Economic Analysis of Indemnity Payments for Wolf Depredation on Cattle in a Wolf Reintroduction Area

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ABSTRACT: Mexican gray wolves were reintroduced into New Mexico and Arizona in 1998. When wolves kill a producing cow, ranchers in the region are eligible to receive an indemnity payment equal to the market value of the lost animal. We developed a model that allows estimation of the present value of the revenue stream that a cow or herd provides and find that if a producing cow is killed, the decrease in the present value of the rancher's revenue stream is about $1,230. Mean indemnity payments are currently $1,000, implying ranchers are not being sufficiently compensated.

KEY WORDS: Arizona, *Canis lupus baileyi*, cow-calf operations, economic valuation, indemnity, livestock predation, Mexican gray wolf, New Mexico, predation, wolf

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INTRODUCTION

The native range of the Mexican gray wolf (*Canis lupus baileyi*) extended from central Mexico north through Arizona and New Mexico and south of Interstate 40. By the mid-1900s most Mexican gray wolf (henceforth "wolf") populations had been eliminated through federal, state, and private control campaigns in response to wolf impacts on the livestock industry. Following the passage of the Endangered Species Act in 1973 and the subsequent inclusion of the wolf as an endangered species in 1976, recovery efforts to save the species from extinction in the United States were enacted (USFWS 2007).

For more than 30 years in Arizona and New Mexico, the threat that wolves posed to cattle (*Bos primigenius*) was nonexistent. This changed in 1998, when the first group of wolves was reintroduced into the Blue Range Wolf Reintroduction Area (BRWRA) in eastern Arizona (Figure 1). Reintroduction was conducted by the United States Fish and Wildlife Service (USFWS) and the Arizona Game and Fish Department under the Mexican Gray Wolf Recovery Program (USFWS 2007).

Cattle ranches are common within the BRWRA and surrounding areas, and wolf reintroduction and increasing wolf populations have led to increased wolf-livestock interactions. According to the U.S. Department of Agriculture's Wildlife Services (WS) records from 1998-2006, wolf predation of livestock in the BRWRA occurred mainly to cattle (cows and calves) and most often during late spring and summer months. In 1998, there were only 2 confirmed or probable cattle depredation incidences by wolves. This number increased to 11 in 2002, 38 in 2005, and during the 2-week period of June 5-18, 2006 there were 9 cattle depredation incidences (USFWS 2007).

Clearly, the change in government policy from wolf eradication to reintroduction has had an impact on the economic returns for ranchers within the reintroduction area. However, despite the harm to ranchers, the policy shift may be socially desirable. A common criterion used to evaluate the social desirability of a change in public policy is economic efficiency: Pareto efficiency is defined as an allocation in which it is impossible to make someone better off without making anyone worse off (Varian 1992). Thus, a Pareto improvement is a change in which someone has been made better off without making anyone else worse off. The policy change in question could not be considered a Pareto improvement since ranchers were arguably made worse off.

However, another economic efficiency known as Kaldor-Hicks efficiency defines efficiency differently. The Kaldor-Hicks concept defines an outcome as more efficient if it is possible to create a Pareto improvement through those made better off compensating those made worse off (Varian 1992). Thus, an outcome is deemed efficient if the winners could make a payment to the losers such that no one is worse off. However, it should be emphasized that if a policy is judged efficient according to this definition, it does not require that a compensating payment actually be made; it only requires that it could be made. Therefore, a policy is judged efficient if the benefits outweigh the costs, regardless of who those benefits and costs fall on.

It is unknown if the shift in policy from wolf eradication to reintroduction is efficient according to the Kaldor-Hicks definition. If the benefits to those who support reintroduction exceed the costs incurred by ranchers, then it is. In this study, no attempt is made to judge the efficiency of the policy shift. Rather, the focus is on estimating the minimum size of the payment that would have to be made to ranchers such that they are not worse off. While Kaldor-Hicks efficiency does not require the compensating payment be made, political acceptability and societal notions of fairness may. A

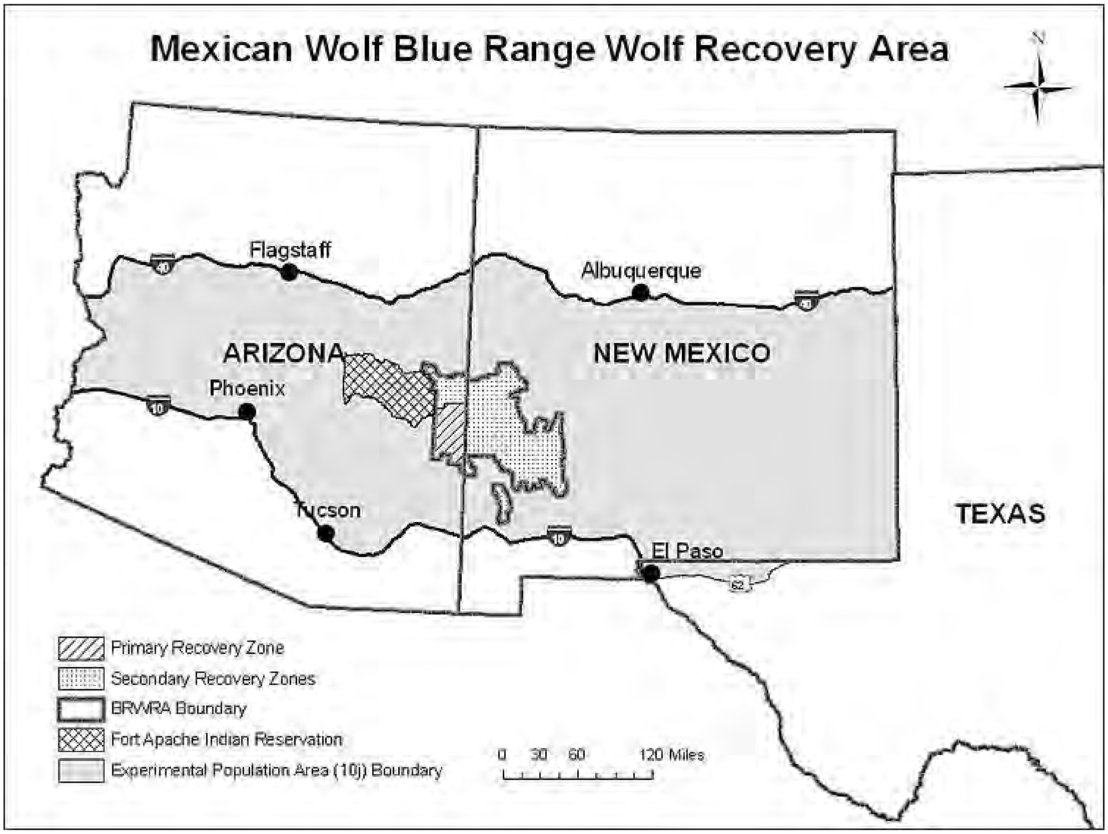

Figure 1. Map of Mexican gray wolf recovery area, including the Blue Range Wolf Reintroduction Area (BRWRA). (USFWS 2012)

sufficient compensating payment may also be necessary for the cooperation of ranchers. Therefore, estimation of the necessary size of this payment is important.

Indemnification programs are a common way to compensate ranchers for livestock losses. Indemnity may be paid to ranchers for an unanticipated livestock death, shifting the cost away from the individual rancher to the government or private individuals and organizations. Generally, indemnity programs' goals are focused for the benefit of endangered species' survival, preservation of habitat or range of wildlife, or to ease recovery efforts of reintroduced wildlife. The economic incentive of these indemnity funds has been vital to the successful reintroduction efforts of multiple endangered and reintroduced species on public and private lands (Defenders of Wildlife 2006, USFWS 2007).

The Bailey Wildlife Foundation Wolf Compensation Trust (henceforth "Trust") is the indemnification program that reimbursed ranchers for livestock losses due to wolf predation in the BRWRA (Defenders of Wildlife 2006). The goal of the Trust was to shift the economic responsibility for wolf recovery away from the individual livestock rancher and towards those who want wolf populations restored in their natural habitat. The Trust offered a lump-sum payment to the ranchers whose animals were depredated by wolves.

Identifying the appropriate amount of indemnity can be difficult, since the effects of a lost animal can linger for many years. The most commonly used benchmark to assess the value of an animal is the fair market price of the animal at the time of the animal's death. However, such an approach fails to consider the loss in revenue due to interrupted production that may occur when an animal is lost. Therefore, this study will estimate the payment that would effectively compensate a rancher for the loss of an animal accounting for any interruptions in production.

METHODS

Earlier studies have established the dual role of cattle as both a capital good and a consumption good (Reutlinger 1966, Jarvis 1974). In particular, the value of a producing cow is a function of this duality. Producing cows are considered a capital good because they are used to produce calves. But at any time, a cow may also be sold to slaughter as consumption good. Additionally, due to a limited lifecycle, a producing cow is a depreciating asset whose value diminishes over time (Mackay et al. 2004). Depreciation can be directly observed in the diminishing slaughter or salvage value of a cow as she ages.

Present value (PV) analysis is commonly used by ranchers to guide management decisions and determine optimum herd size in relation to different market, feed, and capital prices. PV analysis estimates the present value of all future revenue from an asset (the animal or herd). For a producing cow, future earnings include the price its calves can be sold for as well as its own value when culled. When cattle ranchers use this type of analysis, it is common to differentiate between calves and yearlings, cows, bred heifers, bulls, steers, and cow-calf pairs (Reutlinger 1966). The differentiation allows the producer to distinguish between those individual animals (cows, bulls, bred heifers) that have the dual nature of being a capital and consumption good and those (feeder calves and yearlings, steers) that are exclusively consumption goods.

The profitability of cow-calf operations depends greatly on the cow culling and replacement decisions (Melton 1980, Schmitz 1997). Herd size is consciously allowed to grow through the retention of additional heifers when the expected net present value of retaining those additional heifers exceeds the amount they could be sold for. Likewise, herd size is allowed to decrease when the net present value of retaining heifers is less than the price those animals could be sold for (Trapp 1986, Mackay et al. 2004). However, herd size can be influenced by events outside the rancher's control. Cattle can unexpectedly die for many reasons including diseases such as rabies; digestive and respiratory problems; environmental factors such as drowning and lightning strikes; and depredation by predators (USDA 2006). With unanticipated death, the choice between retaining and culling an animal is taken away from the rancher.

The current indemnity program bases reimbursement on the current market price of the cow or calf. However, this amount is insufficient if the animal is a producing cow. Beyond a certain age, the market price of a cow will only (or mostly) reflect its use as consumption good, but its full value to the rancher is also derived from its use as a capital good. The current reimbursement amount is also problematic for another reason. When a rancher loses a producing cow, he/she has the option of purchasing any variety of replacement cows (open cow, bred cow, heifer, bred heifer, or cow-calf pair) from a livestock auction, or they may retain one of their own calves to replace the lost cow. There is significant uncertainty associated with the purchase of a replacement cow. The rancher cannot be sure of the quality of the animal, that the cow calves easily or cares for the calf, or what type of bull sired the calf. Additionally, the animal will lack knowledge of the area it will be introduced to, and the rancher may be uncertain where the animal originated. For these reasons, many ranchers prefer to raise their own replacement heifers, and the uncertainty of buying a replacement animal at auction results in a market price that is below the value of the animal lost to predation**.**

To estimate the correct indemnity amount, an economic model is created that accounts for both the capital and consumption value of a producing cow. Additionally, the model reflects the conventional management practices in the BRWRA region of Arizona and New Mexico. The model assumes a rancher has a single producing cow that produces a calf annually beginning at 2 years of age until the cow is culled in the fall when 10 years old, after producing a 9th calf. To simplify the analysis, it is assumed that all calves are female. To reflect the preference of many ranchers in the BRWRA region, the model assumes the 9th calf from the producing cow will be retained as a replacement heifer. If the producing cow is killed, the calf born in that year will be retained as a replacement.

The value of this producing cow can be viewed as the present value of the revenue stream that it provides. This revenue stream depends on the particular mix of calves produced, the price those calves are sold for, and the cull value of the cow. However, the revenue provided by the current producing cow may not be the only revenue of interest. The retained heifer that replaces it also provides revenue. To the rancher, the relevant stream of revenue is the revenue he/she earns over all the years in which they are in business. This may only include revenue from the current producing cow, but it also includes revenue from the offspring of that cow.

If the original producing cow is killed, the impact on the rancher's revenue is not limited to the lifetime of that cow. A calf that would have been sold must be retained and the production cycle is interrupted and shifted. Therefore, the loss of a producing cow can have impacts that last for many years. Estimation of the harm caused by the loss of the cow must account for how that loss affects the revenue stream realized by the rancher over all the years in which he/she is in business. The present value of the revenue stream realized by the rancher over 15 years when there is no unexpected loss of a producing cow is given by

$$(1) \qquad P_{a} = \sum_{t-0}^{7}\left[\frac{F}{(1+r)^{t}}\right] + \sum_{t-1}^{1}\left[\frac{F}{(1+r)^{t}}\right] + \frac{C_1}{(1+r)^{8}}$$

where F is the price a calf can be sold for, C_{10} is the cull value of a cow at 10 years of age, and r is the annual discount rate. Note that the time frame starts at t = 0 when the producing cow has its first calf at 2 years old. Revenue from selling a calf is not realized in t = 8 or t = 9. In time period 8, the calf born is retained to replace the producing cow, which is culled in the same year. In time period 9, the replacement heifer is not old enough to calve. Additionally, note that we are assuming no mortality risk due to non-predation causes.

If the rancher were to quit the business after 15 years, it may be desirable to include the value of their producing herd in the 15th year under the assumption it would be sold. In the model developed here, the herd consists of only one cow, so Equation 1 can be modified to account for the sale of the producing cow when production stops, to obtain

$$(2) \quad P_{b} = \sum_{t-0}^{7}\left[\frac{F}{(1+r)^{t}}\right] + \sum_{t-1}^{1}\left[\frac{F}{(1+r)^{t}}\right] + \frac{C_1}{(1+r)^{8}} + \frac{C_6}{(1+r)^{1}}.$$

Although the producing cow could be killed at any age, in this model it is assumed it is killed the summer after calving once. Therefore, the rancher will keep the cow's first calf as a replacement and the rancher loses revenue because this calf is not sold. Additionally, since the replacement heifer will not be mature enough to produce the following season, the rancher will lose a year of production. Accounting for the loss of the producing cow, the present value of the revenue stream realized by the rancher over 15 years becomes

$$(3) \qquad P_{a} = \sum_{t-2}^{9}\left[\frac{F}{(1+r)^{t}}\right] + \sum_{t-1}^{1}\left[\frac{F}{(1+r)^{t}}\right] + \frac{C_1}{(1+r)^{1}}.$$

Likewise, the revenue stream accounting for the sale of the herd in year 15 becomes

$$(4)\quad P_{b} = \sum_{t=2}^{9}\left[\frac{F}{(1+r)^t}\right] + \sum_{t=12}^{14}\left[\frac{F}{(1+r)^t}\right] + \frac{C_{10}}{(1+r)^{10}} + \frac{C_4}{(1+r)^{14}}.$$

The difference in the 15-year revenue streams (excluding herd sale in year 15) is given by

$$(5)\quad \Delta P_{a} = \sum_{t-8}^{9}\left[\frac{F}{(1+r)^t}\right] - \sum_{t-0}^{1}\left[\frac{F}{(1+r)^t}\right] - \sum_{t-1}^{1}\left[\frac{F}{(1+r)^t}\right] + \frac{C_1}{(1+r)^1} - \frac{C_1}{(1+r)^8}$$

Note that if r = 0, $\Delta PV_a = -2F$. This key result shows that the decrease in the present value of the revenue stream is approximately equal to the value of 2 calves. It is only approximately equal because exact equality depends on a discount rate of zero. The effects in later time periods that perfectly offset each other with a zero discount rate will not perfectly offset each other with a positive discount rate. A similar result is obtained when the revenue gained from selling the producing cow in year 15 is accounted for, although the difference in present value also reflects the slight difference in the value of that cow at that time due to age. This additional difference can be seen in the last 2 terms of Equation 6:

$$(6)\quad \Delta P_{b} = \sum_{t=8}^{9}\left[\frac{F}{(1+r)^t}\right] - \sum_{t=0}^{1}\left[\frac{F}{(1+r)^t}\right] - \sum_{t=1}^{1}\left[\frac{F}{(1+r)^t}\right] + \frac{C_1}{(1+r)^1} - \frac{C_1}{(1+r)^8} + \frac{C_4}{(1+r)^1} - \frac{C_6}{(1+r)^1}.$$

The above discussion is based on the assumption that the relevant revenue stream is from t = 0 to t = 14. Consideration of different time frames will change Equations 1-6. Therefore, the results section will calculate the change in present value of the revenue stream over a number of different time frames.

RESULTS

Price information was obtained from the 2005 New Mexico Annual Statistical Bulletin as reported by the National Agricultural Statistical Service (NASS 2005). Calves were valued at $720.50, and the price at which a producing cow can be sold for is assumed to decrease linearly from 1-10 years of age, starting at $1,199. The discount rate is assumed to be 3%. Table 1 presents the key results of the model. The loss in revenue equal to the value of 2 calves can be seen in the change in annual revenue in t = 0 and t = 1. Additionally, the changes in annual revenue that would perfectly offset each other when r = 0 can be seen in time periods 8-11. The change in t = 8 is due to the additional revenue from having a calf to sell when there was not one previously. However, this gain is partially offset by the fact that the producing cow is no longer culled in that year. The gain in t = 9 is purely due to having a calf to sell when the rancher did not previously have one. The offsetting negative amounts in t = 10 and t = 11 result from effects exactly opposite of those just described.

Although the changes in annual revenue after t = 1 are perfectly offsetting when r = 0, when r > 0 they tend to reduce the negative impact of the lost cow as the time frame of analysis is extended. This results from the fact that the positive effects always precede the negative effects. Thus, the positive effects are discounted less than the negative effects. This effect is less obvious when the revenue provided by the sale of the producing cow when the rancher stops producing is considered. Note that consideration of this impact makes the timeframe of analysis matter less. Because the replacement heifer is younger than the original cow, she and her producing offspring are worth more when sold in most years. However, there are periodically years in which she and her producing offspring would be worth less. For example, in t = 9, the original cow, had she not been killed, would have already been replaced by her last calf that would be 1 year old at that point. Yet, the heifer that replaces her when she is killed in t = 0 is still alive in t =9. The original replacement heifer is worth considerably less at 9 years old than a 1-year-old calf.

It is interesting that ΔPVa and ΔPVb converge if the timeframe is extended far enough. In relatively shorter timeframes, the difference between ΔPVa and ΔPVb is created by the revenue realized when the producing cow is sold. However, as that sale of that final producing cow is pushed farther into the future, the discounted value of the revenue provided decreases and will eventually approach zero. Therefore, the difference between ΔPVa and ΔPVb is gradually eliminated.

Table 1. Change in the producer's annual revenue and change in the present value of their revenue stream when the herd is not sold (PV_a) and sold (PV_b), evaluated over different time periods (*t*). For example, if the producer sells his/her herd after 10 years, the change in the net present value of revenue over the course of that 10-year time period would be a decrease of $1,128.40.

t	Δ Annual Revenue ($)	Δ PV_a ($)	Δ PV_b ($)
0	-720.5	-720.5	-1,100.0
1	-720.5	-1,423.4	-1,230.3
2	0.0	-1,423.4	-1,235.0
3	0.0	-1,423.4	-1,239.6
4	0.0	-1,423.4	-1,244.0
5	0.0	-1,423.4	-1,248.4
6	0.0	-1,423.4	-1,252.7
7	0.0	-1,423.4	-1,256.9
8	368.5	-1,121.0	-1,297.0
9	720.5	-544.1	-1,178.2
10	-368.5	-831.9	-1,128.4
11	-720.5	-1,381.1	-1,230.1
12	0.0	-1,381.1	-1,233.8
13	0.0	-1,381.1	-1,237.4
14	0.0	-1,381.1	-1,240.9
15	0.0	-1,381.1	-1,244.3
16	0.0	-1,381.1	-1,247.7
17	0.0	-1,381.1	-1,250.9
18	368.5	-1,144.8	-1,282.3
19	720.5	-694.1	-1,189.5
20	-368.5	-919.0	-1,150.6
21	-720.5	-1,348.0	-1,230.1
22	0	-1,348.0	-1,232.9
23	0	-1,348.0	-1,235.8
24	0	-1,348.0	-1,238.5
∞	NA	-1,229.8	-1,229.8

DISCUSSION

Despite the results provided above, it remains unclear what a sufficient amount of compensation for the loss of a producing cow would be. The difficulty is that the change in present value of the revenue stream is dependent on exactly how long the rancher will be in business or on the time frame considered. Based on the annual revenue loss, an argument could be made that a rancher should be paid an amount equal to the value of 2 calves. Yet, this is almost certainly overstating slightly the actual loss realized by the rancher. There are 3 reasons that this overstates the actual loss. First, in the year in which the cow is lost, the rancher's revenue is less by the value of one calf; the loss in revenue equal to the value of a second calf occurs the following year and should be discounted. Second, if the rancher is in business long enough to realize revenue from the next generation of producing cows, the loss will be further reduced due to the aforementioned effects of discounting the offsetting future changes in revenue. Third, compensation equal to the value of 2 calves overstates the revenue loss because it fails to consider the revenue earned by the rancher when the producing cow (or herd) is sold if production is stopped.

Ruling out the value of 2 calves as the correct revenue loss on which to base compensation leaves two options. One is to assume arbitrarily that the rancher will leave the business at some point; compensation could then be based on the decrease in the present value of the revenue stream including the revenue provided by the sale of the cow when production is stopped. However, the assumption would be arbitrary and would affect the results. It is at least clear that if such an assumption is made, ΔPVb rather than ΔPVa is the relevant measure of the loss. This is because the rancher would sell any remaining animal when production is stopped.

The only remaining possibility is to base the loss on the amount to which both ΔPVa and ΔPVb converge ($-1,230). This has 3 advantages. First, it avoids making a choice between ΔPVa and ΔPVb. Second, it avoids making an arbitrary assumption about the correct time-frame of analysis. Finally, it is approximately equal to the mean of ΔPVb (the mean for time periods 0 to 24 is $-1,226). This is a desirable property, since it could be argued that in the absence of information about how long the rancher will remain in business, it should be assumed that production will be stopped in some year with a probability that is constant across all feasible years. Thus, the difference in the expected present value of the revenue stream realized by that rancher would simply be the mean of ΔPVb across all those years.

The model developed and the results it provides are limited in their applicability to the valuation of the loss of a producing cow. Specifically, the model assumed that a producing cow was killed after having its first calf. If the producing cow was killed later in life, the results would be slightly different due to the effects of discounting but would point toward the same conclusions. An exception to this occurs if the cow is killed after having her final (9^{th}) calf. In such a case, the loss to the rancher is simply the cull value of that cow at that time.

Another exception to the results derived here, and one that highlights the simplistic construction of the model, occurs when the replacement heifer is killed before calving. In reality, a rancher has an entire herd from which to source replacement heifers. Yet, the model developed here does not contain a mechanism that accounts for this, because it only incorporates a single cow. When the retained heifer is killed, there are 2 possible losses, depending on the age of the heifer when she is killed. If she is young enough so that calves born in the same season as she was have not yet been sold, then the rancher would select a different calf of the same age as a replacement. No loss of calf production occurs, but the calf used as a replacement is not sold. Therefore, the loss in this case is equal to the value of one calf. If the replacement heifer is old enough such that other calves born in the same season have already been sold, then the rancher must retain an additional calf next season. This replacement will be younger and the rancher will lose a year of production. In this case, the results provided by the model applied to the loss of a 2-year-old will be applicable, although the magnitude of the loss will be slightly different due to discounting.

Ranchers in the BRWRA were reimbursed 100% of the depredated animal's market value if the depredation was confirmed by WS and 50% of market value for probable depredations (Defenders of Wildlife 2006). According to data from the Trust, between June 1999 and January 2006, there were a total of 72 payments made to compensate ranchers for the loss or injury of cattle due to wolves: 53 payments for lost calves, 10 payments for lost cows, and 9 payments for lost heifers, steers, or "cattle." The median indemnity payment for depredated cows was $1,000 and $500 for depredated calves. Based on these median indemnity payments, it is clear that ranchers are undercompensated for their loss. According to the results here, the payment for the loss of a cow should be $1,230 and payment for the loss of a calf should be $721. While the current indemnity payments are proximate to the loss, the proximity is coincidence and the payments are based on a theoretically incorrect approach. The only case in which payment based on market value can be justified is if the loss is a cow about to be culled at the end of its producing life, or a calf. At any other time, the indemnity amount should be based on the value that ΔPVa and ΔPVb converge to, which is driven by the value of 2 calves. However, even this amount may be insufficient despite effectively estimating the revenue loss experienced by the rancher.

There are several factors that the model and the results it provides do not capture. The ultimate purpose of the indemnity payments is to ensure rancher cooperation and increase the likelihood of successful wolf reintroduction. Simply compensating them for lost revenue may be insufficient, since there are costs associated with wolf predation that are not captured by the model. These costs include a change in the way cattle are managed in wolf country, taking the necessary steps to receive a payment once depredation has occurred, and the risk associated with replacing a producing cow with an unproven heifer.

MANAGEMENT IMPLICATIONS

This analysis indicates that ranchers in the BRWRA were undercompensated for their wolf predation losses. More broadly, it shows that indemnity payments have been calculated on a theoretically incorrect approach. Indemnity payments should be based on how predation affects a rancher's revenue: when the depredation involves a producing cow, the revenue impact often exceeds the market value of the lost animal because of disruptions in the production cycle and because many ranchers prefer to retain one of their heifers rather than buying a replacement, yet current indemnity payments do not account for this. Given that rancher cooperation often is critical to successful reintroduction, it is important that indemnity payments sufficiently reimburse them for their losses.

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