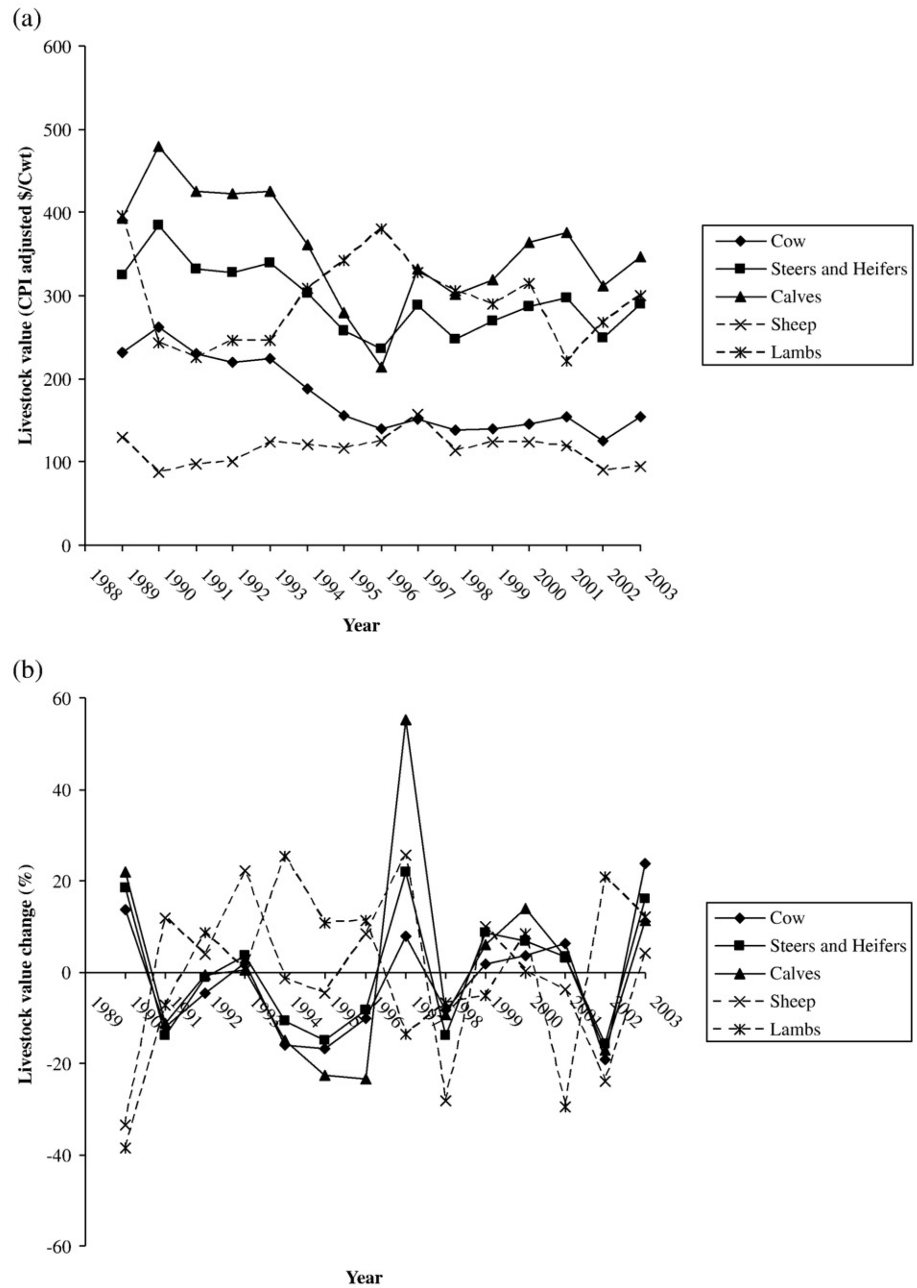


**Fig. 5.** Average 2007 Consumer Price Index (CPI) adjusted August value of livestock (cattle, steers and heifers, calves, sheep and lambs) (a), and percent change in livestock value (b), for Idaho, Montana and Wyoming from 1989 to 2003. Value of livestock in (a) provided in CPI adjusted U.S. dollars per hundredweight (i.e., 100 lb; Cwt). Percent change in (b) is the change in adjusted value from the previous year to the next year. August is the month used to determine livestock value, as that is the month with peak depredations (Musiani et al., 2005) and thus the value at which many livestock are compensated.

dramatically change landscape structure by increasing human presence, as well as fragmenting and removing habitat (Theobald et al., 1997; Mitchell et al., 2002; Sengupta and Osgood, 2003). The implications of rangeland subdivision may be particularly negative for wide ranging herbivores, and their predators (including wolves), as habitat fragmentation can restrict access to forage, water and other resources on the landscape (Hobbs et al., 2008). Therefore, livestock production takes place in agricultural rangelands that provide positive externalities (*sensu* Pigou, 1932; Baumol, 1972) in the form of large tracts of heterogeneous wildlife habitat on private land. These externalities are recognized as clear benefits by some conservationists.

Given the economic trends we identified above, conversion of agricultural land to rural-residential development appears to be a realistic possibility in the Northwestern U.S. We suggest that if wolf conservation is a recognized societal objective (Musiani and Paquet, 2004), then public funds destined to wolves may be used to contribute to habitat conservation more directly – i.e. not just to refund wolf damage to livestock. In practice, wolf conservation programs could contribute funds to support ecologically-friendly livestock production in intact rangelands. Availability of such funds could be justified to wolf conservationists by explaining the benefits offered to large sectors of society by such areas.

One example of an economic tool that could be used to more effectively achieve wolf conservation in agricultural rangelands are conservation performance-payments, which are monetary or in-kind payments made by an agency to individual or groups of landowners that achieve specific conservation outcomes (Albers and Ferraro, 2006; Zabel and Holm-Müller, 2008). In the case of wolf conservation

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in the Northwestern U.S., for example, payments could be made to livestock producers that conserve a certain number of wolves on their land; producers that conserve more wolves would receive larger payments. Conservation performance-payments may therefore provide incentive to conserve wolves. Lethal control of wolves would theoretically become a less-desirable response to depredation for livestock producers, as payments would decrease with fewer wolves. The program would also put fewer burdens on livestock producers to find and report livestock depredation events, and the need to promptly investigate and reimburse losses would no longer be required by the compensating agency (Zabel and Holm-Müller, 2008). Ultimately, such payments could also help livestock producers maintain their operations despite poor livestock prices. We caution, however, that the outcomes of conservation performance-payment programs are still uncertain and therefore should not be widely applied without further testing of their effectiveness. Nevertheless, the economics of wolf conservation may become more explicit with conservation performance-payments, as the costs of wolves to livestock producers and the benefits of agricultural rangelands for wolf conservation are defined by the payment.

The approaches explained above may not resolve the conflicts around wolves, because such conflicts may arise from societal issues of broader relevance. The array of people and groups interested in wolves or affected by wolf presence may be in conflict for reasons other than wolves. Thus, surrogate conflicts may arise that are indicative of broader disputes (not directly wolf-related). For example, people coming from urban areas may be in conflict with rural residents, people relying on academic knowledge may experience tension with those relying on local knowledge, and people relying on “traditional principles” might not appreciate “modern values” or their promoters. In our study area, livestock producers might oppose wolf reintroduction and conservation due to negative feelings prompted as a means to protest federal agencies from establishing greater regulation on private landowners (Montag, 2003; Naughton-Treves et al., 2003).

## 4. Conclusion

We documented excessive killing of livestock for sheep, but not for cattle, and thus could confirm the perception of livestock producers that wolves may kill some types of livestock in excess of food needs. Fear that such a behavior could occur has contributed to negative attitudes towards wolves (Gipson et al., 1998). Thus, managers and scientists should acknowledge that wolves can conduct excessive killing of sheep as they are highly vulnerable due to their morphology, husbandry and behaviour. A single depredation event may have a greater impact on the welfare of an individual sheep producer than cattle producer, which should be accounted for in compensation programs so that those farmers experiencing excessive killing are compensated promptly and efficiently.

In the period during which wolves had endangered species status and were managed by the USFWS with compensation provided by Defenders of Wildlife, the only noteworthy delay in the compensation program occurred at the delivery of the payment (2–3 months); however, timing was comparable to other programs around the world. Nevertheless, reduction in this delay could potentially improve the program by allowing producers to quickly purchase new livestock so they can profit from weight gain and reproduction. Our estimates of the monetary value of cattle and sheep killed were correlated with, albeit significantly lower than the published amount of compensation disbursed by Defenders of Wildlife. Perhaps the discrepancy reflected willingness by compensation providers to refund livestock producers also for unconfirmed loses in the hopes of improving tolerance for wolves. However, it is unclear whether higher levels of compensation translate to increased tolerance (see Naughton-Treves et al., 2003).

This study highlights that the total number of cattle lost due to wolf depredation are minor compared to other causes of death in Idaho, Montana and Wyoming. In addition, livestock depredation costs, although increasing during the study period, were negligible relative to income generated from livestock production in the study area. However, single depredation events can potentially be costly to individual producers. Furthermore, livestock producers in the area were facing significant economic challenges during this period, as the price of cattle declined and the price of sheep remained stagnant and the price of both was highly variable. Given the unpredictability and overall decline in monetary value of livestock, suspension of compensation programs may hamper those ranchers affected by chronic wolf depredation and this might result in further opposition to wolf presence. Thus, compensation programs should be continued in the future, as is common practice for other carnivores that kill livestock worldwide (Wagner et al., 1997; Fourli, 1999). However, compensation providers should be aware that such programs may be limited in their ability for improving tolerance for wolves as surrogate issues related to cultural, political and ethical factors may be more significant at affecting tolerance (Montag, 2003; Naughton-Treves et al., 2003).

In contrast to livestock prices, land prices were increasing and were relatively stable from one year to the next. Thus, land value was much more predictable for livestock producers. Demand for natural amenities (e.g., recreational opportunities, viewscapes; *sensu* Hansen et al., 2002) has contributed to the trend in conversion of agricultural land to higher density rural-residential land uses throughout the U.S., including the study area (Hansen et al., 2002; Sengupta and Osgood, 2003; Brown et al., 2005; Gosnell and Travis, 2005). The trends in land and livestock value we identified may further encourage this recent phenomenon, as, from an economic perspective, selling land would be the best way for livestock producers to profit from their assets. Wide scale changes in land use, from agriculture to rural-residential, are possible which may have significant implications for wildlife conservation and management. Such changes can dramatically alter habitat and increase human presence in agricultural areas (Theobald et al., 1997; Hansen et al., 2002; Mitchell et al., 2002) potentially resulting in a decline in ecosystem services (*sensu* Daily, 1997) provided by private lands. Clearly the economic trends we identified and the literature indicate this phenomenon deserves attention, particularly from groups interested in conservation of species on agricultural lands.

Wolves are a public good, with a negative economic externality (livestock depredation) shouldered by livestock producers. Ironically, large tracts of relatively undeveloped land managed for livestock production may provide a positive externality for wildlife conservation, including wolves; particularly relative to rural-residential development. Therefore the ultimate question is how to reconcile these externalities. Broader societal investment in preserving some forms of livestock production may be necessary to avoid marginalization of rural communities and ensure ecosystem services, including wolf conservation, contributed by some private lands continue to be provided to the general public.

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