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The Cost for Agriculture to Coexist With Wildlife in Colorado

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This study estimated costs incurred by agricultural producers to coexist with wildlife in Colorado, where there is little data, and demonstrates that secondary data sources can provide reliable estimates. Three secondary sources were used: government expenditures, spatial data (e.g., geographic information systems), and published studies. Results showed that secondary data provide comparable estimates to more expensive and time consuming surveys. Costs covered by the government sum to $14,478,523. Total costs increase to $77,162,499 when farm and ranch costs that are not reported to the government are included (e.g., property damage, opportunity costs, prevention, and management). These results inform policy makers and producers alike about the value that agricultural stewardship provides wildlife. Results also provide evidence that secondary data sources are a cost-effective, powerful approach that can supplement surveys.

Keywords agriculture, Colorado, cost, damages, secondary data, wildlife

Introduction

People cannot farm and ranch without at least some interaction with wildlife. This sometimes leaves producers (farmers and ranchers) with difficult choices about how to manage private agricultural lands. On one end of the spectrum, producers may attempt to cut off all access. On the opposite end, producers may promote or enhance wildlife access to agricultural lands. More commonly, landowners manage or limit wildlife access. Research shows that landowners will tolerate some damage because landowners receive some financial and humanistic benefit from the presence of wildlife on their property (Rollins, Heigh, & Kanetkar, 2004), but they will take actions to alleviate damages whenever the costs of

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wildlife surpass their personal value for that wildlife (Conover, 1998; Rollins et al., 2004; Wywialowski, 1994). Likewise, wildlife management policies at the state and federal level affect producer decisions, because policies influence the relative cost or benefit of tolerating or managing wildlife. Public support can have a strong effect on producer attitudes to cooperate. Producers care about financial assistance, but also want some acknowledgment for their non-compensated role in providing a healthy wildlife population.

This article estimated costs to farmers and ranchers for agriculture and wildlife to coexist on their properties in Colorado. It is important to understand how wildlife affect the financial health of ranching, because if ranching prospers, so too will human and natural communities (Knight, 2007). This understanding is also important for wildlife managers. Knowing the financial impact from wildlife can help improve relationships between producers and wildlife managers (Conover & Decker, 1991). Several studies have estimated wildlife damages or costs in the United States. Wywialowski (1994) conducted the first national estimate of agricultural damages sustained by wildlife. In her 1989 survey of 20,001 producers across the United States, approximately 55% of the 13,000 respondents indicated some degree of damage from wildlife. The median total damage cost to agriculture by wildlife was estimated to be $461 million. Conover (1994) published a similar estimate at $438 million based on his own survey in 1992. In a later survey conducted in 1993 and 1994, Conover (1998) found that 80% of farmers reported damage. He estimated that agricultural producers (farmers and ranchers) spent about 43.6 hours and $1,002 per person, each year, to mitigate wildlife damage, yet 54% still experienced over $500 in damages. Expanding these estimates to the national level, Conover (2002) estimated that wildlife cost agriculture $4.5 billion annually.

The economic impact of wildlife to producers is incomplete in the literature. We contribute to the current literature in two ways, first by showing that secondary data can be used to estimate wildlife related costs incurred by agricultural landowners, and second by providing an estimate for a western state, where there is a paucity of information. Three major sources of secondary data were used: government data collected through damage compensation or assistance programs; spatial data used in Geographic Information Systems (GIS); and results from previously published studies. We conclude with a discussion about the context of our estimate, such as comparisons to other studies and recommendations for future cost–benefit studies.

Methods

Literature in related fields describes two primary data collection methods to estimate private costs: site visits and farmer and rancher surveys. Site visits (e.g., MacGowan et al., 2006) are more accurate than surveys but they are expensive and narrowly focused by species, crop, and geographic region (Conover, 2002). Surveys, on the other hand, are prone to self-reporting and response biases, but can be applied to wider areas. The methods used in our study are akin to a survey, but use secondary data rather than information directly reported from survey respondents.

Following Conover (2002), our study delineates wildlife costs to agriculture in three dimensions:

1. Opportunity costs—lost profits from products that cannot be produced when wildlife are allowed access to agricultural lands (e.g., forage, crops, or livestock deaths).
2. Property damages—the cost to repair damages related to wildlife (e.g., fencing).
3. Prevention and management—the cost to prevent or manage wildlife damage.

The advantage of using a secondary data approach is that many types of results can be combined to form a more complete picture than is typical of any single survey, and often these results can be achieved at only a fraction of the price and time. As this study shows, the secondary data approach produces results that are consistent with those produced from survey data.

We propose a third method to calculate wildlife damage, using secondary data. We make two estimates: the government expenditures method and the multiple source estimate. First, in the government expenditures method, measures are confined to information collected through government wildlife agencies, specifically the Colorado Division of Wildlife (CDOW) and the United States Department of Agriculture Wildlife Services (WS). These two sources of secondary data can be considered reliable because damages are recorded through in-person site visits by trained personnel and data are maintained for several years. In the second method, the multiple source estimate, the costs of wildlife are estimated using a collection of secondary data sources and three cost dimensions: opportunity cost, damages, and prevention and management information.

Method 1: Government Expenditures

Governmental expenditures are relatively well documented, especially from the two major government agencies that assist agricultural producers with wildlife, the CDOW and WS. While both agencies have many programs that deal with wildlife, the CDOW manages at least two that are particularly relevant to agriculture, the Habitat Partnership Program and the Game Damage Program. Detailed descriptions about all of their programs can be found at http://wildlife.state.co.us/. The Habitat Partnership Program concentrates on management and prevention, with the assistance of 19 locally based partnerships throughout the state. The Game Damage Program compensates producers for applicable damages and provides funding for prevention materials, such as fencing to prevent damage to haystacks from elk (*Cervus canadensis*). WS focuses on prevention. Through formal and informal agreements and cooperation, CDOW focuses more on game species, whereas WS puts more emphasis on non-game species, especially livestock predators. In this method, we simply sum available information across our two main data sources.

Method 2: Multiple-Source Estimate

Opportunity costs, damages, and prevention and management costs from CDOW and WS give only a partial picture of what wildlife cost agriculture, since many private landowners choose not to involve the government (Rollins et al., 2004; Yoder, 2002). This means that non-reported costs must be found by alternative means. Yoder (2002), for example, devised a complicated statistical method to estimate actual deer-inflicted (*Odocoileus hemionus* or *O. virginianus*) crop damage based on the smaller number of losses that are reported to the government in Wisconsin. His estimate of $1,000 per farm, which was adjusted for under reporting, is consistent with other survey results (e.g., Conover, 1998; Wywialowski, 1994).

Although the CDOW collects crop-specific damage information, the data do not reflect damages that are not reported to them. The objective of this second method was to add non-reported costs (opportunity, property damages, and prevention and management) to those already accounted for in the government expenditures method. For example, forage competition from wild ungulates and prairie dogs (*Cynomys ludovicianus*) may be included.

Secondary data sources may include detailed GIS maps of land ownership, available forage, and wildlife and livestock offtake. Offtake is forage consumed, which only serves as a lower-bound estimate of all wildlife consumption because wildlife also consume more expensive crops like corn. Many wildlife species (rodents, fox, raccoons, and birds) typically are not included in offtake estimates (Rollins et al., 2004; Wildlife Services, 2005). The cost of wildlife offtake was estimated as the sacrificed weight gain that beef calves could have produced with forage that was instead consumed by wildlife.

The major species of concern in Colorado include deer, elk, moose (*Alces alces*), pronghorn (*Antilocapra americana*), big horn sheep (*Ovis canadaensis*), and mountain goats (*Oreamnos americanus*), each of which consume forage on private lands and also eat haystacks and cultivated crops such as wheat and corn. Only a fraction of crop and haystack damage is observable from claims to the CDOW. A more complete accounting would require a survey. Spatial data used to estimate the amount of forage offtake (equated as lost cattle production) should reflect that wild ungulates will consume from private lands—with a simplifying assumption that their food source is proportional to forage availability on private and public land.

Our study used an approximation of annual forage consumed (i.e., offtake) by wildlife on public and private lands of Colorado. Our estimate was adjusted based on the distribution of rangeland production, ensuring that offtake levels reflect forage eaten by both wildlife and livestock. Estimates of wildlife abundances (and corresponding offtake) were assigned to elk, mule deer, white-tailed deer, moose, pronghorn, bighorn sheep, and mountain goat. Offtake was also estimated within counties for cattle, sheep, goats, and horses. Rangeland vegetation production was estimated and merged with a recent land cover map of Colorado. These data sources were used in analyses that quantify the percent offtake by wildlife on public and private lands, using the methods described below.

We took rangeland production estimates for a normal precipitation year from high resolution (i.e., county-level) soils maps, known as SSURGO (Soil Survey Geographic Database) data, produced by the Natural Resource Conservation Service (Natural Resource Conservation Service, 2009a). We collated and merged maps of the Colorado SSURGO data. We used common geographic properties (i.e., spatial grids with 1 acre resolution, square cells 63.61 m on a side) and English units throughout, using projection UTM 13 and datum NAD27. For areas not mapped by SSURGO (36% of the state), we used the State Soil Geographic Database known as STATSGO (Natural Resource Conservation Service 2009b). STATSGO has rangeland production estimates analogous to SSURGO data, but for far larger mapping units. To modify forage production, we used a fine resolution (30 m) statewide land cover map (CVM v8; Theobald, Peterson & Romme, 2004). We set irrigated pasture lands so that production equals 3000 lbs ac^{-1} yr^{-1}. We assigned zero forage production to areas classified as water, ice/snow fields, "urban grassy," high-density residential, commercial, industrial, quarries/mines, sand dunes, and row crops. Production estimates for other land cover types were not altered.

The CDOW utilizes various methods (e.g., aerial counts, mark/resight, population modeling) to estimate post-hunt wildlife populations. Populations were estimated for spatial units called data analysis units that are unique to each species (Colorado Division of Wildlife, 2009a). We joined these estimates to the spatial digital analysis units acquired from the Natural Diversity Information Source (Colorado Division of Wildlife, 2009b). Estimates of animal equivalents based on forage needs were from Wyoming Fish and Game (1998), as cited in Willers (2002). The exception was mountain goats, with their conversion (8.2 animals per standardized animal unit) inferred from information from CDOW personnel (http://home.windstream.net/ bsundquist1/og6.html). Forage offtake within each digital analysis unit was estimated by converting the estimated animal populations by the species conversion value, then multiplying by 800 lbs used by each animal unit each month, then by 12 to yield annual forage offtake for the digital analysis unit (Holechek & Pieper, 1992). In some cases the data analysis units included more area than was occupied by a species (e.g., mountain goats inhabiting steep slopes). Because of that, we acquired spatial maps of ranges within data analysis units for each of the species (Colorado Division of Wildlife 2009b). Offtake was restricted to areas within the digital analysis units and within each species' range. Lastly, offtake was distributed within these areas using a linear relationship to forage production.

County-level inventory data for cattle, feed lot cattle, sheep, goats, and horses were calculated from the recently released 2007 US Census of Agriculture (National Agricultural Statistics Service 2009d). Feed provided to these animals comes from both local and remote sources, but the ratio is unknown. We assumed that these animals receive feed from remote sources, and calculated the difference from the county-level estimates of cattle feeding. Conversions to animal units were 1.0, 1.25, 5, and 5, respectively, for cattle, sheep, goats, and horses. Detailed livestock offtake were not available on the county-level, so we defined the distributions in one of two ways. In one case, we created spatial data for each species such that the offtake distribution throughout each county was linearly related to productivity. In the second case, livestock offtake was calculated within private lands only, still linearly related to forage production.

Prairie dogs are another competitor for forage. The opportunity cost from prairie dogs was based on estimates of the number of colonies on private land (EDAW, 2000) and a Colorado study showing how much less beef cattle gained when colonies were present (Derner, Detling, & Antolin, 2006). There are 174,549 acres hosting active towns on private lands. Using data from a site near Nunn, Colorado, Derner et al. estimated that the weight gain for cattle grazing in pastures with prairie dogs, as compared to cattle grazing where there are no prairie dogs, is: $Y = 98.71 - 0.21C$, where Y is the percent weight gain when prairie dogs are present, and C is the percentage of the pasture colonized. Across all of Colorado, the average percentage of each pasture colonized is unknown. For the purposes of this study, we used a central value of $C = 50$ for each acre reported as colonized by the CDOW. For example, $Y = 98.71 - (0.21)(50)$, yielding 88.21% when 50% of a field is colonized, relative to a non-colonized field. For comparison, at $C = 75$, estimated weight gain would be 83% of what it otherwise would have been, and at $C = 25$, weight gain would be 93% of expected gain in a non-colonized pasture.

Finally, we added wildlife management and damage prevention costs. Prevention included state and federal government expenditures, plus private costs. Habitat Partnership Program funds were not included since the program accounts for both prevention and promotion to reduce conflicts between wildlife and livestock. Conover (1998) found that farmers and ranchers in the West spent about 85.6 hours per year on prevention and management. Excluding part time producers as suggested by Conover (2002), we estimated 85.6 prevention and management hours for the 13,364 Colorado farmers and ranchers that had annual sales of $10,000 (National Agricultural Statistics Service, 2009c) or more per year at $12/hour.

Results

Cost estimates for the first method (government data) are summarized in Table 1. The first two rows show game damages and costs of the CDOW and WS programs, respectively.

Table 1
Government and partner costs for wildlife management on agricultural lands

Source	Description	Source cost	% Total cost	Cumulative costs
CDOW	Game Damage Claims (elk, bear, deer, pronghorn, mountain lion)	$514,679[a]	4	514,679
USDA-WS	Farmer/Rancher reported damages	$393,604[b]	3	908,283
CDOW	Prevention Materials/Advice Provided (elk, bear, deer, pronghorn, mountain lion)	$352,240[c]	2	1,260,523
USDA-WS	Prevention Materials/Advice (multiple species; primary species was coyote[h])	$1,218,000[d]	8	2,478,523
CDOW	Habitat Partnership Program	$2,000,000[e]	14	4,478,523
CDOW	Habitat Partnership Program	$10,000,000[f]	69	14,478,523[g]

[a]Source: Colorado Division of Wildlife (CDOW), 2008a.
[b]Source: US Department of Agriculture—Wildlife Services (WS), 2005.
[c]Source: CDOW, 2008b.
[d]Source: WS, 2009: Assumes 58% of $2.1 million total funding went to agriculture.
[e]Source: CDOW, 2008c.
[f]Source: CDOW, 2008c: Assumes private contributions are 5 times public contribution, as stated in the cited document.
[g]There is the potential to subtract up to $160,000 from this value, to accommodate the possible double counting of mountain lion and bear damages that could have already been claimed in CDOW's damage claims program, line 1.

Species cited in this work include: elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), moose (*Alces alces*), pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadaensis*), mountain goat (*Oreamnos americanus*), black bear (*Urus americanus*), mountain lion (*Puma concolor*), coyote (*Canis latrans*), and prairie dogs (*Cynomys ludovicianus*).

The next four rows reflect prevention and management costs of the CDOW and WS programs.

In total, WS, the CDOW, and private partners collectively spend $14,478,523 per year (in 2007 dollars) helping Colorado producers manage wildlife. This is reflected in the bolded entry "Cumulative Costs" in Table 1. With respect to damages, only a small part, about 4% of the total cost ($514,679), was paid to directly compensate producers through the CDOW game damage compensation program. WS also reports damages when they provide assistance but they do not compensate producers for losses (although some of the losses reported to WS could have been compensated by CDOW). CDOW compensation is only provided for bear (*Urus americanus*) and mountain lion (*Puma concolor*), while most WS loss reports were from coyotes (*Canis latrans*). The cost of bear and mountain lion damage equaled approximately $167,000, which could be subtracted from the total cost estimate to avoid double counting. The total cost of damages reported, when adding the CDOW and WS records, equals $908,283. This represents about 7% of total cost.

Prevention expenses were also reported by WS and CDOW. These are reflected in the remaining four rows. Altogether, about 10% of total costs were provided in the form of prevention materials and assistance. The largest expense was on prevention and management through the CDOW Habitat Partnership Program. The CDOW spent about $2 million directly and $10 million through private and public partners, which totals about 83% of the total government cost.

Cost estimates for the second method, multiple source data, are summarized and referenced in Table 2. The table is divided into four sections: predation losses, ungulate competition, prairie dog competition, and prevention cost. At $77,162,499, the total cost was greatly increased over government expenditures.

Beginning with predation losses, sheep and lamb losses were estimated to be $1,127,249 annually. Approximately 2,200 sheep and 8,000 lambs were lost each year to bears, mountain lion, and coyote (National Agricultural Statistics Service, 2009a). Coyotes were the number one predator in Colorado, perhaps accounting for over 80% of predation losses to sheep and cattle (Wildlife Services, 2005; Yeary, 2009). The predation losses discussed above were based directly on secondary data. Information from other studies shows that NASS records underreport losses by about 5-fold for sheep and lambs (Wildlife Services, 2005). Therefore, the initial estimated losses for sheep in row 1 were multiplied by 5 to yield a total loss of $5,636,246 in row 2.

About 700 cows and 4,000 calves are thought to be lost to predation each year (National Agricultural Statistics Service, 2009b), totaling $2,509,150 (Table 2). No estimates about reporting errors were available for cattle and calves, so losses were adjusted by half the adjustment that we made for sheep and lambs. That is, actual cattle and calf losses in row 4 were assumed to be 2.5 times (half of the value for sheep) higher than what is reported in row 3.

The sum of predation losses for cattle and sheep was $11,909,121. Jahnke, Philips, Anderson, & McDonald, (1987), however, suggested that associated costs, such as damaged fences or costs for carcass disposal should also be included in the cost of predation. Jahnke et al. call these additional costs indirect costs, finding that actual losses are about 62% higher than the price of livestock lost. Therefore, total direct livestock costs were multiplied by 1.6 to add the indirect costs, yielding a total cost of $19,054,594 for predation in row 5. Sheep and lamb losses were about 6% of total losses, and cattle/calf losses were about 5% of total losses, before adjusting for indirect costs. Total predation ($19 million) was about 25% of all costs when accounting for indirect losses, split roughly equally between sheep and cattle.

Wild ungulate competition was estimated to be almost $32.5 million, or about 42% of total costs. It was estimated that in a year of average precipitation and with wildlife populations from 2008, offtake would total approximately 975,041 tons. Of that, about half (477,477 tons yr-1; 49%) comes from private lands, the rest was from public lands. Note that this estimate was sensitive to the seasonal distributions of wildlife, not included here. It was estimated that total livestock offtake was 8,961,807 tons yr-1, so wildlife offtake was 9.8% of the total offtake in the state. Of this, 4.8 % of offtake by wildlife was from animals feeding in private lands. Overall, the values show that offtake by wildlife and livestock combined leaves 72% of total rangeland production remaining on the landscape, when livestock were distributed throughout counties. Two of the 64 counties in Colorado (Weld and Morgan) had significant negative values that imply a forage deficit. To put these results in further context, if wildlife were completely prevented from using private lands, an additional 477,477 tons yr-1 would be available for livestock, which would support 99,474 additional animal units. That would increase the statewide livestock holdings by about 5.2%,

Table 2

Agricultural costs to support wildlife in Colorado (adjusted to 2007 dollars via Consumer Price Index (US Department of Labor and Bureau of Labor Statistics 2009))

Source	Description	Source cost	% of cost	Cumulativetotal
Predation losses	Sheep and Lambs	1,127,249[a]	1	1,127,249
	5× Multiplier for underreporting	Multiply cumulative cost by 5[b]	6	5,636,246
	Cows and Calves	2,509,150[c]	3	8,145,396
	2.5× Multiplier for underreporting	Multiply cumulative cost by 2.5[d]	5	11,909,121
	1.6× Indirect Cost Multiplier	Multiply cumulative costs by 1.6[e]	9	19,054,594
Ungulate competition	Elk, deer, pronghorn, moose, bighorn sheep, & mountain goats	32,520,500[f]	42	51,575,094
Prairie dog competition	Competition for forage	10,289,664[g]	13	61,864,758
Prevention cost	Producers + State + Federal	15,297,741[h]	20	77,162,499

[a]2,200 sheep and 8,000 lambs lost annually, valued at $136.00/head and $91.00/head, respectively (NASS, 2009a), inflated to 2007 dollars through the consumer price index (USDLBS, 2009)

[b]Source: WS, 2005. Value appears slightly higher than 5 times previous value due to rounding.

[c]Source: 700 cows and 4,000 calves lost annually, valued at $1045.00/head and $408.00/head, respectively (NASS, 2009b), inflated to 2007 dollars through the consumer price index (USDLBS, 2009)

[d]No specific studies about reporting error could be found for cattle. Therefore, the cattle multiplier was estimated at half of sheep and lamb under reporting, or 2.5×.

[e]Jahnke et al., 1987

[f]99,474 livestock animal units consumed by wildlife (explained in methods section of text), which would support 76,519 cows and 65,041 calves (A typical cow/calf pair consumes 1.3 animal units and the weaning rate in Colorado is about 85% (Peel, 2009)). Average sales weight is 500 pounds/head, the price is $100/cwt—(500)*($1.00)*(65,041) = $32,520,500.

[g]Assumes prairie dog colonization rate of 50-percent cover per acre: (acres colonized) * (1-Y:C=50) * (cattle sales weight) * (cattle sales price), or, (174,549 acres)(1-.8821) (500 lbs.)($1/lb) = $10,289,664.

[h]Sum of state, federal and private costs. State ($352,240) and Federal ($1,218,000) prevention costs cited in Table 1; Private prevention cost ($13,727,501) is based on 85.6 hours (reported in Table 2, Conover, 1994) at $12/hour for each producer. The number of producers, 13,364, had annual sales over $10,000, according to the 2008 State Agriculture Overview for Colorado (NASS, 2009c).

We also calculated opportunity cost from prairie dogs. The assumed prairie dog colonization rate for private lands was 50% cover per acre, while the "cost" was a lost opportunity from cattle grazing. The summed opportunity cost, based on 174,549 acres, colonized at 50%, is $10,289,664. Prairie dogs cost producers the equivalent of over $10 million per year, or about 13% of total costs.

Finally, we calculated prevention costs. Prevention includes state costs ($352,240) and federal costs ($1,218,000) from Table 1, plus private costs. Excluding part time producers, and using a methodology suggested by Conover (2002), Colorado's 13,364 farmers and ranchers that had annual sales of $10,000 (National Agricultural Statistics Service 2009c) spent an estimated $13,727,501 per year for prevention and management, which totals over $15 million, or about 20% of total costs.

The identified costs (including opportunity costs, damages, and management and prevention costs) sum to $77,162,499 million annually, which was about $5,774 per full-time farmer/rancher.

Discussion and Conclusions

This article incorporated two methods for assessing the costs to agriculture to coexist with wildlife in Colorado. There have been few published estimates of these costs in recent years and even fewer for the Western region. The multiple source estimate of $77.2 million for Colorado was comparable to the results of other studies, demonstrating that secondary sources are a potentially valid place to find information on the costs of wildlife damage. For example, simply dividing Conover's (2002) $4.5 billion by 50 states yields approximately $90 million per state. Adjusting for inflation, and making adjustments for consistency, a Montana study would have found the cost in Colorado to be $62 million (Hoag, 2009). Yoder (2002) estimated that damage in Wisconsin was $60–75 million when inflated to 2007 dollars.

How much wildlife damage does it take to justify a program to manage and control wildlife or to compensate producers for damages? This is a question best left to policy makers. However, researchers can provide valuable information about situations and locations where wildlife and agriculture are in conflict, which can then provide guidance about courses of action. A basic review of economic benefits places the costs into context. While this study focused on costs, the benefits of wildlife are over 30 times greater than the costs to agriculture (2.8 billion/77 million). This effectively addresses how the costs incurred by private agricultural operators compare to the benefits provided by wildlife. A study prepared for the CDOW (Pickton, 2004) states that in Colorado hunter and angler expenditures alone generated more than $918.38 million (2007 dollars) each year. In this same study, wildlife viewing generates an estimated $657.84 million in direct expenditures and $442.46 in indirect expenditures (both in 2007 dollars). Loomis and Richardson (2008) estimated that the average visitor willingness to pay for either a hunting or wildlife viewing experience may be double what people spend. Counting only hunting and wildlife viewing, the direct benefits were $1.4 billion dollars and nearly $2.8 billion when counting for indirect expenses (e.g., hotels).

These estimates do not include many costs and benefits that are difficult to measure, but more importantly, the estimates also ignore the distribution of costs and benefits. Based on a survey of 241 Ontario fields in 1998, Rollins et al. (2004) found that costs were highly concentrated, while benefits were widely distributed, meaning that some people received more benefit than costs and vice versa, regardless of the totals.

An important concept to consider is the tolerance threshold, which is the maximum amount of damage landowners will tolerate to get their own personal benefits from wildlife, whatever they include. If exceeded, producers will manage wildlife to reduce damages (Conner, 2002). Studies have typically found that more than half of producers have not reached tolerance threshold (Conover 1994, 1998; Rollins et al., 2004). Rollins et al. (2004) found that overall, in Ontario, Canada, the benefits to producers was 10 times higher than the costs, when just accounting for producers' views. This information shows that the next generation of these estimates needs to account for distribution and if possible at the producer level. For example, a survey could indicate regions, farm types, species or other measurable characteristics where there are large trends that are either above or below the threshold.

Table 1 shows that government funds cover about than 20% of total costs related to wildlife damages. There is little doubt that limited government budgets will go further if they are targeted where damage is above tolerance. But this would require information. This study is helpful in that regard, but the analysis, and those before it, cannot address how costs and benefits change over time as human and animal populations change and peoples' views change. State and federal officials could design a more objective and continuous sampling process. Decision makers could conduct surveys to learn about producer damages, but surveys are susceptible to bias, and may be prohibitively expensive with fixed budgets. Agency personnel could be consulted; however, Saltiel and Irby (1998) found that estimates from game wardens, biologists, Montana extension specialists and other agency personnel differ significantly from producers. Perhaps a better balance between cost savings and precision is to survey both producers and wildlife professionals, and combine these results with the high quality secondary data now available. For example, specific crop damage data available from CDOW could be combined with GIS information about crops and wildlife and reconciled with survey data.

In conclusion, we show that private agricultural producers incur substantial cost to support wildlife in the state of Colorado, beyond what is reported to—or compensated by— government. Accounting stances may differ between wildlife protectors and agricultural producers. That is, there is also cost to wildlife as a result of agriculture; however, these estimates should be explored in another study. This study shows that government agencies estimate damages at approximately $14,478,523, but total costs increase to $77,162,499 when including uncompensated damages.

In the context of wildlife damage estimates, we show that the use of secondary data reflects a viable and cost effective method that may show similar results to a survey. Surveys might be appropriate to obtain highly focused estimates of agricultural producer willingness to accept payment for wildlife damage incurred by a specific species. Such data might be necessary for calculating compensation for damage incurred from specific wildlife species, readjusting estimates to reflect externalities, or determining regional estimates where further specificity is necessary. However, based upon results of this project, it can be concluded that secondary data can serve as an effective solution for estimating wildlife damage.

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