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Dealing With Deadstock: A Case Study of Carnivore Conflict Mitigation From Southwestern Alberta

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Livestock deaths are an unfortunate reality for livestock producers and dead livestock (i.e., deadstock) disposal options can have implications beyond the ranch itself. In Alberta, Canada, natural disposal (i.e., disposing of the carcass in a manner that allows for scavenging) has increased since the 2003 detection of bovine spongiform encephalopathy (BSE) in Canadian cattle. Prior to BSE, rendering companies removed deadstock for free. However, rendering companies started charging producers to remove deadstock to offset costs associated with new regulatory requirements enacted by the Canadian Food Inspection Agency, which has resulted in increased on-farm natural disposal of deadstock. This increase has ecological implications because deadstock are a major attractant for large carnivores. Carnivores feeding on deadstock are often near other agricultural attractants such as stored grain and feed, silage, and living livestock, which can exacerbate conflict potential and pose a risk to human safety. To help mitigate conflicts associated with deadstock, the Waterton Biosphere Reserve's (a local non-profit) Carnivores and Communities Program (CACP) supported expansion of community deadstock removal efforts beginning in 2009, including reimbursement of on-farm removal costs, bear-resistant deadstock bins, and a livestock compost facility (operational 2013–2014). Here, we present an evaluative case study describing the development, implementation, and results of the deadstock removal program, including the compost facility. We tracked the number of head of livestock removed each year, the number of participating landowners, the average cost per head, and total program costs. We also used an online survey to assess participants' perspectives of the deadstock removal program and future needs. To date, the CACP has removed >5,400 livestock carcasses, representing between 15.1 and 22.6% of available carcasses in the program area, and 67.3% of livestock owners indicated they currently use the deadstock removal program to dispose of deadstock. Average cost to compost an animal was significantly less than other removal methods ($36.89 composting vs. $79.59

non-composting, one-tailed *t*-test, unequal sampling variances: $t = 4.08$, df = 5.87, $p = 0.003$). We conclude by discussing both ecological and social implications for deadstock removal as a conflict mitigation measure and make suggestions for future management considerations.

Keywords: carcass disposal, coexistence, community-based conservation, deadstock, human-wildlife conflict, large carnivores, livestock, program evaluation

INTRODUCTION

Global livestock production is a major world economy; billions of livestock are produced across the globe with a gross production value in the trillions of dollars (Xu et al., 2015). Due to natural losses, disease, slaughter and accidents, significant numbers of carrion are generated from the livestock industry each year. Livestock deaths are an unfortunate reality for livestock producers, with implications for dead livestock (i.e., deadstock) disposal options extending beyond the farm or ranch itself. These include the direct costs to livestock producers, time invested by producers to manage deadstock, costs to partnering organizations or government agencies, agricultural and wildlife policy implications, and even human safety risks. In areas with carnivore presence, an additional layer of complexity is added because deadstock can be a major attractant for large carnivore species (Northrup and Boyce, 2012; Morehouse and Boyce, 2017; Wilson et al., 2017). Across the globe, carnivores have been documented scavenging on livestock carcasses (Servheen, 1983; Wilson et al., 2005; Lagos and Bárcena, 2015; Ciucci et al., 2020). Not only does this behavior have nutritional ecology implications for the wildlife species (Robbins et al., 2004; Coogan and Raubenheimer, 2018), but it also raises concerns about disease spread (Gwyther et al., 2011; Ogada et al., 2012; Cunningham et al., 2018).

Consequently, regulations that govern the disposal of deadstock are becoming more common across many countries, and livestock disposal and associated policies have implications beyond the ranch that need to be considered (e.g., Gwyther et al., 2011; Northrup and Boyce, 2012; Lagos and Bárcena, 2015). These regulations, for instance, can impact wildlife species that have become accustomed to the availability of carcasses. For example, following an outbreak of bovine spongiform encephalopathy (BSE), the European Union implemented sanitary legislation that prohibited the abandonment of livestock carcasses in the field, which in turn resulted in negative impacts on vultures by decreasing their productivity and population growth and increased vulture attacks on livestock (Mateo-Tomás et al., 2019). Similarly, European wolves decreased their consumption of carrion following regulatory changes and instead increased predation on wild ungulates (Lagos and Bárcena, 2015). In Israel, Bino et al. (2010) manipulated the availability of poultry carcasses through a sanitation protocol to evaluate the spatial and numerical responses of overabundant red foxes. Fox survival rates were reduced in treated areas and the study results suggested that improved sanitation was an effective tool for controlling overabundant canids (Bino et al., 2010). Additionally, access to anthropogenic food resources such as livestock carcasses can reduce predatory behavior (Ciucci et al., 2020). For example, in Italy, Ciucci et al. (2020) observed large numbers of wolf scavenging events, and livestock carcasses accounted for 75.8% of wolf-scavenged carrion. Similar findings were observed by Morehouse and Boyce (2011) in Alberta, highlighting the global applicability of carcass management. Further, the effects of carcass disposal are noticeable by local communities; in a survey, Humphries et al. (2015) found that 90% of farmers in their South African study area acknowledged that their carcass disposal habits could increase jackal numbers. Thus, as illustrated by these examples, the influence of livestock disposal options is not limited in scope to the livestock operation itself.

In Alberta, Canada, there are several legal disposal options for dead bovines as governed by the *Disposal of Dead Animals Regulation* within the Animal Health Act (Province of Alberta, 2014). These options include disposal in a landfill, burial, burning, composting (in a compost facility or on-farm), rendering and natural disposal (Province of Alberta, 2014). Natural disposal, which refers to disposing of the carcass in a manner that allows for scavenging, has been historically used and accepted across Alberta's livestock producers; it is an easy and inexpensive option for deadstock disposal (Xu et al., 2015). Rendering refers to a process wherein deadstock are converted into usable materials; specified risk material (SRM), which is material capable of transmitting BSE, is dehydrated and disposed of in landfills (Xu et al., 2015). Natural disposal has increased in prevalence since the detection of BSE in Canadian cattle in 2003 (Northrup and Boyce, 2012). Prior to BSE detection, rendering companies would remove deadstock free of charge (Stanford and Sexton, 2006). Post-BSE changes in regulations by the Canadian Food Inspection Agency (CFIA) have altered how SRM must be handled. However, complying with CFIA regulations has increased costs to the rendering companies who in turn have passed the cost of meeting these regulations on to the producer by charging for their services (Stanford and Sexton, 2006). Current (2021) rendering company rates in southwestern Alberta are \$0.14 per pound with a minimum charge of \$120 per deadstock pickup. These charges are often prohibitive to producers and have resulted in an increase in on-farm natural disposal of deadstock (Bergeron and Gagnon, 2006; Northrup and Boyce, 2012; Morehouse et al., 2020). For example, in two counties in southwestern Alberta, an average of 1,538 cattle carcasses were removed by the local rendering company per year prior to 2003; this is in contrast to an average of 291 deadstock removed per year after 2003 (Northrup and Boyce, 2012). Presumably, the cattle that are no longer being removed by the rendering company are now left on the landscape, which in turn poses human and environmental health and safety risks, including the potential for human-wildlife conflict. For example, deadstock might be acting as a supplemental food source for carnivores in the area. Research has shown that supplemental food sources can result in increases in abundance, productivity and survival of carnivores (Yom-Tov et al., 1995; Newsome et al., 2015)—-potentially exacerbating human-carnivore conflicts in landscapes shared by both people and carnivores.

Such is the case in southwestern Alberta where four native carnivore species [black bears (*Ursus americanus*), grizzly bears (*Ursus arctos*), cougars (*Puma concolor*), and wolves (*Canis lupus*)] extensively use private lands that are also used for agriculture and crop production. While data on population abundance is limited for most of the carnivores present in this region, research has shown that the grizzly bear population is stable to increasing with the highest density in Alberta (Morehouse and Boyce, 2016; Alberta Environment and Parks, 2020). This high-density bear population has contributed to concerns regarding human safety and bear conflicts, particularly because southwestern Alberta is an area of the province where carnivore home ranges overlap substantially with agricultural land uses.

In turn, this overlap makes coexistence between people and carnivores a persistent challenge (Morehouse et al., 2020). Past research has shown that deadstock and stored grain are the primary attractants on this landscape (Northrup and Boyce, 2012; Morehouse and Boyce, 2017), and all four carnivore species have been documented scavenging on deadstock (Morehouse and Boyce, 2011; Banfield, 2012; Northrup and Boyce, 2012). This is potentially problematic as it can draw carnivores into an unwanted area (e.g., close to home site) and essentially "introduce" them to other on-farm attractants such as stored grain, outdoor pet food, human garbage, livestock, gardens, and more (e.g., Tourani et al., 2014; Mohammadi et al., 2019). For example, Capitani et al. (2016) conclude that livestock depredation by wolves is bolstered by uncontrolled carcass disposal. We note, however, that other studies have found that uncertainty remains around the relationship between carcass disposal and livestock depredation (e.g., Mech et al., 2000; Bradley and Pletscher, 2005). Regardless, carnivore presence near livestock and other agricultural attractants can be costly. Indeed, livestock depredation is an important and often expensive issue, not only in Alberta but across the world (Muhly and Musiani, 2009; Morehouse et al., 2018; Widman and Elofsson, 2018). Further, factors such as missing animals, reduced livestock weight gain, decreased conception rates, and increased rancher time are additional costs that are often more difficult to track (Sommers et al., 2010; Steele et al., 2013; Jacobsen and Linnell, 2016). Thus, while challenging, reducing human-carnivore conflicts is important from both conservation and economic perspectives.

Non-lethal tools such as securing or removing attractants can be powerful measures for reducing human-carnivore conflicts (e.g., Wilson et al., 2017; Morehouse et al., 2020). Commonly, this includes electric fencing or other materials such as fladry, lights, and noise makers that will deter livestock predation; livestock guarding animals (i.e., dogs, donkeys, llamas); human vigilance (i.e., shepherds, guardians); and secure overnight locations such as barns or sheds for calves, lambs or other small stock (van Eeden et al., 2018; Young et al., 2018; Sibanda et al., 2020; Rigg et al., 2021). However, social acceptance and actual implementation of preventative measures are not necessarily guaranteed. Barriers can include lack of belief in the effectiveness of the mitigation measure or lack of public trust in government agencies or organizations implementing these measures (Wilson et al., 2014; Noga et al., 2018). Other barriers include enduring cultural values for traditional, and often lethal, carnivore management techniques (Treves and Naughton-Treves, 2005; Hughes and Nielsen, 2019), limited financial resources to implement mitigation techniques (Smith et al., 2020), additional labor (time and effort) to implement and maintain preventative measures (Graham and Ochieng, 2008), inadequate policy measures (i.e., predator compensation; Lee et al., 2017), and practical limitations that may preclude participation (i.e., remote location of a producer and limited access to urban resources; Hughes et al., 2020). However, where livestock producers (or other stakeholders) have been engaged in collaborative decision-making processes, enabled to share their voice and build local capacity to take action, conflict mitigation measures have been more widely accepted and practiced (Redpath et al., 2017; Wilson et al., 2017; Expósito-Granados et al., 2019; Hughes et al., 2020; Morehouse et al., 2020; Marino et al., 2021; van Eeden et al., 2021).

To help mitigate carnivore conflicts associated with deadstock in southwestern Alberta, the Waterton Biosphere Reserve's (WBR) Carnivores and Communities Program (CACP) supported the expansion of community-led deadstock removal efforts in 2009. The WBR is a community-based, non-profit organization that co-founded the CACP to support initiatives that would improve human-carnivore coexistence. This is done by engaging rural residents in hands-on programming that reduces livestock loss, property damage and safety risks. Specifically, the deadstock removal program operates over four municipalities (Cardston County, Pincher Creek, Ranchland, and Willow Creek) in southwestern Alberta (**Figure 1**) and includes two components: deadstock bins and on-farm deadstock removal. The deadstock bins are large, metal bear-resistant containers that producers can use to dispose of dead livestock, thereby removing the attractant from their property. The WBR pays the rendering company to empty the bins. On-farm deadstock removal is the other option, where WBR pays for on-farm deadstock removal by the rendering company when bins are not available or practical for the producer. The four partnering municipalities provide in-kind support for WBR to operate the program. In 2012, Cardston County partnered with WBR, Chief Mountain Landowners Group (another local non-profit) and Alberta Environment and Parks (provincial government) to explore, develop and ultimately implement a new component to deadstock removal in Cardston County – deadstock composting. Composting is the biological breakdown of organic materials. Kalbasi et al. (2005) succinctly describe the process of carcass composting as "*temporarily burying dead animals above ground in a mound of supplemental carbon and allowing decomposition by thermophilic microorganisms to heat up the pile, kill most of*

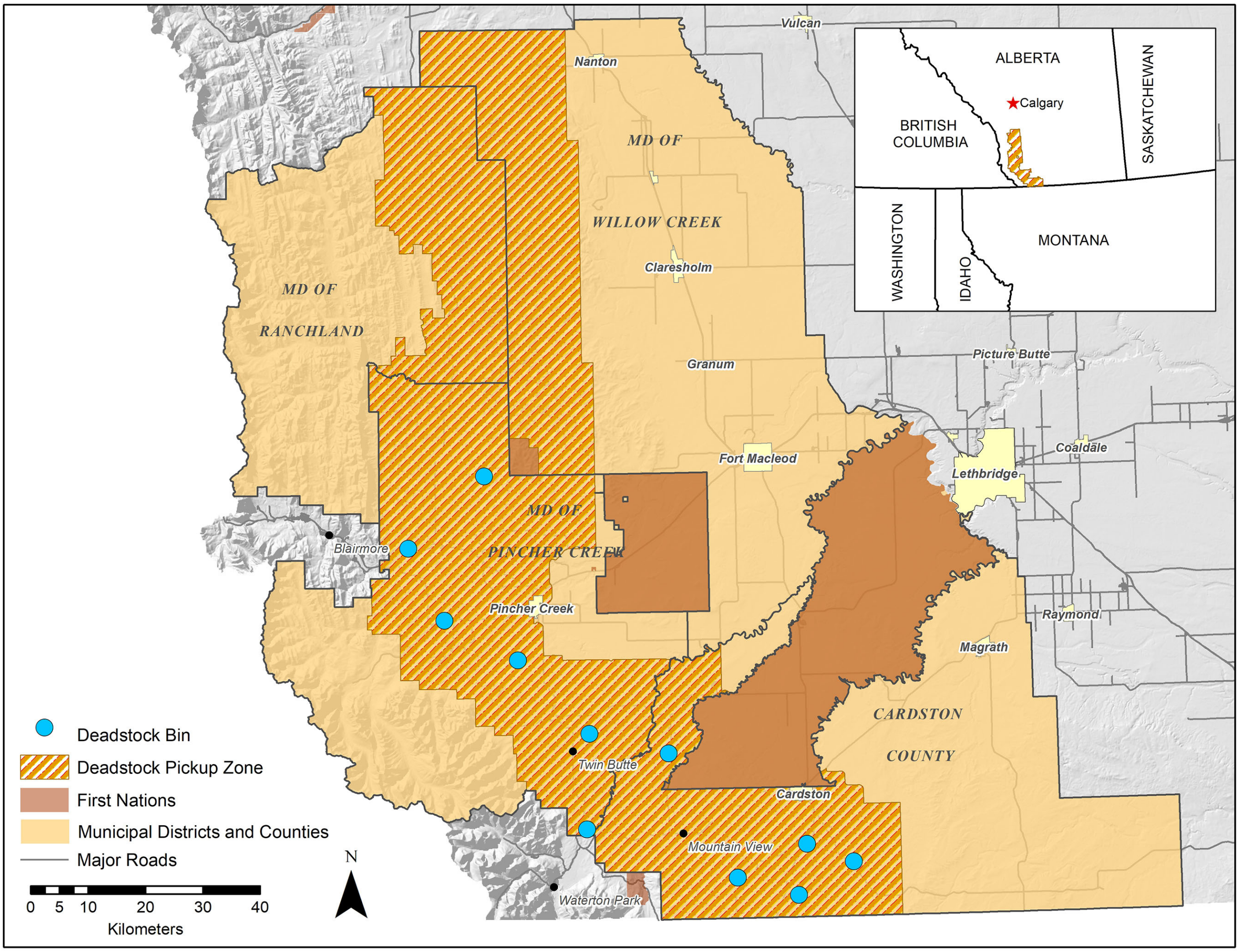

FIGURE 1 | Map of the Waterton Biosphere Reserve's Carnivores and Communities Program deadstock pickup zone in southwestern Alberta.

the pathogens and digest the carcass tissues under predominantly aerobic conditions." Cardston County secured provincial and federal grants and provided in-kind support to construct the first livestock mortality composting facility in Canada. While WBR did not have financial resources to contribute to the facility construction, WBR paid for the deadstock pickup (completed by a county employee) and facility operation and worked with Cardston County to address emerging regulatory issues to ensure smooth facility operation. The compost facility operated as a pilot program for two years, 2013–2014.

Previous work in the area has demonstrated a decrease in large carnivore conflict incidents, specifically those related to deadstock, since the implementation of the deadstock removal program (Morehouse et al., 2020). However, further work is required to fully understand the financial, social, and policy successes and challenges of the deadstock removal program. Indeed, evaluations of conflict mitigation programs are not common in the literature yet are needed to move conflict-mitigation science forward (van Eeden et al., 2018). Here, we present an evaluative case study describing the development, implementation, and results of the CACP's deadstock removal program, including the compost facility. Using our evaluation, we describe the success the deadstock removal program has had as a carnivore conflict mitigation measure, as well as the socio-political challenges that led to the suspension of some program components. We discuss the ecological, social and financial implications for community-based deadstock removal as a large carnivore conflict mitigation measure and provide suggestions for future policy and management considerations.

METHODS

To evaluate overall effectiveness of the program, we tracked the number of participants, the number of deadstock removed annually, the average removal cost per deadstock, and total program costs. We also used an online survey to assess landowner's perspectives on the deadstock removal program, and the program's future needs.

Deadstock Data

The deadstock removal program began in 2009, though was not fully operational in its current form until 2013. Thus, we considered only data from 2013 through 2020 in most components of our evaluation. For each year within this 8-year time period we tracked the number of participating livestock owners and the number of deadstock removed within each of the four participating municipalities through records kept by the WBR and participating municipalities. Additionally, using records compiled by the WBR CACP coordinator and participating landowners, we estimated the total number of deadstock removed from the previous years (2009–2012) and added this to the total removed from 2013 to 2020 for a grand total of deadstock removed from the CACP area.

Since we were also interested in understanding the impact of deadstock removal as a carnivore conflict mitigation measure overall, we also estimated (within a range) the percent of available deadstock removed by the CACP's program on a yearly basis. For each municipality within the deadstock zone, we calculated the proportion of the municipal district (MD) that fell within the deadstock pickup area. Although the deadstock removal program removes mules, bison, horses, and goats in addition to cattle, almost all animals removed are cattle; thus, we used the number of available cattle for our estimates of the total number of deadstock removed. We used 2011 Alberta Census of Agriculture data as our source of information for the number of live head of cattle within the MD boundaries (Alberta Agriculture and Rural Development, 2014); we acknowledge that data may have changed since 2011, but more recent data were not available at the required spatial resolution. We then multiplied the number of live cattle within each MD by the proportion of the MD that is within the WBR's deadstock pickup zone to estimate the total number of live cattle within the deadstock pickup zone. The deadstock removal program, however, is not available to intensive livestock operations. An intensive livestock operation is a location where large numbers of animals are in a confined (fenced or enclosed land or buildings) location for the purpose of growing, breeding, sustaining, or finishing (e.g., feed lot). Thus, we worked with staff from the four MDs to estimate the number of live cattle on intensive livestock operations that occurred within the deadstock zone and excluded those numbers from our estimate of cattle occurring in the MD. We then calculated the estimated number of cattle deaths (i.e., the number of dead cattle available for pickup through the WBR's deadstock removal program). We used a 3% death rate (Canfax Research Services, 2011; Western Beef Development Centre, 2015; University of Saskatchewan, 2018) to calculate the estimated number of cattle deaths within the deadstock zone. We then used this number to estimate the percentage of deadstock removed by the CACP per year. We considered this percentage to be the low end of the range.

To further refine our estimate and calculate an upper range, we used additional data from the Alberta Census for Agriculture. The Alberta Census for Agriculture reports the number of acres within each MD that are considered farmland (Alberta Agriculture and Rural Development, 2014). Farmland is further broken down into a variety of categories including land in crops, summer fallow, tame or seeded pasture, natural land for pasture, woodland and wetland including Christmas Tree Area, and other land (Alberta Agriculture and Rural Development, 2014). The sum of these categories is equal to the total land area of Alberta farms. Natural land for pasture (NLP) is defined as "*areas used for pasture that have not been cultivated and seeded, or drained, irrigated or fertilized. Includes native pasture/hay (indigenous grass suitable as feed for livestock and game); rangeland (land with natural plant cover, principally native grasses or shrubs valuable for forage); grazeable bush (forest land and bushy areas used for grazing, not land cultivated for crops or with dense forest), etc.*" Thus, we considered NLP to be the area in which livestock were grazed.

For each MD in our program area, we calculated the proportion of the MD that was NLP. We then assumed that the proportion of NLP within the deadstock zone would be the same proportion within the MD boundaries. We calculated the number of livestock present within the deadstock zone by assuming that the same ratio of livestock to NLP occurred in the deadstock zone. As above, we excluded cattle in intensive livestock operations from this estimate and then used a 3% death rate to estimate the number of cattle deaths within the deadstock zone. We estimated the percentage of dead livestock removed each year by the CACP and considered this percentage to be the high end of the range.

Cost Data

From 2013 through 2020, we tracked the amount of money spent annually on the deadstock removal program in Canadian dollars (CAD). We used the total amount spent on the deadstock removal program and the number of livestock removed to calculate the average cost per dead animal removed. Thus, we present only the dollar amount charged against the WBR's operating grants and not in-kind or matching funds, as these were not tracked.

To compare the cost effectiveness of the composting facility to the deadstock bins and on-farm removal, we summarized data from Cardston County in 2013–2014 (i.e., the time frame in which the compost facility was operational) and compared it to the data from the rest of the program area for the same time period. We used a one-tailed t-test with unequal sampling variances to evaluate if the average cost to compost a dead animal was less than the average cost to remove a dead animal for the non-composting parts of the program (i.e., bins and on-farm pickup).

Social Survey

In 2018, we used an online survey to collect data to evaluate the effectiveness of the CACP (Morehouse et al., 2020). The survey was created in Survey Monkey and included an assessment of the deadstock removal program. The survey was also made available in a printed version for individuals without internet or with a preference for a hard copy. We directly emailed the survey to CACP participants and community members using the program's

TABLE 1 | The number of head of livestock removed each year from each municipal district (MD) or county through the Waterton Biosphere Reserve's deadstock removal program.

MD/county	Number of head removed									Total removed	Average per year (SD)
	2009–2012[b]	2013[a]	2014[a]	2015	2016	2017	2018	2019	2020		
Cardston[a]		435	450	137	176	228	195	195	180	1,996	250 (121.8)
Pincher Creek		109	360	249	324	329	440	352	332	2,495	312 (97.3)
Willow Creek		11	23	9	13	17	41	23	23	160	20 (10.2)
Ranchland		50	35	29	7	5	62	38	42	268	34 (19.7)
Total	560	605	868	424	520	579	738	608	577	5,479	685 (127.6)

[a]*From late January 2013 through April 2014 Cardston County operated a livestock compost facility.*
[b]*Numbers are not available per MD/County for this time period.*

TABLE 2 | The number of individuals participating in the Waterton Biosphere Reserve's deadstock removal program per municipal district (MD)/county per year.

MD/county	Number of individuals participating								Average per year (SD)
	2013[a]	2014[a]	2015	2016	2017	2018	2019	2020	
Cardston[a]	40	40	35	32	32	27	36	34	35 (4.3)
Pincher Creek	49	40	42	50	50	50	50	50	48 (4.1)
Willow Creek	9	7	5	7	6	11	10	6	8 (2.1)
Ranchland	6	5	5	4	4	6	6	7	5 (1.1)
Total	104	92	87	93	92	94	102	97	95 (5.6)

[a]*From late January 2013 through April 2014 Cardston County operated a livestock compost facility.*

list serve. We also advertised the survey in local newspapers, shared on the WBR website and social media (Facebook), and placed posters in strategic public locations (Morehouse et al., 2020). The survey was available online for 7 weeks, with two reminder emails sent. Limitations with this sampling technique include selection and social desirability bias (Palinkas et al., 2015), but because this was a case study designed to asses the perceptions of individuals familiar with the CACP, along with survey duration, multiple completion reminders, and time and costs associated with probabilistic techniques, we believe our approach was effective and appropriate (Dillman et al., 2009; Barratt and Lenton, 2010; Woodhouse et al., 2015; Morehouse et al., 2020). The full details on the social survey can be found in Morehouse et al. (2020).

Here, we consider only responses from individuals that identified as landowners raising livestock, and only the questions related to the CACP's deadstock removal program, in our evaluation. These questions were not fully explored in Morehouse et al. (2020).

RESULTS

Deadstock and Costs

In total, between 2009 and 2020 the CACP's deadstock removal program removed 5,479 livestock carcasses from the program area (average number of carcasses removed per year = 457, SD = 260.8) (**Table 1**). Most carcasses were removed from Cardston County and the Municipal District of Pincher Creek (**Table 1**). On average, 95 (SD = 5.6) individual landowners participated in the deadstock removal program each year (**Table 2**). We estimated that on a yearly basis the deadstock removal program removed between 15.1 and 22.6% of the available livestock carcasses within the deadstock removal zone (**Table 3**).

The average cost to remove a livestock carcass was higher in the MDs of Willow Creek and Ranchland than in Cardston County and Pincher Creek (**Table 4**); this was due to exclusive use of on-farm pickup rather than deadstock bins. The regions of Willow Creek and Ranchland within the deadstock zone are sparsely populated as compared to Pincher Creek and Cardston County and due to long travel distances for producers, deadstock bins are not practical in these municipalities. In total, the average cost to remove a single livestock carcass across the program area was \$112.08 (SD = 35.48, maximum cost = \$206.40 in Ranchland in 2017, minimum cost = \$71.23 in Cardston in 2018; minimum and maximum are excluding 2013 and 2014 prior to rendering company rate increases) (**Table 4**). The 3-year average for WBR to operate the program was \$62,667 (SD = \$10,786).

During the operation of the Cardston County compost facility, 842 livestock carcasses were composted. By comparison, only 588 livestock carcasses were removed from the landscape from other municipalities for the same time period of 2013–2014 through the deadstock bins and on-farm carcass pickup. The average cost per head to compost an animal in Cardston County in 2013–2014 was \$36.89 (SD = \$4.96). In comparison, the average cost per carcass removed in 2013–2014 for the other three municipalities participating in the WBR's deadstock removal program was significantly greater at \$79.59 (SD = \$24.18) (one-tailed t-test, unequal sampling variances: $t = 4.08$, df = 5.87, $p = 0.003$).

TABLE 3 | Estimated number of cattle and cattle deaths occurring in the Carnivores and Communities Program (CACP) deadstock pickup zone each year in southwestern Alberta.

Low estimate

MD/county	Area in deadstock pickup zone (km^2)	Estimates for deadstock pickup zone: Number of cattle (ILOs excluded)	Cattle deaths (ILOs excluded)	Percent (%) deadstock removed by CACP
Pincher Creek	1,636	64,266	1,928	16.2
Cardston	1,304	24,585	738	33.9
Willow Creek	1,168	31,751	953	2.1
Ranchland	902	13,745	412	8.2
Average				15.1

High estimate

MD/County	Area in Deadstock Pickup Zone (km^2)	Estimates for deadstock pickup zone: Natural Land for Pasture (km^2)	Number of Cattle (ILOs excluded)	Cattle Deaths (ILOs excluded)	Percent (%) deadstock removed by CACP
Pincher Creek	1,636	665	40,492	1,215	25.7
Cardston	1,304	345	15,284	459	54.5
Willow Creek	1,168	493	31,462	944	2.1
Ranchland	902	626	14,364	431	7.9
Average					22.6

Intensive livestock operations (ILOs) are excluded from estimates. Two scenarios are presented, a low and high estimate of the percent of available deadstock removed per year by the CACP.

TABLE 4 | The average cost in Canadian dollars (CAD) to remove each dead animal per year per municipal district (MD)/county.

MD/county	Average cost ($ CAD) per head								
	2013	2014	2015[b]	2016	2017	2018	2019	2020	Average per year (SD)
Cardston[a]	-	$122.49	$100.05	$83.51	$87.95	$71.23	$106.34	$100.49	$96.01 (16.73)
Pincher Creek	$43.55	$54.67	$90.98	$105.52	$111.74	$80.26	$95.46	$120.21	$87.80 (21.91)
Willow Creek	$94.64	$101.48	$153.44	$178.31	$133.88	$148.78	$149.72	$138.17	$137.30 (23.32)
Ranchland	$93.83	$89.37	$87.21	$155.14	$206.40	$135.03	$92.74	$141.83	$125.19 (43.79)
Total									$112.08 (35.48)[c]

[a]*From late January 2013 through April 2014 Cardston County operated a livestock compost facility. The costs in this table exclude composting costs.*
[b]*On February 1, 2015, rendering company rates increased from $0.09/lb to $0.14/lb and the minimum pickup fee rose from $75 to $120.*
[c]*Average across all MDs/counties and years.*

Social Survey

We had 116 completed surveys with 74 of respondents identifying as livestock owners (50 males, 24 females; ages ranged from 25 through >75 years old). Other respondents were rural residents or landowners that did not own livestock. Of these livestock owners, 97.3% indicated that they were aware of the deadstock removal program, and 67.3% indicated they currently used the CACP deadstock removal program to dispose of their deadstock (**Table 5**).

Boneyards (i.e., locations on privately owned property where producers dispose of livestock carcasses by surface disposal and the remains are accessible to scavengers) were the most commonly reported method for carcass disposal after BSE but before the implementation of the CACP (**Table 5**). However, 49.0% of respondents felt that boneyards contributed to increased carnivore activity on their property (**Table 5**).

Motivations for livestock owners participating in the deadstock removal program included reducing personal costs associated with carnivores (72.7%), learning how to address ongoing problems with carnivores (68.2%), and personal interest (68.2%) (**Table 5**). However, despite high awareness and use of the program, only 28.8% indicated they would be willing to pay

TABLE 5 | Survey questions and available responses, sample size, and percent response to questions related to the Waterton Biosphere Reserve's Carnivores and Communities deadstock removal program.

Question and available responses	Percent (%)
How do you currently dispose of deadstock? (n = 52)[a]	
Carnivores and communities deadstock removal program	67.3
On-farm composting	23.1
Boneyard	21.2
Deep burial	13.5
Other	11.5
After BSE and before the CACP, how did you dispose of deadstock? (n = 52)	
Boneyard	40.4
Rendering company	28.8
Burial	11.5
Other/combination of above	19.2
If you have/had a boneyard, do you think it contributed to increased carnivore activity? (n = 51)	
Higher with a boneyard	49.0
Lower with a boneyard	7.8
Undecided	43.1
If program funding became an issue, would you be willing to pay for the deadstock removal service? (n = 52)	
Yes	28.8
No	34.6
Undecided	36.5
Why have you participated in the deadstock removal program? (n = 44)[a]	
I wanted to reduce personal costs associated with living with carnivore species	72.7
I wanted to learn how to address ongoing problems with carnivore species	68.2
Personal Interest	68.2
Programming was easy to access	36.4

[a]Individuals were allowed to check all responses that applied; thus percentages will not total 100.

for deadstock removal if CACP funding were no longer available (**Table 5**).

DISCUSSION

Our evaluation indicates that the CACP's deadstock removal program was effective. To date, the WBR has removed over 5,400 dead cattle, resulting in a decrease of large carnivore incidents related to deadstock (see Figure 4, Morehouse et al., 2020). Our findings further support results from a previous program evaluation where provincial occurrence records (i.e., complaint data) were used in conjunction with social survey data to evaluate the overall effectiveness of the CACP (Morehouse et al., 2020). The program evaluation found that not only do conflict occurrence data indicate evidence of CACP success, but the social survey data indicate support of the program and the importance of removing deadstock (Morehouse et al., 2020). Indeed, Morehouse et al. (2020) previously showed that local residents were supportive of the deadstock removal program and believed that the program helped to reduce conflicts with large carnivores. Here, our results provide further clarity to this information and indicate that most individuals responding to our survey not only support, but actually use the program. Also of importance is the evidence that at least some members of the community have now shifted away from the use of boneyards to the use of the CACP's deadstock removal program.

Importantly, our results also demonstrate that social acceptance of mitigation efforts is a key requirement to long-term behavioral change (Dickman et al., 2013; Expósito-Granados et al., 2019; Hughes and Nielsen, 2019). While the requirement for mitigation efforts to be socially acceptable by practitioners is somewhat self-evident, it is not yet common in the literature to measure metrics of acceptance. Here we have clearly demonstrated a link between the social acceptance and ecological efficacy of a conflict mitigation solution. Conflict mitigations would likely not be adopted or "sanctioned" by the requisite community or political entity if those mitigations did not resonate with the needs of the people experiencing carnivore-agriculture conflicts. We believe the community-based nature of the CACP is a key component to its adoption in the region, and our results add to the growing body of literature demonstrating the positive impact that participatory approaches can have on both people and wildlife (Wilson et al., 2017; Störmer et al., 2019; Morehouse et al., 2020; Marino et al., 2021). It is possible that moving forward, traditionally used cultural practices (i.e., boneyards) may be replaced with alternative ways of dealing with deadstock. Likewise, more progressive policy thinking may give way to improvements on existing programs (e.g., predator compensation) or investments in new approaches (e.g., deadstock composting).

Successful adoption of the deadstock removal program by producers served as a mechanism to fulfill the carcass management challenge created by BSE policy changes. This policy change resulted from the detection of BSE and subsequent fee increases associated with removing deadstock from ranches. In turn, this meant the need for on-farm disposal of deadstock increased across the study area (Northrup and Boyce, 2012; Morehouse et al., 2020). At the same time, increased carnivore conflicts and high-density carnivore numbers were documented for this region (Northrup and Boyce, 2012; Morehouse and Boyce, 2016, 2017; Loosen et al., 2018; Morehouse et al., 2020). However, conflicts related to agricultural attractants have decreased since 2009, at least in part due to the deadstock removal program (see Figure 5, Morehouse et al., 2020). Reducing on-farm deadstock disposal is important because that practice has the potential to increase carnivore activity (**Table 5**), which in turn can exacerbate human-carnivore conflicts and increase human safety risks. Our results indicate the deadstock removal program is removing between 15 and 23% of the available livestock carcasses within the deadstock removal zone each year. As a single mitigation option, we believe this to be a substantial reduction in the availability of this attractant. We note, however, that the remaining carcasses are not necessarily available to large carnivores; some individuals compost on-farm, pay for rendering services themselves, or bury the carcass. While the deadstock removal program has not completely eliminated or solved the deadstock issue, it provides an important alternative for producers in the area and is in integral component to the CACP's multi-faceted approach to conflict mitigation.

The deadstock removal program, however, comes at a high cost ($75,000 in the 2020/2021 fiscal year) to the WBR, which is a small non-profit organization. For example, on average over the last 3 fiscal years, the deadstock removal program represented 36.4% of the CACP budget. If funding became an issue and these costs had to be borne by participating producers, the yearly cost per producer would be approximately $643. Our data demonstrate a financial benefit to composting; the average cost per head to compost an animal in Cardston County in 2013–2014 was $36.89 - significantly less than the average cost per head in 2013–2014 for the other three municipalities participating in the CACP's deadstock removal program. Composting reduces costs by replacing more expensive removal by the rendering company with less expensive pickup by a local individual and subsequently lower hauling costs. Further, the compost facility allowed for more frequent pickup of deadstock because removal was not dependent on rendering company availability. Several hundred animals were composted, representing 15.4% of all animals removed between 2009 and 2020. By these measures, the program appeared quite successful. That said, whether successful conflict mitigations are scalable in time and space is a central consideration to broaden their sustainability. If something that works depends on high capital costs, intensive upkeep, or specialist facilitation to simply operate, it may not be a feasible strategy in the long-term, particularly as greater scrutiny is applied to spending tax-payer monies if there is increased competition for public funding (i.e., grants). Although current Canadian regulations prohibit the sale of compost containing SRM (CFIA, 2020), composting does create a usable product and final SRM compost can be used for land reclamation provided the land is not grazed by livestock for at least 5 years (Xu et al., 2014a). Further, compost research is an active field and advancements might allow for further uses in the future, potentially creating opportunities for economic benefits. Finally, once established, carrion composting has benefits that can extend to other sectors as well. For example, in Canada, an estimated 45,000 large mammal-vehicle collisions occur each year (Huijser et al., 2009), and composting could be a solution for road-killed carcass disposal.

Despite the evidence of cost-effectiveness, increased service, high levels of use and satisfaction, along with attempts by the WBR staff to communicate these benefits with the Cardston County government, the compost facility was closed and no official reason for the decision was provided (Cardston County, 2018). This disconnect between local politics, the needs of landowners, and successful conflict mitigation initiatives highlights the issue of who holds the power in decision-making arenas, and what agendas are pursued, as well as why a multi-party, representative governance structure with checks and balances to buffer against these challenges, is required (Hughes et al., 2020). Despite the ultimate closure of the facility in Alberta, we believe that composting is a solution to the deadstock removal problem that should be reconsidered in Canada and elsewhere. Research has shown that composting is an effective method of inactivating both bacterial (e.g., *Listeria, Escherichia coli, Salmonella*) and viral pathogens (e.g., Newcastle disease and foot-and-mouth disease) (Gwyther et al., 2011; Xu et al., 2015). Further, current research results support the idea that composting can result in effective degradation of infectious prion proteins in carrion (Xu et al., 2015). We note, however, that adequate design and operation of compositing facilities is essential to ensuring that carrion is completely degraded and free of pathogens (Xu et al., 2014b).

From a broader perspective, identifying alternatives to trucking SRM to approved landfill facilities will likely yield additional ecological and economic benefits. Currently, both transportation and disposal of SRM materials are strictly regulated by the Canadian Food Inspection Agency (CFIA), and this has translated in the marketplace to few companies offering such services. In the western Canadian provinces of British Columbia, Alberta, and Saskatchewan, a single company collects the majority of all SRM contaminated materials (both dead carcasses and waste from feedlots and slaughterhouses) produced (that are collected and not disposed of on-farm). These raw materials are then rendered into usable and SRM-waste materials at two plants in Calgary, Alberta and Saskatoon, Saskatchewan; rendered SRM materials are then further transported to a single CFIA-approved landfill in Coronation, Alberta. While functional, this model suggests few locally available off-farm disposal options and has potentially increased trucking needs and the risk of regional- and cross-contamination of SRM from long trucking distances between points of origin and disposal (Fonstad et al., 2003; Glanville et al., 2009; Pandey et al., 2020).

Though well-beyond the scope of this study, it is worth mentioning that increased investment in more localized solutions for safe SRM disposal, whether those be rendering, composting, or something else, could also establish the infrastructure to develop additional economic opportunities for rural communities. Both the markets for, and research on, the development of value-added products from animal carcasses beyond traditional uses as animal feeds have expanded rapidly since BSE, and a variety of products are now widely used across a range of consumer goods globally (Toldrá et al., 2012; Tizazu et al., 2016). Further, more experimental options for disposal like conversion of deadstock to biofuels (Banković-Ilić et al., 2014) and electricity (*via* biogas generation; Fedorowicz et al., 2007; Wang, 2014) could offer practical solutions to ever increasing energy demands. One such example of biogas generation, produced in part from deadstock among other agricultural wastes, currently exists in Lethbridge, Alberta. Investment in this arena could help to integrate practical and safe removal of livestock carcasses with realistic coexistence with large carnivores while also diversifying opportunities for rural communities often dominated by single or few economic sectors – in effect a win-win-win. Additional benefits of localized solutions include climate benefits by reducing the carbon footprint and wildlife collisions risks associated with long-distance trucking.

Indeed, conflict mitigation is a multidisciplinary challenge and requires a multidisciplinary solution. There is broad agreement in the literature that conflict mitigation policy should be evidence-based (Baylis et al., 2016; van Eeden et al., 2018; Morehouse et al., 2020), yet most evaluations of conflict mitigation programs are often single discipline in their focus. For example, evaluations are usually either of social acceptance (e.g., Dickman, 2010; Salvatori et al., 2021) or ecological efficacy (van Eeden et al., 2018), but rarely both (Karanth and Ranganathan, 2018; Sibanda et al., in press). This is problematic because a singular focus on either social or ecological outcomes is unlikely to provide sufficient information to develop long-term mitigation strategies. Indeed, because conflicts occur at the interface of ecology, economics, sociology, and politics, mitigations must consider multiple disciplines to be successful.

Adding to this complexity is the fact that human-wildlife interactions are not static. Although carnivore populations are in peril in some regions of the world, they are growing and rebounding in others due to various conservation efforts and policies (Linnell et al., 2001; Miller et al., 2013; Chapron et al., 2014). Simultaneously, the human-wildland interface in many regions is expanding with human population growth and economic development (Ellis et al., 2010), and with this comes a broad range of socio-ecological effects, including the potential for (or increasing of) human-wildlife conflict (Leu et al., 2008; Bar-Massada et al., 2014; Nyhus, 2016). Additionally, the efficacy of conflict mitigation measures can, in some instances, wane over time (Musiani et al., 2003; Shivik, 2006), making conflict mitigation a constantly evolving field. Further, the persistence of human-wildlife conflicts without resolution can lead to frustration within local communities (Best and Pei, 2019). As the frustration surrounding conflicts grows, communities and individuals can become increasingly less supportive of mitigation efforts (Barua et al., 2013; Megaze et al., 2017; Karanth and Ranganathan, 2018). Thus, for all of these reasons, we believe it is important to routinely evaluate and modify conflict mitigation efforts to ensure they are having the intended effect and resonate with the communities that are implementing them.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Although our case study focused on southwestern Alberta, carnivore conflict associated with dead livestock and the associated disposal options, are a global issue. In Canada alone, it is estimated there are 250,000 tons of SRM generated annually from cattle and sheep slaughter (Xu et al., 2015). The proper disposal of deadstock plays an important role in preventing the transmission of infectious pathogens to both people and animals (Xu et al., 2015). In areas where people and wildlife, particularly carnivores, overlap, there are other issues to consider including human-carnivore conflicts and related economic and safety impacts. Deadstock are a large attractant for food-seeking carnivores, and restricting access to or removing this attractant can be a powerful tool in human-carnivore conflict mitigation (Morehouse et al., 2020). There is no one "best" disposal method for livestock mortalities, but our data combined with existing literature on livestock disposal show that a community-based program of deadstock composting can be a safe, low-risk, cost-effective disposal method that resonates with local people's needs and values - which ultimately increases the potential for long-term sustainability.

DATA AVAILABILITY STATEMENT

Because of confidentiality, ethics consent, and agreements made with the community, we are not able to share raw individual data from our social survey. We can share the survey design and questions on request. Requests to access the datasets should be directed to Andrea T. Morehouse, amorehouse@winiskresearch.com.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AM, CH, NM, and JB conceived the ideas and designed the methodology. AM analyzed the data. AM, CH, and JT wrote the first draft of the manuscript. All authors contributed to subsequent drafts of the manuscript and gave final approval for publication.

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