Background Discussion Paper

Literature Review of Livestock Compensation Programs: Considering Ways to Assist Livestock Producers with Grizzly Bear Conservation Efforts in Montana

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Executive Summary

This discussion paper overviews the rationale, history, and empirical basis for programs designed that use financial instruments to foster coexistence between livestock producers and large carnivores, with a focus on grizzly bear conservation in Montana. The paper's objective is to enhance the ability of those wishing to build on Montana's existing livestock compensation program to understand other similar programs, their strengths and weaknesses, via a summary of existing literature. I reviewed > 100 articles, papers, and white papers (only a few of which focused on grizzlies in North America), and provide a synopsis of issues and information most relevant to moving the conversation forward in Montana.

I identified 5 non-exclusive objectives that have been suggested as justifying compensation programs: 1) to reduce retaliatory or preventative killing of predators; 2) to improve producer attitudes toward predators generally; 3) to improve compliance with suggested conflict avoidance/reduction schemes; 4) to assist the economic sustainability of large, working ranches that have potential to coexist with predators (thereby preventing these lands from being subdivided and converted to rural residences); and 5) to improve economic equity (i.e., fairness), by distributing the costs of large carnivore conservation among a larger group as opposed to having them fall solely and squarely on the shoulders of affected producers. Perhaps counter-intuitively, survey research has generally found that improving producer attitudes toward predators (the 2nd of these) has generally been found not to occur.

I reviewed programs in 16 jurisdictions of North America, and in 8 European countries that are appropriately categorized as "ex-post compensation". I reviewed an additional 11 programs that do not fit neatly into the "ex-post" compensation model, including a few that could

be described as “payment for performance” (which itself is a sub-genre of “payment for ecosystem services”). Most relevant to the situation in Montana are programs in i) Alberta (where confirmed depredations are compensated at full market value [FMV], and probable kills [at 50% FMV] are defined by their proximity to a confirmed depredation geographically and temporally); ii) British Columbia (where claimants are reimbursed at 80% of FMV but can become certified to verify their own losses); iii) Wyoming (which, depending on broad geographic and local topographic characteristics, reimburses losses from grizzly bears at 350% of FMV and from wolves at 700% of FMV); and Washington (which reimburses losses to wolves at 200% of FMV if on a large pasture). Most European countries also have compensation programs (which include damage from lynx and wolverines, and where most depredated livestock are sheep rather than cattle). Most European countries subsidize agriculture to one degree or another; these programs vary greatly in scope and expense.

Although it is almost universally acknowledged that, when depredation occurs, true economic losses are greater than merely the replacement cost of dead livestock, I found only 8 studies that generated empirical (field) data useful for quantifying those costs. Five studies help to understand the proportion of true depredations never detected (what I term “direct costs”). Three studies help understand the magnitude of what I term “indirect costs”, primarily reduced weight of young livestock at sale and reduced conception rate of adult females. Although all provide insight, none stands by itself as providing a clear model for how reimbursement would achieve full compensation fairly and equitably. The most commonly cited study, from the Upper Green River in Wyoming, suffered from design and analytical flaws, rendering inferences from its results unreliable. (One additional economic analysis suggests that FMV itself understates true long-term costs to producers).

Most field investigators (and all theorists and economic modelers) who have considered compensation programs prefer some variant of “payment-for-performance” over payment solely for losses. The former models are seen as both more economically efficient (incurring lower transaction costs) and as better at incentivizing coexistence with carnivores. Evidence that implementing such programs in practice is very challenging is provided by the few working examples I was able to find. The most frequently cited is the Swedish program where herders of semi-domestic reindeer are paid according to a formula that rewards them for documented presence of lynx and wolverines in their grazing areas (rather than for losses incurred). I

conclude that it would be very difficult to emulate this model for predators affecting livestock in the large landscape of western North America, but that financial assistance to damage prevention activities (prioritized over, albeit not entirely replacing ex-post compensation) is practicable, and would achieve the conceptual advantages of a payment-for-performance system.

Introduction

This discussion paper has been prepared to assist individuals and groups interested in learning from the experience of others, as they work to consider improvements in the current program in Montana that reimburses livestock owners for losses from large carnivores. It is organized into four sections covering inter-related topics: 1) rationale for livestock compensation programs; 2) brief summary of existing livestock compensation programs throughout the U.S and other countries, 3) summary of research bearing on the question of appropriate compensation amounts, and 4) an overview of financial instruments to encourage coexistence with large carnivores other than 'ex-post' compensation. My understanding is that almost all livestock producers affected by large predators in Montana take the view that the current compensation system that pays producers for documented losses, while a good start, does not adequately account for the actual level of losses incurred. This overview will not revisit or provide detail on producer views (except as incorporated into the literature), not because they are not important or valid, but rather because the way I can best contribute to the discussion is to review the literature produced by researchers and managers. Because of my current position, I focus where possible on damage caused by grizzly bears. However, because very little of the literature is similarly restricted, I review pertinent work dealing with all relevant predators. I've found it instructive to include work done in other countries, but one should acknowledge at the outset that socio-economic conditions may differ from those in Montana. This review is also limited to the issue of wild carnivore conflicts with livestock production; it does not address other kinds of property damage (e.g., crops) directly, although most of the concepts involved are likely relevant (Wagner et al. 1997). It also does not address other concerns (e.g., human safety). Finally, an analysis of how payments might be better funded (while obviously critical) is beyond the scope of this review.

My attempt is to review the literature available to me objectively; where I offer an opinion, I've tried to identify it clearly as such. All opinions expressed are solely my own and should not be interpreted as necessarily those of MFWP or the state of Montana.

It is universally recognized that conserving large carnivores — particularly those that have historically been the target of human persecution or eradication programs — has costs, and that oft-times those costs are disproportionately borne by livestock producers. Economic instruments to address these costs have become increasingly common, not only in North America, but worldwide (Dickman et al. 2011, Nyhus et al., 2003, 2005.). By far, the most commonly adopted model has been what is generally termed "ex-post" compensation, in which producers who have lost (or can show that they've lost) livestock to predators are provided cash (or, rarely, replacement livestock) by governments or private organizations according to some formula related to the value of what was lost. For simplicity, I'll sometimes refer to these programs simply as "compensation programs". Because compensation programs are so much more common than other economic instruments, and because Montana's current program primarily (although not entirely) also uses this model, most of this review will focus on them.

Most investigators and practitioners who have considered existing compensation programs view them as useful and perhaps even necessary to allow for carnivore conservation, but almost all have also been critical of them. Montag (2003) overviewed fundamental issues of ex-post compensation programs as 1) unanticipated negative consequences (setting up unrealistic expectations among both producers — if predators other than those subject to compensation produce greater losses — and the public — if it comes to believe that conflicts are thereby solved), highlighting legal and philosophical conflicts regarding the roles of government and the private sector regarding wildlife (e.g., governments typically claim sovereign immunity for liability for damage from wildlife, yet often agree to pay for it in these cases), 3) they may mask larger values issues, i.e., between rural and urban residents, that remain unresolved (or, at least, under-discussed); and 4) even if effective, they address only some of the legitimate concerns about having large carnivores on the landscape (e.g., safety). Other discussions of limitations and difficulties

of the general approach are found in and Larson et al. (2019), Linnell (2013), and Nyhus (2016).

Few compensation programs generate high levels of satisfaction among participants (Montag 2004, Montag et al. 2003, Ravenelle and Nyhus 2017, Vynne 2008). In a literature review assessing 138 compensation programs, Ravenelle and Nyhus (2017) found about twice as many negative as positive comments about the programs, and that

> "*…approximately three-quarters of the negative comments (73%) were related to the operation of the compensation scheme. The most common negative process-related comments were that payments were too low (12%), funding was unsustainable (7%), and payments were too slow (7%). Just over three-quarters of the positive comments (77%) were related to the outcomes of compensation programs. The most common positive comments were that compensation programs help people with economic losses related to human wildlife conflicts (17%); increase fairness by spreading the cost of wildlife damage to those who want to conserve wildlife (14%); and improve attitudes toward wildlife (14%).*"

Some authors have used general arguments or simple economic models to suggest that compensation programs could even have unanticipated negative consequences on biodiversity conservation or local economies (Bulte and Rondeau 2005, 2007; Rondeau and Bulte 2007). These authors worried about a situation in which incentives to agriculturalists (primarily crop-producers in countries with weak governance) could result in the expansion of agriculture at the expense of wildlife habitat. As with any theoretical economic model, the math could be impeccable but the model itself not useful if its underlying assumptions describe a system other than the one at issue. The conditions that worried these economics seem unlikely to characterize rural Montana where agricultural expansion is unlikely, the boundaries delimiting public and private lands are essentially set, and where the private lands in question are not necessarily inimical to providing habitat for wildlife.

1. Rationales for a livestock compensation program

The literature contains at least five non-exclusive objectives for livestock compensation programs (Lee 2011, Morrison 2013, Nyhus et al., 2005): 1) to reduce retaliatory or preventative killing of predators (e.g., MacLennan et al. 2009); 2) to improve producer attitudes toward predators generally (Agarwala et al. 2010, Naughton and Treves 2005, Steele et al. 2013, Treves et al. 2009); 3) to improve compliance with suggested conflict avoidance/reduction schemes; 4)

to assist the economic sustainability of large, working ranches that have potential to coexist with predators (thereby preventing these lands from being subdivided and converted to rural residences); and 5) to improve economic equity (i.e., fairness), by distributing the costs of large carnivore conservation among a larger group as opposed to having them fall solely and squarely on the shoulders of affected producers. (Fourli 1999, Montag et al. 2003, Montag 2004). Assessing the strengths and weaknesses of any given program (and thus considering any improvements) is difficult unless one understands its objective.

Compensation programs in which a primary objective is to reduce (generally illegal) killing of large carnivores are mostly located in developing countries, where some combination of poverty, governance seen as illegitimate, and/or weak enforcement allows such unregulated and typically unreported killing to be a real concern (Bulte and Rondeau 2005). For my purposes here, I'll assume that illegal killing of large carnivores by producers in the context of livestock loss is a negligible issue in Montana, and that we can safely ignore its minimization as a possible objective of compensation.

Improving livestock producer attitudes toward large carnivores is frequently voiced as an objective of compensation programs, and success in this regard has been claimed by at least one paper (Nyhus et al. 2003). However, all research I've reviewed that has attempted to measure producer attitudes rigorously has concluded that attitudes toward predators, per se, are generally not improved as a result of compensation for losses (Agarwala et al. 2010, Marino et al. 2016, Montag et al. 2003, Naughton-Treves et al. 2003, Naughton and Treves 2005, Rigg et al. 2011, Treves et al. 2009). That is not to suggest that producer attitudes are made worse by compensation programs, nor is to suggest that producer attitudes are immutable. Additionally, continued negativity toward large carnivores should not be misinterpreted to mean that producers necessarily dislike being compensated. The topic of what factors underlie livestock producer attitudes is complex (Dickman 2010, Jacobsen and Linnell 2018, Kansky and Knight 2014, Kreye et al. 2017a, Lischka et al. 2019, Treves and Bruskotter 2014) and beyond the scope of this review. Suffice it for now that I would not consider that improving attitudes toward large carnivores is an expected (or necessarily, a required) objective of financial compensation for losses.

As reviewed below, many existing compensation schemes require that claimants engage in some type of preventative program as a precondition for receiving payments. Others do not,

but still intend that participation itself encourages producers to adopt preventative measures. My review of the literature suggests that this issue is sufficiently complex that explicitly identifying prevention as an objective of compensation is not helpful. Minimizing livestock damage from large carnivores may or may not be associated with compensation, but in any case, is an important but potentially separate objective, deserving of efforts, programs, and resources in its own right. I return to this subject later in the paper.

A fourth objective is that assisting the economic sustainability of large, working ranches that have potential to coexist with predators contributes directly to large carnivore conservation by providing unfragmented habitat, even if the presence of those livestock sometimes generates conflict ending with the death of individual carnivores. The replacement of large ranches with rural residences, as could occur if ranchers sell to the highest bidders, would reduce the issue of livestock depredation but at the cost of reduced habitat effectiveness and increased non-livestock related conflicts (possibly even more lethal to the predators). Thus, from the perspective of large carnivore conservation, livestock ranching can be a preferred land-use to the conversion of those lands to rural residential development (e.g., Muhly and Musiani 2009)

The fifth and final proposed objective, which I'd summarize as "social fairness" is also frequently cited in the literature, but — with some exceptions (e.g., Muhly and Musiani 2009, Anderson et al. 2014) — is rarely explored in depth. Perhaps it is simply taken for granted. Yet it seems a very straight-forward argument, and one that doesn't require much investigation to evaluate success. If society, as reflected in the laws, regulations, and policies of a democracy, values the presence of large carnivores in geographic areas where they can cause harm to individuals, a case can be made on first principles that these costs should be borne equitably by all of that democracy's citizens rather than falling disproportionately on citizens living in those areas. A nationwide poll found general support among U.S. respondents for compensating landowners for any lost income — at least when caused by "endangered species" — but also for the view that landowners should not have the right to use their property in ways that further species' endangerment (Czech and Krausman, 1999).

Although all five objectives deserve consideration, the reader should be aware that I find the fourth and fifth most cogent and persuasive, and thus that any subsequent bias in this report may reflect that view.

It is worth noting that, in Montana, livestock producers pay an annual tax to the Montana Department of Livestock (DOL), termed "per capita" fees, that help fund DOL programs. For 2020, fees were $2.29/head of cattle, and $0.54/head of sheep or goat (https://liv.mt.gov/Centralized-Services/Per-Capita-Fees). Although these funds are not used directly for compensation or conflict prevention, some funding supports USDA Wildlife Services (which conducts livestock depredation investigations under an MOU with USFWS and MFWP), and up-to-date payment is a requirement of claimants wishing to take advantage of Montana's depredation compensation system through the Livestock Loss Board. As of 2017, Wildlife Services also received funding from producers who contributed to county-level programs in 26 Montana counties for cattle and 47 counties for sheep.

2. Overview of existing compensation programs

Programs to compensate livestock producers for losses to large carnivores have now become common throughout the world, but even when they share objectives, they vary considerably in the details of how they are funded and administered. Limiting the list to those providing relief for damage caused by wolves, grizzly bears, or mountain lions, I count programs in 16 jurisdictions of North America (Table 1), and in 8 European countries (Table 2). I found an additional 11 programs useful to consider throughout the world that do not fit neatly into the "ex-post" compensation model; these are discussed in Section 4 of this report.

Overview of North American programs

Alaska has no compensation program. With that exception, however, essentially all jurisdictions in North America with grizzly bears, almost all with wolves, and many with mountain lions now have compensation programs of some sort. Table 1 allows comparison of North American programs for selected attributes that are typically documented, and that affect how well each performs. I did not include a column for program objectives or rationale; these are often either assumed or are not articulated clearly. Nor did I include a column to capture whether some sort of verification is required for a claim to be accepted and paid because this requirement is evidently common among all programs.

All North American programs listed in Table 1 will consider reimbursing costs from damaged or killed cattle; almost all will compensate for killed sheep, goats, and horses as well. Most programs compensate livestock documented as having been killed by covered predators at

fair market value (FMV); in some cases, this is based on the program's own schedule of prices, in others based on an independent schedule. Some programs using FMV consider the value at the time of the livestock loss; others base it on a date in the future when, presumably, the lost animal would have increased in weight and thus be of higher value if sold. A few jurisdictions pay slightly below FMV, and a few pay more (see case studies, below). Some programs limit per animal payments at a maximum amount (typically $2,000 US), and some pay only if damage exceeds a minimum threshold.

Field verification often fails to find evidence of all animals killed by large carnivores (see Part 3 of this report), and even when found, it is often impossible to determine with certainty the cause of death. Almost all jurisdictions distinguish livestock "confirmed" as killed by a predator from those labeled "probable" (in some cases, additional categorizations are used). Most North American jurisdictions compensate producers for dead livestock categorized as "probable", but typically (although not universally) at half the value of a confirmed loss (Table 1). Most, although not all, also pay veterinary expenses associated with livestock injured but not killed by predators.

Because livestock are lost from numerous causes other than predators — and even where predators are present, non-predation losses typically exceed depredation losses (Oakleaf et al 2003, Hebblewhite 2011, Mabille et al. 2016) — payment for livestock that are unaccounted for but for which no direct evidence links their disappearance to predators remains a difficult issue. Where compensation of confirmed losses is greater than FMV (e.g., Wyoming, in some cases Washington, see below) the rationale for doing so is generally an acknowledgment that at least some unaccounted losses are likely related to any confirmed losses to the same producer in the same year. For some jurisdictions, program documentation appears to evade the issue of the proportion of missing livestock killed by predators.

Many, although not all, jurisdictions only accept claims from producers showing some type of effort to prevent depredations proactively. (The column of Table 1 summarized this should be interpreted cautiously due to the wide variety of preventative measures, requirements for their adoption, and subsidies or payments — or lack thereof — available to producers).

Compensation funding comes from a variety of sources, depending on legal instruments applicable at the time, legal status of the predator species, and economic conditions of potential funders. Canadian programs tend to receive relatively more support from the federal government

than U.S. programs, notwithstanding greater legal protection in the U.S. generally for wolves and grizzly bears. An exception is funding from the Wolf Livestock Demonstration Project Grant Program, initially authorized by Congress in 2009 and reauthorized occasionally since then. Half the appropriated funds in any given year are typically granted for compensation programs, the other half for preventative programs. Authorized states can apply for grants under this program, administered by the U.S. Fish and Wildlife Service, and if successful, must provide a 50 percent cost-share match. The best-known program funded by an NGO, Defenders of Wildlife (DOW), may well have functioned to jump-start government funding, but now that there is greater government funding than in the 1990s, the DOW program has transitioned away from paying compensation.

Worth mentioning briefly — despite not being as billed by its own literature as a large-carnivore compensation program *per se* — is the Livestock Indemnity Program administered by the Farm Services Agency (FSA) of the U.S. Department of Agriculture. Initially envisioned as providing relief from losses causes by natural disasters when authorized as part of the Agricultural Assistance Act of 2007 and the Food, Conservation and Energy Act of 2008 (Johnson and Smith 2010), the program was subsequently revised by the 2014 Farm Bill to allow compensation for losses to *"Federally reintroduced predators or species protected by Federal law, including avian predators and wolves"* (7 CFR Parts 1400 and 1416, Supplemental Agricultural Disaster Assistance Programs, Payment Limitations, and Payment Eligibility, Final Rule). This language would also seem to authorize compensation for damage caused by grizzly bears, but I was unable to find documented evidence that it has been used for that purpose. The program provides 75% FMV for losses over "normal expected loss", and evidently does not require field verification. The program is administered by regional FSA offices, which would appear to be granted considerable discretion in handling depredation claims.

Case studies: Selected North American programs

For purposes here, it is most useful to examine programs in nearby jurisdictions more closely because socio-economic (and cultural) conditions are most similar to Montana, and because they have an identical (or nearly identical) suite of large carnivores.

Alberta

The Alberta Compensation program began in 1974 and is based on the province's wildlife act of 1997 (Province of Alberta 1997, 2020), which distinguishes between livestock

killed by people and livestock damaged or killed by predators (defined as grizzly bears, black bears, wolves, lions, and eagles). Livestock (defined as cows, sheep, goats, swine and bison, but not horses) belonging to producers who depend on livestock for a substantial portion of their income and if valued > Cdn $100 are compensated at 100% of FMV after being confirmed by investigators from either Alberta Fish and Wildlife, Alberta Agriculture, or a municipal Agricultural Service Board (Morehouse et al. 2018). If the kill is categorized as "probable", compensation is paid at 50% of FMV, but no compensation is provided for missing livestock. Uniquely among programs reviewed, the Alberta program does not depend on investigators to declare a "probable kill", but rather designates a livestock carcass as "probable" if found < 10 km from, and within a 90-day window of a confirmed kill or injury. Producers losing calves can elect to receive payment as soon as possible after the loss, or wait until October and receive the (presumably higher) value for a reference 550-pound calf. All funding in the early 2000s came from an excise tax on recreational hunting and fishing licenses, but since 2014 has been split approximately equally with a federal program that supports Canada's agricultural sector. The Alberta Conservation Association (ACA), an NGO, administers the program on behalf of the government. During 2000-16, 70% of claims were for damage from wolves, 11% from grizzlies, 8% from cougars, and 6% from black bears (Morehouse et al. 2020). Claims for damage from wolves, and even more so, grizzly bears, have been increasing in recent years. Livestock represented were 87% cattle, and 10% sheep; the mean number of cattle lost per claim was 1.25 cows and 3.44 sheep. Total compensation payments during 1976-81 (when coyotes were also covered) averaged $199,467/yr[1], and from 2001-15 (without coyotes) averaged $204,586/yr (but rose to $384,494 in 2015).

Based on a survey of landowners in SW Alberta, Lee (2011) reported a high rate of dissatisfaction (76%) with the Alberta program. Most respondents favored a more extensive program (covering additional species of livestock and carnivores), a reduced burden of proof that the lost livestock had been depredated, and also desired full compensation for "probable" kills. A formal proposal incorporating these suggested revisions was prepared on behalf of the NGO Waterton Biosphere Reserve Association (Morrison 2013). In addition, Morrison (2013) proposed that the FMV payment be increased to FMV *2.5 (i.e., a multiplier) to cover indirect costs of depredation. Although Morrison (2013) provided a thorough qualitative rationale for a

[1] Authors did not clarify whether dollars are US or Canadian.

multiplier, she did not justify the 2.5 value via reference to specific literature. Lee et al. (2016) extrapolated findings from a survey to estimate province-wide economic impacts. As of late March 2019, proposals to increase compensation in Alberta were still being discussed (Glen 2019).

Wyoming

The Wyoming compensation program is particularly instructive for those considering Montana's program (Bruscino and Cleveland 2004, Morehouse et al. 2018). Although "livestock" is not defined clearly by Wyoming statute, compensation for damage from wolves, grizzly bears, black bears and mountain lions appears limited to calves and sheep (Wyoming 2020, Chapter 28, Section 3). Although the Wyoming program does not appear to recognize a category of "probable" loss (instead, compensating damage that is "more likely than not" to have been caused by a covered predator), it includes more measures than any other North American program in attempting to make producers whole for missing animals that may have been depredated by predators (i.e., a 'multiplier'). Calves and sheep in "areas occupied by grizzly bears" and terrain, topography and vegetative characteristics render detection of carcasses difficult are compensated at FMV*3.5 if killed by a grizzly, black bear, or lion. Sheep in areas "not occupied by grizzly bears" are compensated at FMV*3.0 if killed by a black bear or lion. I was unable to find in either the regulation or Wyoming statue a definition or process for determining areas "occupied by grizzly bears". Calves and sheep in areas where wolves are "designated as trophy game animals" and terrain, topography and vegetative characteristics render detection of carcasses difficult are compensated at FMV*7.0 in "wolf areas" (essentially the northwestern quarter of the state, as defined in Wyoming Title 23, Game and Fish § 23-1-901). A bill under consideration would set up a parallel system administered by the Wyoming Department of Agriculture, which would extend the geography covered for wolves to other parts of the state (Reynolds 2020). The derivation of these multiplier values is not provided in the regulation, nor is the appropriate multiplier clarified if both grizzly bears and wolves are present. Claimants are required to document the total number of livestock lost (regardless of cause), which is used to ensure that in no case would the compensation exceed the value of all lost livestock. Claimants are also required to allow hunting for the predator species damaging the livestock where the depredation occurred (it is unclear how this provision applies to grizzly bears under ESA protection), as well as to not restrict hunting generally. Similar to Alberta, the

Wyoming program sets the value of calves as what they would have fetched had they been allowed to grow to selling weight in the fall. Investigations are conducted by the Wyoming Game and Fish Department (WGFD). Appeals by the claimant in cases of denial or insufficient compensation can be made in writing, in which case the Wyoming Wildlife Commission empanels an arbitration panel consisting of 3 people (1 selected by WGFD, 1 by the claimant, and the third by the 2 selected panel members). Decisions of the arbitration panel are final (Thuermer 2020). The program is funded by application fees from hunters vying for big game draw permits.

Idaho

Idaho statute 36-1109 states that while landowners have an obligation to "*take all reasonable steps to prevent property loss from black bears, grizzly bears, or mountain lions*", that that prevention of depredation "*shall be a priority management objective of* [IDFG]" (State of Idaho, 2020). Compensation for damage caused by wolves is dependent on the state succeeding in its application to the USFWS for funds from the Wolf Livestock Demonstration Project, authorized by P.L. 111-11 (Omnibus Public Lands Management Act of 2009). A 50% match (which can be in-kind services) is required of the producer (State of Idaho 2019); 100% of FMV is paid in mid-November (Morehouse et al. 2018). According to Morrison (2013), a multiplier can be applied for wolf depredation at the discretion of the compensation board, but I was unable to confirm this.

Losses from grizzly bears are potentially eligible for compensation under Idaho's Wildlife Damage Law (State of Idaho 2018) but only after delisting. At that time, only claims for cattle, sheep, and goats exceeding $1,000 would be paid (at 100% FMV), subject to a $1,000 deductible. Half the claim value would be paid immediately, the remaining half held back pending availability of funds. If claims exceed available funds, proportionate payment would be made. Minimum claims accepted are $1,000 per occurrence. USDA Wildlife Services is charged with verifying damage cattle sheep and goats only (the law would also appear to provide for compensation for loss to berries, bees, beehives, and honey from grizzlies, although not crops). I was unable to find documentation of a compensation plan in Idaho for grizzly bears under listed status.

Washington

The state of Washington, with the smallest area and largest population of northwestern U.S. states, has an extensive wildlife damage program, most of which is oriented toward compensating farmers and orchardists for damage from ungulates (WAC 220-440). The state has only a handful of grizzly bears (in the western-most portion of the Selkirk Recovery Zone), and to date, livestock depredation by grizzlies has not emerged as an issue. However, livestock depredation by wolves has produced considerable controversy. Washington's wolf compensation program requires that claimants first enter into a damage prevention cooperative agreement with WDFW, the terms of which are negotiated. Payment of claims (including associated veterinary costs [including to herding or guarding dogs]) classified by WDFW as "confirmed" is at 100% of FMV at the time of typical sale, and classified as "probable" is at 50% of FMV. However, if the depredation occurs on a grazing site exceeding 100 acres in size, payment is at 200% of FMV for confirmed and 100% for probable losses up to a maximum of $10,000/claim (i.e., a multiplier of 2x is applied; WDFW 2019). WAC 220-440-180 explains that the multiplier is intended to account for missing livestock that could not be confirmed, but I was unable to find specific numeric justification for either the multiplier (2x) or the 100-acre distinction. Producers can also apply for compensation for indirect wolf-related reductions in livestock pregnancy rates and weight gains if they can show such losses exceeded the 3-year running average of previous losses (WAC 220-440). Adjudication of such claims is made by WDFW (which employs full-time staff to work on these issues). Producers must notify WDFW within 30 days and complete their claim within 90 days. A Livestock Review Board (5 members, 2 of which represent the livestock industry, 2 represent conservation interests, 1 member appointed at large) can also review disputed claims for indirect losses, but to date, disputes have been rare.

British Columbia

Two elements of the British Columbia program differ from those reviewed above. First, in contrast to Wyoming and Washington where some claimants may expect > 100% FMV, the British Columbia program pays 80% of FMV (Morehouse et al. 2018). Second, British Columbia is the only jurisdiction I reviewed that provides an opportunity for producers to verify their own losses – at least from some predators - (and thus be eligible for compensation). Citizens interested in being certified to verify losses caused by wolves and coyotes must complete a course offered by B.C. conservation officers. Losses to sheep and cattle from wolves and coyotes are handled by the Livestock Protection Program

(https://www.cattlemen.bc.ca/lpp.htm), administered by the B.C. Cattlemen's Association. Lee (2011), Morrison (2012) and Morehouse et al. (2018) all report that damage from both species of bears are compensated by a similar program, but I was unsuccessful in finding details on that aspect of the program. Garth Mowat, during his presentation to the GBAC on April 9, 2020, indicated that there has not been compensation to livestock producers from grizzly bear depredation, a statement which would be consistent with my inability to find specific documentation of compensation for damage caused by grizzlies.

Overview of European compensation programs

The distribution and abundance of both wolves and grizzly bears has increased during the last 2 decades in Europe (*U. arctos*, the only species of bear in Europe, is termed "brown bear"), where protected areas tend to be smaller, and agricultural production closer at hand than in western North America. Most European countries have stronger traditions of supporting what are viewed as public goods through taxation than in the U.S., and many actively subsidize agriculture. Unlike in western North America, the overwhelming preponderance of livestock killed by predators in Europe are sheep rather than cattle (Linnell and Cretois 2018), despite the downward trend in sheep numbers since at least 1990. Finland, Sweden, and Norway also have semi-domestic reindeer (*Rangifer tarandus*), typically herded loosely and extensively in forested regions. Europe has no analogue to mountain lions (which are restricted to the western hemisphere), but wolverines (Persson et al. 2015) and Eurasian lynx (Lopez-Bao et al. 2017, Mabille et al. 2015) are both considered consequential killers of livestock. Still, reviewing European programs can provide context in thinking about improving the funding or effectiveness of programs in the U.S (Table 2).

Aspects of note from selected European compensation programs

Most European programs include economic instruments to encourage damage prevention as well as compensating for damage already occurring. Specific to bears, France, Norway, Sweden, and the Catalonia region of Spain spend more on preventing bear damage *per bear* than compensating damages *per bear*; other countries are the reverse (Bautista et al. 2017). However, this may merely reflect the low number of bears in 3 of those 4 countries. The total costs/bear have been greatest in Norway and France. A few studies have noted that the number of claims has been more tightly correlated with attributes of the area in question, e.g., pastoral vs. forested, or characteristics of the compensation scheme itself, than with predator abundance *per se*

(Bautista et al. 2017, 2019; Boitani et al. 2010, Rigg et al. 2009, Swenson and Andren 2005, Widman and Elofsson 2018). That is, the European experience has been that compensation costs have not necessarily tracked changes in carnivore numbers closely (although see Mabille et al. 2015 for a study showing a correlation of compensation costs with carnivore abundance).

Most European programs benefit from considerable public funding; a notable counter-example is the small compensation program in Bulgaria that appears to be funded entirely by an NGO (Fund for Wild Flora and Fauna 2020), and which mainly provides substitute livestock (rather than cash) for those killed, as well as helping with livestock-guarding dogs. At the other end of the spectrum, the compensation programs in France and in Norway (for all carnivores) are generous and expensive, both on a per predator (Bautista et al. 2019), and a total (Linnell and Cretois 2018) basis.

France appears to be unique within Europe in paying greater than market value for lost animals, in part to account for indirect value lost (Morrison 2012). As in most Western European (although not necessarily Eastern European) countries, both wolves and bears were functionally extirpated in France by the late 20th century. Under the current compensation systems, possibly because bears in France currently resulted from a translocation whereas French wolves recolonized naturally, higher compensation is paid for losses from bears than to wolves. Although verification of depredation is required, indirect effects are addressed in France by adding flat fee of 115 Euros to a base rate of FMV * 1.1. Particularly when considering that the French program also subsidizes shepherd salaries, the French program is arguably the most generous to producers in Europe (Fourli 1999). Another large program is in Norway, where, as of almost 2 decades ago, 2 million sheep were reported to graze on unfenced (and poorly monitored) montane and forested habitat (Swenson and Andren 2005).

The compensation programs in Italy have elicited particular criticism in the literature, despite it being among the smallest in terms of total costs (Linnell and Cretois 2018). Boitani et al. (2010) argued that Italy's program, which varies administratively by region, has paid out large sums (mean of €822,200 annually in Tuscany alone during 1995-2003, including prevention efforts) while failing to reduce illegal killing of wolves, a critique later echoed by Marino et al. (2016).

3. Research relevant to assessing the true cost of livestock depredation

As overviewed (Tables 1,2), most existing systems attempt to meet their objectives by compensating producers at something approximating the market value of livestock confirmed as lost to large carnivores. (Wyoming stands out as a notable exception, with Washington and France also generally paying more; programs in British Columbia, Manitoba, Italy, and Greece generally pay somewhat less than FMV). As intuitive and simple as this system is, it most often fails to fully reimburse producers for true losses. Here, I review the limited research I've found that is pertinent to the question of appropriate payments beyond the obvious; i.e., FMV for confirmed depredations. I consider "direct effects" the actual death of livestock due to depredation (some of which is either never recovered, or cannot be confirmed definitively). I consider "indirect effects" economic costs of large carnivore attacks or presence other than death. Possible indirect effects I've seen listed, some of which have yet to be investigated (Howery and DeLiberto 2004, Morrison 2013, Rafferty 2015): include: 1) non-lethal injuries, 2) lowered conception rate of adult females, 3) reduced weight, particularly of calves and lambs, at sale; 4) repairing broken fences; 5) repairing damaged buildings; 6) cost of silage and grain losses; and 7) landowner's time (e.g., including helping with inspection, time spent with veterinarians). Table 3 summarizes the main results of the papers reviewed.

Direct effects: detection of livestock lost to predators.

Many authors have noted that neither ranchers nor researchers are likely to find carcasses from all livestock killed by predators. Here, I review the handful of studies that attempted to quantify that statement.

In addition to radio-collaring 17 grizzly bears found on 2 cattle allotments on the Bridger-Teton National Forest (and Teton National Park), Anderson (2002) also radio-tagged 233 calves (32% of the total number of calves) in 1995. Researchers were able to locate and confirm cause of death for 132 calves during the study, 51 of which (39%) they attributed to grizzly bears. Anderson et al. (2002) considered it reasonable to extrapolate the proportion of deaths attributable to grizzly bears (39%) to all missing animals as well, because i) black bears were not implicated in depredation, ii) wolves had not yet arrived in the area, iii) the composition of missing cattle was similar to that of cattle for which cause of death was confirmed, and iv) the proportion of 32 additional calves dying from grizzlies did not differ based on whether or not they were radio-collared. Thus, because 60 calves were missing, Anderson et al. (2002)

estimated that an additional 27 calves were killed by grizzly bears during their 3-year study but not detected, yielding a detection rate of grizzly-killed calves of (65%; i.e., 51 of 78). (Noteworthy, albeit not directly related to the compensation issue, is that this study also suggested that calf killing was done by only a few adult males; when these bears were removed, depredations declined dramatically).

Working from a similar research design but a different predator in a different environment (dense coniferous forest interspersed with small meadows and riparian areas), Oakleaf et al. (2003) collared 4 wolves from a pack whose territory included grazing leases, as well as 462 calves, over 2 grazing seasons. Calves dying were found both by research personnel and by ranchers using the allotment. Although they estimated that wolves killed only an estimated 1.2% of calves yearly, (and that roughly twice that percentage died of non-wolf causes), Oakleaf et al. (2003) also concluded that "…carcass detection rates were low in our study, [suggesting that] this method of compensation [Defender of Wildlife paying FMV for confirmed kills only] would result in payment of one-eighth the actual losses to wolves". The suggestion of a needed multiplier of eight has since been cited by a few other authors. However, while not inaccurate, the estimate of the ⅛ ratio of detected/actual wolf depredations should be understood within the context of its limited sample size. The total number of wolf-killed calves actually found during the 2 seasons of field work by researchers was 4; an additional 2 were found by ranchers. Extrapolating to the entire calf population, Oakleaf et al. (2003) estimated that 16 calves died from wolves. Thus, estimated detection would have been 25% if using researcher-only found calves, and 37.5% if combining both methods of finding carcasses. But even if one views the rancher-based detection rate of 0.125 (⅛) as the most applicable for purposes here, the 95% confidence interval around it would be 0.016— 0.383, suggesting a multiplier to account for undetected wolf-killed calves based on Oakleaf et al. (2003) could be as low as 2.6 or as high as 62.6.

Breck et al. (2011) radio-tagged 930 calves on 2 cattle ranches in Arizona/New Mexico over 2-3 years to investigate depredation related to the Mexican wolf reintroduction. About 2/3 of monitored calves were on a ranch with rough topography, year-round grazing and calving, intensive livestock monitoring, and suspected of having high depredation. The remaining third were on a site with flatter terrain, seasonal grazing and calving, less intensive livestock monitoring, and suspected lower levels of predation. Monitoring and detection of lost calves was

conducted by the ranch staff at both locations. Unsurprisingly, calf mortality was higher (6.5%) on the former than the latter ranch (1.9%, none of which was due to predators). Mortalities on the former ranch were attributed to lions (67.5%), wolves (7.5%), black bears (7.5%) and coyotes (2.5%). The detection rate of dead calves was 77.5% where depredation was high and monitoring intensive; detection was 33.0% where depredation was not documented, and monitoring intensity lower. Detection was higher for calves killed by wolves than by lions. Breck et al. (2011) concluded that detection of lost calves was higher where calves were more likely to die from predators, but also higher where ranch staff were more active in searching for them (the two were not unrelated). They further recommended that if loss verification is to be based on data from producers themselves that the relative effort expended by different producers be quantified and considered when justifying payment amounts. Importantly, they also found that year-round calving was a high-risk factor for depredation. Although cattle ranches in the northern Rockies region typically restrict calving to a short period of early spring, Scasta et al. (2018) found that the duration of parturition among cow-calf (although not sheep) operators in Wyoming was strongly related to their likelihood of experiencing depredation (longer parturition time associated with higher predation).

Sommers et al. (2010) compared numbers of calves lost in the Upper Green River area of Wyoming during 3 times periods they termed "pre-grizzly bear", "grizzly bear only", and "grizzly-wolf". They assumed that calf loss rate during the first period could be used as a standard measure, by which any increase during the 2nd two periods could be interpreted as the effects of the added predators. They then extrapolated their estimated grizzly only, and grizzly-wolf caused calf mortality rates (from a sample of ranches) to the total number of calves pastured to produce a newly estimated number of predator-killed calves, and compared these with the number of calves confirmed lost by USDA Wildlife Services during the same time period (and thus compensated by WFGD). Sommers et al. (2010) also found a correlation (incorrectly analyzed in their paper as a regression) between period-specific predation-related and non-predation related calf mortalities during the study period, which they interpreted as demonstrating that depredation caused increased stress-related disease mortality. They concluded that actual losses to grizzlies were 3.8 times higher than those reported by producers and confirmed by Wildlife Services, and that actual losses to wolves were 177 rather than the 28 confirmed (i.e., 6.3 times greater). These detection ratios are quite similar to the multipliers

currently used by WGFD (see above), but I was unable to find documentation that Wyoming used them as a rationale.

The work of Sommers et al. (2010) was critiqued by Hebblewhite (2011) on two fundamental grounds: i) by simply comparing time periods with differing presence of predators and considering any differences in calf mortalities to have resulted from the predators, the implicit assumption was made that all other potential factors were constant among time periods (i.e., the design lacked an experimental control that could have obviated the need for making this strong assumption; and ii) no other potential causative factors were considered in interpreting the changes in calf losses observed. Hebblewhite (2011) concluded that these deficiencies alone should be enough to cause managers to be skeptical of the interpretations Sommers et al. (2010) made of their data. Strengthening his argument, Hebblewhite (2011) re-analyzed the original data in the context of multiple competing hypotheses, adding the potential conflating variables stocking density, producer reporting rate, and summer precipitation. Both his suite of models and his best fitting model confirmed the original authors' conclusion of a significant predator effect, but also found support for other factors that Sommers et al. (2010) failed to consider. In addition to declining with the arrival of the new predators, Hebblewhite (2010) found that calf survival decreased with stocking density and increased with summer precipitation (thus weakening the importance of the predators only). Hebblewhite's re-analysis suggested no significant difference between calf loss during the pre-predator and the grizzly bear-only periods, and that available data were more consistent with an all-predator-related calf loss rate estimate of 2.0% (95% confidence interval 0.54% to 3.8%) than the 3.6% estimated by Sommers et al. (2010). Thus, the multipliers Sommers et al. (2010) had suggested as required to account for undetected depredations were similarly overestimated.

In my view, the deficiencies that Hebblewhite (2011) identified with the design and analysis of Sommers et al. (2010) are real, and unfortunately, render unreliable the estimated non-detection ratios suggested by the latter authors. That is not to say – as Hebblewhite himself pointed out – that predators had no effect, or that confirmed and compensated losses in the Upper Green River were comprehensive. No doubt many true losses went unconfirmed and uncompensated. However, my view is that numerical results from Sommers et al. (2010) should not be relied on as a guide. An issue illustrated by these two papers is the tremendous amount of

effort (and careful consideration of design) needed to tease apart a phenomenon as tricky as livestock depredation and its detection.

Indirect effects: reduced weight gain

In their paper reporting on a comprehensive simulation model of ranch-level economics in the presence of depredation, Rashford et al. (2010) concluded that reduced weaning weights of calves could easily have greater economic impact to producers than their direct loss (because reduced weight would apply to all calves even if only a few were lost to predators). They noted, however, that "*no definitive analysis… [on the effects of predators on calf weaning weights] … is known to exist*". However, Ramler et al. (2014) made an important contribution to resolving this deficiency by their work on Montana cattle ranches exposed to wolves. In a carefully designed study that used known wolf pack locations and known wolf depredations, as well as auxiliary information bearing on calf weights, Ramler et al. (2014) investigated whether calf weaning weights were affected by predation, while also considering a number of plausible covariates (calf age, stocking density, measures of year-specific vegetative productivity [NDVI and its standard deviation], precipitation, whether range riders were employed, as well as inherent differences in ranches and cattle breeds). Ramler et al. (2014) found no evidence that the mere presence of a wolf pack overlapping the cattle ranch affected calf weaning weights. Similar to Hebblewhite (2011) in the case of calf depredation, Ramler et al. (2014) found that climate and ranch-specific husbandry practices accounted for the majority of variation in calf weaning rates. That said, they found a small but significant reduction in calf weaning weights on ranches that had experienced 1 or more confirmed depredation events, even when accounting for all other plausible explanatory factors. Although the mean weight reduction was only 3.5%, the projected economic impacts were, as Rashford et al. (2010) and Steele et al. (2013) had suggested, greater than the direct effects, because the lost revenue from lighter sale weights applied to all calves sold (whereas direct losses were typically only a small proportion of the herd). Ramler et al. (2014) estimated that at prices applicable at the time, an average ranch from their study sample would have incurred $6,679 in losses from the sale of calves 3.5% lighter than they would otherwise have been, considerably more than the loss incurred by depredation of a calf or breeding cow.

A weakness of the Ramler et al. (2014) was the small number (18) of ranches that were able to cooperate and provide the detailed data necessary. That said, there is an additional reason to credit their necessarily correlational and associative research on wolf-related reduced calf

weaning rate. Even the best studies that depend on statistical correlations are improved when independent work provides convincing evidence for the fundamental biological mechanisms that plausibly explain the observed patterns. In the case of reduced weight gain, empirical studies of cattle behavior and movement patterns by Kluever et al. (2008, 2009), Laport et al. (2010), Muhley et al. (2010), and Clark et al. (2017) have shown that cattle exposed to wolf packs, surrogates for wolves, or actual predation tended to group-up more and use less productive habitats, thus providing an explanation based in energetics of why their calves grow more slowly. Valerio et al. (2018) demonstrated that metabolic pathways of cattle in NE Washington (as detected from feces) differed in cattle that had recently been in close (defined as ~ 130 m) proximity to a wolf pack from those who had not, although implications of this for cattle health or production were not pursued (however, Valerio [unpublished, cited in WDFW (2019)] also failed to find evidence of habitat shifts among 65 GPS-collared cattle in response to presence of wolves in northeastern Washington)[1]. Notably, more producers responding to a survey by Scasta et al. (2018) reported indirect effects likely to affect reduced weight gain (e.g., nervous behavior, change in distribution patterns, reduced grazing time, 27%) than reported losses to conception rates *per se* (19%).

Working with sheep producers in Norway (where, according to the authors, sheep are housed indoors during winter but released onto forested or alpine pastures in spring post-lambing), Mabille et al. (2016) found that autumn lamb weights, aggregated on a municipal (not a producer) basis, were negatively related to summer stocking density, May temperatures, and May precipitation, and positively related to previous snow fall amounts. However, they found no relationships – at the spatial scale investigated – between autumn lamb weights and the density of brown bears, lynx, or wolverines. (Wolves were present only in a small portion of their study area). In contrast, Mabille et al. (2016) did find that predator densities, as quantified, were significant predicators of direct losses (depredations). Their findings might superficially seem contrary to those of Ramler et al. (2014) above, but recall that the Montana study similarly found no effect on calf weight from the mere presence of wolves, only from actual depredation. As

[1] To complete the picture, Skonhoft et al. (2017) report on a population-dynamic model of semi-domestic reindeer in Norway in which predation causes density-dependent responses including calf weight *gain* in the presence of predators, and when coupled with Norway's generous compensation system, actually generates a net benefit for Saami herders. That system is unique however in that these herders work with what is almost a wild animal.

well, it is unclear whether Mabille et al. (2016) might have detected an effect on lamb weight had they been able to examine data at the finer, producer-scale level as did Ramler et al. (2014).

In a large scale questionnaire survey of sheep producers in Sweden, Widman et al. (2018) failed to find effects of predator density or experience with depredation on lamb weight at slaughter, but noted that here, the timing of sale can be delayed so as to allow lighter-weight lambs more time to achieve desired weight. Widman et al. (2018) did, however, report an 18-24% reduction in live-born lambs per ewe in herds living with high carnivore densities, as well as in herds having experienced a depredation, relative to herds with low carnivore (wolf, brown bear, and lynx) densities. Respondents having experienced depredations also reported spending an average of 1.9 days more on fence maintenance, 3.2 more days searching and retrieving lost sheep, and 2.6 more days bringing animals in for the night than did those living with low carnivore density. Losses of both ewes and lambs were also correlated with predator density. Direct and indirect effects were statistically independent of one-another (i.e., the interaction term of the 2 factors in the statistical model was not significant), suggesting the economic effects of direct and indirect effects were additive.

Steele et al. (2013) noted that there was "…*relatively little scientific literature available…"* to parameterize indirect effects in their model, including importantly, reduced conception rates of adult female cows. They hypothesized possible percentage reductions in conception rates of 1%, 3%, and 6% based on "…*interviews with five producers in northwest Wyoming; one producer in Alberta, Canada; and two wildlife services officials*."

An alternative approach to FMV

In a somewhat technical economic approach, Anderson et al. (2014) did not address either the direct effects of undetected depredation, or indirect effects such as slower growth rate. Rather, they took issue with the concept that FMV at time of loss (or of sale) is the most appropriate compensation. Anderson et al. (2014) argue that accounting for lost future production, by modeling the change in net present value, more accurately portrays the value of a lost cow or calf. Although they acknowledge that there is not a single unambiguously correct future date in the revenue stream on which to base projections, they estimated that, in the case of cattle ranchers losing animals to Mexican wolves in Arizona or New Mexico, FMV under-estimated true losses of cows by approximately 23% and of calves by approximately 44%.

4. Alternative economic approaches to coexistence

A number of authors have made the case for alternatives to traditional compensation systems that would provide financial incentives to co-exist with, and perhaps even to encourage large carnivores in ways other than having an outside entity pay for losses. However, the most commonly implemented scheme is a close variant of ex-post compensation: insurance. Although the fundamental socio-economic arguments for some variant of "payment for eco-system services" approach are compelling, there are only a few case studies involving carnivores, and authors promoting this PES approach have succeeded better in listing the challenges they would face than in proposing schemes that would produce the desired incentives while being socially, economically, politically, and technically feasible (Bautista et al. 2017, Boitani et al. 2010, Breck et al. 2011, Bulte and Rondeau 2005, Dickman et al. 2011, Fernandez-Gil et al. 2018, Skonhoft 2017). Empirical examples with relevance to the Northern Rocky carnivore/livestock conflicts are summarized in Table 4.

Insurance Schemes

In theory, insurance against depredation should differ from most ex-post compensation programs in its incentive structure and funding. If risk is pooled among participants and a premium paid up front (as in typical insurance), costs would be born mostly by producers and not by governments, hunters, or NGOs (as is common for compensation, Table 1). This would allow producers the freedom to decide whether it would be in their interest to pay premiums in order to lessen their risk of needing to later make a claim (Marino et al. 2018). In theory, funding in this way would also relieve governments the burden of continually resourcing the program, increasing its sustainability. Unlike the way automobile or private (non-group) health insurance typically works, I was unable to find examples in which an agency or company calculates the cost of premium required from producers based on a measure of individual risk. Thus, insurance schemes I reviewed appeared only superficially different from ex-post compensation in most aspects.

The insurance program in Greece is funded mainly by fees paid by farmers, but these fees are obligatory (Fourli 1999, Karamanlidis et al. 2011), so unlike most crop insurance, there is no decision space for the producer to weigh the costs and possible benefits of participating. Damage from wildlife is aggregated into the same program containing a mandatory insurance program for

other agricultural losses (e.g., weather, disease). Producers must present evidence of livestock loss to a semi-public insurance agency, which determines the cause of the damage (e.g., bear, wolf), decides annually on payout rates per species (Karamanlidis et al. 2011 actually call this "compensation"), whether the damage meets the threshold of 5% to be eligible, and also collects an inspection fee to discourage false declarations and cover some of the inspection costs (although as of the late 1990s it was quite small: 1.3€/sheep, 16.3€/cow, Fourli 1999). Morrison (2012) reports that damage from bears is paid at 100% of FMV, whereas damage from wolves is paid at 80% of FMV. Unlike in most other European countries, cattle are depredated more than sheep in Greece, with mean annual compensation of €80,629 paid during 1999-2006 (Karamanlidis et al. 2011).

The literature I reviewed included description of 3 livestock depredation insurance schemes that worked so poorly that they were ultimately abandoned. In Italy, Marino et al. (2016, 2018) reported that the voluntary insurance program in effect during 2005-2010 began by paying out only 70% of FMV for cattle and sheep and 50% of FMV for horses. In 2010, compensation was increased to 100% of FMV, but reduced for producers who had experienced substantial damage in previous years. However, similarly to the Greek program, premium costs were largely subsidized (in this case by the provincial government), but the relatively low remaining costs accruing to producers (averaging €110/yr) was still the source of considerable discontent. In 2014, under pressure from livestock associations, this insurance program was abandoned, and a more traditional ex-post compensation system reinstated (Marino et al. 2016, 2018). Participation in, and satisfaction with the Italian wolf depredation insurance program was low. Additionally, the intended incentive to adopt preventive measures was weak. To quote from Marino et al. (2016):

> *"Despite the fact that the insurance compensation was conditional upon the use of prevention measures, we did not find evidence that this condition resulted in a greater use of adequate husbandry and surveillance among the insured holders that we interviewed, suggesting that the conditionality clause of the insurance may have not been thoroughly enforced…our results clearly indicate that the insurance program failed to mitigate conflict over wolf conservation, as well as to increase tolerance toward wolves among local livestock owners. We suspect that this conclusion may also explain the abrupt abortion of the insurance scheme in 2014 by the regional government. Not only did all conflict descriptors increase steadily throughout the insurance compensation period but also just a small minority of sheep owners subscribed the insurance. On average, only 4.6*

% of all active sheep owners subscribed to the insurance compensation program, a figure confirmed by our independent survey of sheep owners (4.3 %).”

Miquelle et al. (2005) described a short-lived program in Siberia to discourage sika deer farmers from taking retaliatory actions on tigers, which worked initially because its inception coincided with an atypically low depredation year. When farmers who paid premiums but suffered no losses began disenrolling, the common pool needed to keep premiums tolerably low became too small, so the program became insolvent. Similarly, Nemtsov (2003) summarized a partially subsidized, short-lived program in Israel focused on depredation by wolves and golden jackals that featured a graduated deductible in which no payment would be made for the 1st animal lost in small herds, for the first 2 lost in larger herds, and for up to 5 lost for herds > 800 head. Only 80% FMV was paid after the deductible was met unless electric fencing or livestock guarding dogs were in place, in which case 100% of FMV was paid. The program lasted only one year however, due to unhappiness among subscribers with the cost: benefit ratio, and the decision by the cooperative to instead prioritize funding fences and guard dogs.

Although a bit far afield, the insurance program for rubber tree farmers in Yunnan, China is worth a brief discussion. As seen elsewhere, the program has not been well received by producers (only 8 of 208 interviewees fully satisfied with program, Chen et al. 2013) because payouts were insufficient to cover actual costs. The program quickly became financially unsustainable, and Chen et al. (2013) argued that the lack of geographic specificity in assessing risk was a large part of the problem. Because elephant damage was an “idiosyncratic event”, varying greatly spatially, the one-size-fits-all nature of the insurance program failed to match the problem. These authors developed a hypothetical insurance system that tied premium amounts to depredation risk, but further argued that, to be sustainable, such a (more expensive) program would require additional subsidies. Chen et al. (2013) suggested that in addition to increased government aid, a tax on tourists (who are centralized to a single location where wild elephants can occasionally be observed [author’s own experience]) might be levied to increase the program’s financial sustainability.

The experience of insurance schemes in the context of large carnivore coexistence is summarized by Marino et al. (2016):

“The viability of insurance schemes and their efficacy in reducing reliance on public spending depend on high subscription levels…as costs of damages are thus

distributed among a wide pool of subscribers making the schemes self-sufficient. If the only ones who subscribe to the insurance are those at high risk of damage, premiums are deemed to increase to the point of becoming unaffordable."

Payments in advance for anticipated damage or for biological performance

Ex-post compensation systems necessarily incur transaction costs associated with finding, verifying, and paying compensation for lost animals. The complication of appropriately compensating true costs is reflected in Part 3 (above). Thus, some variant of 'payment- in-advance-regardless-of-number-of-livestock-lost' (a subset of 'Payments-for-Ecosystem Services', PES) has appeal for its potential simplicity, in addition to more directly incentivizing the presence of carnivores and minimizing the 'moral hazard' implied by a system that potentially allows producers to ignore conflict prevention and instead rely on compensation for possibly lax practices (Can et al. 2014, Kreye et al. 2017b, Macon 2020, Nelson 2009, Skonhoft et al. 2017, Zabel and Roe 2009).

Schwerdtner and Gruber (2007) describe two systems in place in the state of Saxony, Germany where European otters (*Lutra lutra*) are a protected species, but where a centuries-old tradition of fish farming in artificial ponds is common. Because otters eat fish (and presumably don't distinguish commercially raised carp in privately-owned ponds from native fish in natural waterbodies), a conflict between the economic interests of producers and the conservation interests of the public emerges. Fish farmers can make claims for traditional compensation if damage exceeds a certain level, but to do so requires engaging in considerable work (e.g., draining ponds, documenting normal production to compare with their claim of excessive depredation by otters, verification by conservation officers). Alternatively, fish farmers can elect to be paid €103/ha/pond annually, in payment-in-advance-scheme that is regarded as compensation for helping feed the otters. The scheme is based on contracts that are concluded between individual fisheries and conservation authorities and run for five-year periods. Schwerdtner and Gruber (2007) concluded that payment ahead of time is more efficient (cheaper) than the conventional compensation system largely because of its lower transaction costs.

More generally, Schwerdtner and Gruber (2007) in abstracting how a performance-based payment system might work, categorize livestock-carnivore situations into four that they label A through D, depending on the spatial and temporal consistency or predictability of damage. They

conclude that performance-based payments would be easiest and fairest in their case A, where damage is predictable both spatially and temporally, and most difficult in their case D, where it is not predictable either spatially or temporally. In my view, it seems most likely that grizzly bear and wolf livestock depredation both fit most closely into their case D, the most difficult one, for performance-based payments. Schwerdtner and Gruber (2007) suggest that although investigation and transaction costs of (conventional) ex-post system may be high, they may be still be lower than for a performance-based system if, unlike in their otter/fish case study, the costs of monitoring the performance (e.g., predator population size and spatial distribution, as well as predicting the site-specific probability of damage ahead of time) is even higher. Unlike livestock depredation by wolves or grizzly bears, the level of predation by otters on carp was amenable to estimates via modelling, thus underpinning that system's annual payment level.

The oft-cited (and, as nearly I can determine, only existing and relevant) payment-for-conservation-performance system is in Sweden, where cooperatives containing ethnic Saami producers of semi-domestic (but free-ranging) reindeer experience conflicts with large carnivores (primarily lynx and wolverines, which evidently have few native prey, Fernandez-Gil et al. 2018, Linnell and Cretois 2018). (Similar reindeer-carnivores conflicts occur in Norway and Finland [Swenson and Andren 2005, Næss et al. 2011, Skonhoft et al. 2017], but to date, neither has emulated the system described here). In a system that replaced an earlier ex-post compensation program in 1996, Saami villages are paid by the Swedish Ministry of Agriculture annually according to a formula that uses the number of lynx and wolverine offspring documented within the village's reindeer herding area that year as well as the amount of monetary damage to reindeer those offspring would be expected to cause (Fourli 1999, Swenson and Andren 2005). Villages then decide collectively how to allocate funds among individual producers (Zabel et al. 2008). The principal is that, rather than incentivizing reindeer herders to accept depredation because it does not cost them, the program — because it pays the same irrespective of the number of reindeer lost — should incentivize herders to keep their herds safe, thus turning carnivore performance payments into income. Fourli (1999) reported that producers remained dissatisfied with the level of performance payments. However, Zabel et al. (2008) concluded that the governance and institutional arrangements within the Saami villages were conducive to effective and enduring common-pool resource management. However, at the time, Zabel et al. (2008) were cautious about ascribing a conservation benefit to the program; documented

wolverine reproductive events in the area showed no definitive trend during 1996-2006, and poaching remained a primary cause of wolverine mortality. More recently however, Persson et al. (2015) presented data from radio-telemetered wolverines though 2011 suggesting a growth rate of ~ 4-6% annually in the wolverine populations, coincident with an increase in the number of PES program participants, which they interpreted as preliminary evidence of success of the conservation objectives.

Nistler (2007) mentioned a privately funded demonstration project in northern Mexico to pay participating ranchers who have rare felids on their lands as documented using remote cameras. During 2007, they were paid the equivalent of $50-$300 per photograph of jaguars, cougars, ocelots, or bobcats. The incentive structure of this program is obvious, but I was unable to find any more recent documentation of its progress (or indeed whether it still exists).

Recently, a payment for performance system to augment compensation and preventive measures has evidently been piloted, aimed at ranchers in Arizona and New Mexico whose land provides habitat for reintroduced Mexican wolves. A payment formula has been proposed that uses a point system to prioritize funding recipients, and requires information on wolf territory and core area locations, number of wolf pups surviving to the end of the calendar year, number of livestock exposed to wolves, and presence of preventive measures (Mexican Wolf/Livestock Coexistence Council 2014:12). The estimated budget for the performance payment portion only was $250,000 in 2014. I was unable to obtain information on how this program has progressed (or even if it has been funded and initiated) since the initial proposal was published (Mexican Wolf Livestock Coexistence Council. 2014, USFWS 2018).

5. Discussion

This review of the literature has made it clear to me that economic instruments to facilitate coexistence of livestock with large carnivores are, and will continue into the foreseeable future to be, a necessity in the Northern Rockies. Compensation for loss, the current system in Montana (and most other places) may not be the optimal instrument, but even if a better one can be devised, will likely be with us for the immediate future (potentially along with other instruments). The literature also provides a compelling case that simply paying fair-market

value for verified losses substantially under-compensates producers incurring losses. Exactly what value would be a more-accurate metric of true loss is less clear.[1]

A simple start would be a more forthright acknowledgement that confirmed losses understate true losses. This direct effect can, in theory, be addressed via a 'multiplier', perhaps applying only under some geographic constraints (as in Wyoming), or for certain sized operations (as in Washington). Multipliers have varied from as low as 1.3 to as high 7. My read of the literature suggests that detection of carcasses from grizzly bear depredations is typically higher than from wolf depredations (thus justifying a lower multiplier, which may explain the different values for grizzlies and wolves used by Wyoming). However, indirect effects may be as, or even more influential to producer finances, and these effects may be felt by large portions of the producer's herd (e.g., all offspring). For this reason, policy makers may wish to consider dropping the term "multiplier" in favor of "compensation ratio" (as suggested by Steele et al. 2013), because an improved system may require more complexity than simply "multiplying" the number of confirmed losses by a constant. In my personal view, the term "compensation ratio" also more nearly suggests that the objective is to more closely *compensate* a true loss, whereas "multiplier" can too easily impart the sense that producers automatically get an unearned bonus.

Increasing the "compensation ratio" could invoke additional concerns regarding what many authors have termed 'moral hazard', i.e., the notion that producers able to be fully compensated would be incentivized to minimize measures to prevent loss (because they would be compensated equally regardless of their investment), or even that they would "game" the system, exposing their least valuable animals to predators, or fudging records to capitalize on payments. In my personal view, it seems unlikely that more than a very small fraction of livestock producers receiving any kind of payment would game the system, or attempt to gain more from it than actual losses. Even in Kenya, where both the economic margin of producers and the respect for rule of law are likely lower than in the Northern Rockies, evidence suggests that claimants for losses have been honest (MacLennan et al. 2009). I would not expect the number of producers taking undue advantage of any system to be zero, but it also seems to me that the optimal system for most users (and for the public) would necessarily allow for a small

[1] Lee et al. (2016), while not providing new empirical data, appear to suggest that a multiplier of 4 would more accurately reflect the total loss to cattle producers in Alberta. In so doing, they cite work done by Hoag et al. (2011) in Colorado, but that work similarly contains little empirical support, and deals primarily with loss sheep and lambs to coyotes.

number of ‘leakage’ (cheaters, as it were), because the costs of driving that number to zero would outweigh the benefits overall. An attempt to devise a system so fool proof that ‘moral hazard’ would be nil would produce one so restrictive that it would fail to gain the support it needs, and thus fail. We should expect and accept a small moral hazard as the price paid for having a system that, on balance, works for producers and achieves its stated objectives. (That said, Schick [2017] suggests that some Oregon ranchers may have been gaming the county-administered compensation system in place there).

Should an improved system include measures to encourage, or require, claimants to adopt preventive measures? This recommendation is made repeatedly in the literature on fundamental principles (Fourli 1999, Ravenelle and Nyhus 2017):

“The most common recommendation for improving compensation programs was to link payments to conflict prevention measures. Making compensation conditional on adoption of preventative activities may encourage farmers to implement approaches to reduce the risk of future conflict”. Ravenelle and Nyhus (2017)

However, there is not much empirical evidence that such requirements result in better compliance with program terms or better conservation of large carnivores. That said, many programs do contain such requirements, and even those that do not also provide subsidies for (or encouragement of) preventive measures. As well, studies that could potentially demonstrate a causal link between compensation and prevention (in either direction) would be very difficult to conduct. I see merits to the arguments on both sides of this issue: On one hand, it seems logical that if society is paying individuals for losses they sustain, it could encourage (or even insist) that those individuals take actions to reduce future losses. On the other hand, if the primary rationale for payments is one of equitable distribution of costs across all members of society, simple compensation (or compensation-like) payments to individuals achieves this, and asking individuals suffering losses to expend their personal funds to further reduce future losses would be additional to this, and thus revive the very imbalance in benefits-costs that the payment is intended to reduce. This conundrum is resolved, however, if public (or other private) funding is also provided to assist (or pay entirely) producers in developing pro-active preventative measures.

As reviewed above, many practitioners (and essentially all theorists) who have considered economic instruments favor some variant of payment-for-existence-of carnivores (PEC) over simple compensation. Dickman et al. (2011) concluded that

> "*The major failing of compensation and insurance schemes is that the costs of carnivore presence still usually outweigh the benefits, providing no incentive for conservation…PEC recognizes that, if external beneficiaries want the long-term conservation of globally iconic but locally problematic species, they will have to develop and fund strategies to outweigh the local costs incurred, which will require significant investment from stakeholders such as governments and conservation agencies."*

In my personal view, there are at least two sets of problems with instituting some type of 'payment for performance' system – at least as modeled by the Swedish carnivore/reindeer system - for grizzly bears in Montana despite its theoretical attractiveness. The first set is logistical (see, for example, Nelson 2009, Zabel and Roe 2009). It would be very difficult (and costly) to document, much less quantify, grizzly bear occupancy of one producer's grazing area vs. another's. Because grizzlies typically roam over areas much larger than any individual grazing area, assigning proportional credit to separate producers would be an exercise in modeling, and prone to multiple interpretations (and thus controversy). The second set of problems is more fundamental: While society-at-large should recognize tangibly individual producer's contribution to providing habitat for grizzly bears (*sensu* Muhly and Musiani 2009), I'm not sure we want to *encourage* grizzly bear use of ranch-lands as much as tolerate it as a tactic toward the larger goal of connected populations statewide. Providing a financial incentive for grizzly bear use of private land could lead to a paradoxical inequity: Because grizzlies are attracted to anthropogenic food sources and social policy is to minimize these attractants so as to force grizzlies to use naturally-occurring foods, a rancher who manages attractants well could easily see less grizzly use than a neighboring rancher who does not. Simply rewarding producers for having grizzlies on lands they manage could yield the undesirable outcome of disincentivizing the very behavior – keeping people safe and bears out of trouble – that we wish to reward.

However, if instead, the "performance" for which payment is envisioned is a site-appropriate set of 'bear hygiene" actions (e.g., securing attractants, electric-fencing calving areas, employing range-riders) that are prioritized on lands where fundamental topographic and

biological characteristics are attractive to grizzlies, the theoretical-economic arguments underpinning 'payment for performance' might be realized while still getting the incentive system right. The study by Karlsson and Sjöström (2011), working with Swedish sheep producers affected by wolf depredation, found that their attitudes toward wolves, while still generally negative, were made somewhat less so as a function of the proportion of their pasture provided with (government-subsidized) predator-proof fencing (a finding that contrasts with the lack of attitude change in the case of compensation payments). Recently, Morehouse et al. (2020) reported evidence that a community-based program focused on prevention has resulted in improved producer attitudes despite an increase in the total number of grizzly bear-related incidents. Notably, incidents associated with attractants in southwestern Alberta had evidently declined since initiation of the program, suggesting that the total increase was primarily a function of grizzly bear abundance, and that interventions to reduce conflicts were having a beneficial effect.

In Montana, financial instruments to help producers alter their systems in recognition of bear presence are already in existence, both from the NGO and the public (via the LLB's prevention grant system) spheres, but they probably require strengthening. If even full payment for preventive actions is deemed an insufficient 'payment for ecosystem services', perhaps some additional financial instrument (awards, targeted tax breaks) could be considered to augment it.

In my personal view, even if a payment for performance system as idealized above could be implemented, a traditional compensation system would still be needed, if nothing else because even the best conflict-prevention system will not be perfect. But such ex-post payments (regardless of the details), while necessary, should be viewed long-term as a bridge toward, and a backup for, societal assistance to livestock producers for conflict prevention. In this vision, the need for ex-post payments should decline as more investments are made in prevention. Because the need is unlikely to ever disappear entirely, an effective, fair, and accepted compensation program will likely always be a part of a comprehensive system of coexistence.

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Table 1. Summary of livestock compensation programs in North America including grizzlies, wolves, and/or lions. Adapted from Morrison (2012) and Morehouse et al. (2018), and supplemented where possible with updated information.

Jurisdiction	Predators considered (W = wolves, GB = grizzlies, L =lions)	Livestock considered: C = cattle, S = sheep, G = goats, H = horses, 0 = other	Value of confirmed kills paid (FMV= fair market value)	Probable losses of livestock compensated	Injuries to livestock compensated	Missing animals compensated	Preventive measures required	Funding F = federal; S = state/province, H = hunters; P = private group
Alberta	W, GB, L + black bear, eagle	C,S,G,O	FMV	Yes, FMV* 0.5 if within 90 days and 10 km of confirmed loss	Yes, for veterinary expenses	?	No	F: 48%; H: 52%
Arizona/New Mexico	Mexican wolf	C (others at discretion of Council)	Calf: $750, Yrlg: $1K; Cow: $,1.2K; Bull $2K	Yes = 50% of confirmed	Yes	?		F:100%
British Columbia	W, L + coyote (some sources indicate GB)	C	FMV* 0.8 (Calves< 4 mos: $300(Cdn): older claves 75% FMV; bulls, dairy cattle) up to $2K.	No	No	No	Yes	F: 60%; S: 40%
Colorado	L + black bear	?		?	?	?	Yes[1]	F, S, H
Idaho	W	C,S,+dogs	FMV, possible multiplier on case-by-case basis	Yes: FMV if funds available	Yes	Yes, case-by-case	Yes (50% match)	F: 100%
Idaho[1]	GB[4]	C,S,G	FMV -- $1,000 deductible	unclear	uncle	No	Unclear	H: 100%
Manitoba	W, L + black bear, coyote, fox	C,S	90% FMV up to $2K	Yes: 50% FMV	Yes	No	Yes	F:60%, S:40%
Michigan	W, L + coyote	C,O	FMV	?	?	Depends	No	S: 100%
Minnesota	W	?	FMV up to $2K	No	Yes	No	?	S: 100%
Montana	W, GB, L	C,S,G,H,O	FMV	Yes	Yes if funds available	No	No	~ F 10%, S 85%: P 5%
Ontario	W, L + others	C, others	FMV (specified in a table)	No	Yes	No	Yes	F,S
Oregon[2]	W	C,S,G,H,O	FMV	Yes	Yes	Depends[3]	Yes	F: 100%
Saskatchewan	W, L + black bear, coyote, lynx, fox, eagle	C,S G,H,O		Yes: 50% FMV	Yes: up to 80% FMV	No	Yes	F: 60%, S:40%
Yukon	B, ?	?	Determined by board	?	?	?	Yes	F, S
Washington	W	C,S,H,O	FMV if on site of < 100 acres; FMV*2 if > 100 acres	Yes, half of confirmed values	Yes	Yes	Yes, cooperative agreement with WDFW	F (wolves only); S for other species
Wisconsin	W	C,S,G,H,O	FMV	Yes; FMV	Yes	Yes, over 'normal' levels	Yes	S: 100%
Wyoming[1,2]	W, GB, L+ black bear	C,S,G,H	FMV*7 if wolf near Yellowstone; FMV*3.5 if grizzly; otherwise, FMV	unclear	Yes	Yes (via multiplier)	No	H: 100%

[1] Claimant must allow big-game hunting.

[2] Administered on county basis.

[3] See Schick 2017 for details.

[4] Applicable only after grizzly bears are delisted.

Table 2. Summary of livestock compensation programs in Europe including brown bears and wolves. Adapted from Fouri (1999), Morrison (2012), Linnell and Cretois (2018), and Bautista et al. (2019), supplemented where possible with updated information. See Table 3 for other European programs using approaches other than 'ex-post' compensation.

Jurisdiction	**Predators considered W = folk B = brown bear**	**Livestock considered C = cattle, S = sheep, G = goats, H = horses, 0 = other species (varies)**	**Value of confirmed kills paid**	**Probable losses compensated**	**Injuries compensated**	**Missing animals compensated**	**Preventive measures required**	**Funding F = federal; S = state/province, H = hunters; P = private group**
Bulgaria	W, B + fox, jackal	S,G	Replacement in kind; forage can also be provided	?	?	?	Yes (private group provides LGDs)	P: 100%
Finland	W, B + lynx, wolverine	C,S,G,H,O (reindeer)	FMV only if > €250; deductible also €250, also pays for damaged fences, buildlings	?	?	?	Yes	F: 100%
France	B	?	(FMV*1.10) + €115) per animal	Unclear if 'probable' is recognized as a category	Yes, 100%	No (but see value, missing implicitly accounted for)	?	
Italy[1]	W, B	C,S,G,H,O	FMV*0.6 to 1.0 (vaired by program and time-period)	Unclear if 'probable' is recognized as a category	In some regions	?	Yes	S: 100%
Norway	W, B + lynx, wolverine, eagle	C,S,reindeer	FMV	Yes. FMV after estimated normal losses subtracted	?	Yes	No	
Poland[1]	W, B	?	From provincial lists	?	?	?	Yes	
Sweden	W,B,+ lynx	S	FMV		Yes	Yes	Yes, but electric fences subsidized	F
Switzerland	W + lynx	?		?	?	?	?	F: 80%; S; 20%

[1] Programs vary regionally.

Table 3. Summary of empirical information useful for improving estimate of true costs of livestock depredation by large carnivores.

Source	Aspect Researched	Predators/Livestock	Primary Findings	Weaknesses
Anderson et al. 2014	Decrease in rancher's revenue stream from loss	Mexican wolves/cattle	If payment were based on net prevent value instead of FMV, fair compensation would increase by ~ 23% for cows and ~44% for calves.	Assumptions regarding the future plans of any individual ranching operation
Anderson et al. 2002	Undetected actual depredations	Grizzly bears/cattle	Estimated detection of calves killed by grizzlies was 65%.	Not primary objective of study
Breck et al. 2011	Undetected actual depredations	Mexican wolves/cattle	Detection 77% where depredation and monitoring high and livestock grazed (and calves born) year-round; 33% where both low and livestock grazed seasonally	Year-round calving probably not applicable for Montana producers; small sample size
Hebblewhite 2011	Undetected actual depredations	Wolves+grizzlies/cattle	Sommers et al. (2010) results unreliable because poor study design necessitated relying on strong, untested assumptions. Estimated instead that losses from predators were more likely to have been 2.0% than the 3.6% estimated by Sommers at al. (2010)	Retrospective analysis of a separate study that had design flaws
Mabille et al. 2016	Livestock growth rate; compensatory predation among multiple predators	Bears+lynx+wolverines/sheep lambs	Predator density positively and independently related to lamb loss, but no evidence of predator density affecting autumn lamb mass.	Working with data aggregated at county or municipal level might have masked effects occurring at a smaller spatial scale
Oakleaf et al. 2003	Undetected actual depredations	Wolves/cattle	Wolf-specific morality rate ~ 1.2%, non-wolf mortality 2.3%. Four found dead but 16 estimated to have died.	Small sample size, study site possibly unrepresentative
Ramler et al. 2014	Lower growth rate among animals exposed to predators	Wolves/cattle	Sale weight of calves on ranches with at least 1 confirmed wolf depredation were on average 22 lbs.(3.5%) lower than on those without.	Small sample size, study ranches possibly unrepresentative
Sommers et al. 2010	Undetected actual depredations	Wolves+grizzlies/cattle	Grizzly and wolf depredation entirely additive; calf losses due to grizzlies estimated as 3.6 times confirmed losses; wolf losses 6.3 times confirmed losses	Lack of control in experimental design; hidden assumptions; no consideration of potential confounding factors
Widman et al. 2019	Per capita productivity; increased labor time	Wolves+bears+lynx/Catte+sheep	Live lamb/ewe 18-24% lower in herds experiencing depredation than herds in low carnivore areas. Labor costs increased where depredation has occurred.	Possible response bias; possible confounding variables; some indirect labor costs may not apply in N. Rockies for cattle ranches

Table 4. Summary of other forms of economic instruments to assist coexistence between livestock producers and large carnivores, worldwide. Adapted from Morrison (2012), Linnell and Cretois (2018), and Bautista et al. (2019), supplemented where possible with updated information.

Jurisdiction	Type of program	Predators considered W = wolves, B = brown bears	Livestock considered C = cattle, S = sheep, G = goats, H = horses, 0 = other	Value of confirmed kills paid	Probable losses compensated	Injuries compensated	Missing animals compensated	Preventive measures required	Funding F = federal; S = state/province, H = hunters; P = private group
Austria	Insurance	B + lynx		FMV	Yes	?	?	No	Producers
China (Yunnan)	Insurance	Asian elephants	Rubber plantations	< FMV	N/A	N/A	N/A		F
Germany	Insurance/Performance hybrid	Otters	Fish		?	?	?	?	
Greece	Insurance[1]	W,B, other		Bears: FMV, Wolves: FMV*0.8	?	?	?	Yes	Producers, augmented by Federal in extreme cases
Israel[3]	Insurance	W + golden jackal	C,S	100% FMV if prevention adopted; otherwise 80% - deductible	?	?	Yes, 80%	See Value	F: 25%, producers 75%
Italy	Insurance	W							S: 80%, P: 10%, producers 10%
Mongolia	Performance	Snow leopard	S	N/A – purchase of producer-made handicrafts if conservation measures adopted	N/A	N/A	N/A	Yes	P: 100%
Pakistan	Insurance	Snow leopard		Receives accumulated premiums back		?	?	?	Producers, augmented by ecotourism revenue
Russia	Insurance	Tigers, leopards	Farmed sika deer	Negotiable	?	?	?	?	Producers: 100%
Spain[2]	Compensation/insurance hybrid	W,B	S	FMV (some regions more)		?	No	No	Regional gov't, but claims only accepted from producers with private insurance
Sweden	Performance	W,B, + lynx, wolverines, eagles	Reindeer	N/A. 200,000 Krone per carnivore offspring; lesser for lone wolverines/lynx	N/A	N/A	N/A	N/A	F: 100%

[1] Premiums are obligatory

[2] Programs vary regionally

3 Program no longer in existence