Mitigating Wildlife-Vehicle Collisions in an Urban Environment

An Appraisal of the Trends and Costs Associated with Wildlife-Vehicle Collisions in Calgary, AB Canada

Hixon Center for Urban Ecology Fellowship Report 2014
15 December 2014

Emily R. Zink
Master of Environmental Science 2015 Candidate
School of Forestry and Environmental Studies
Yale University

Advisor: Dr. Susan G. Clark

TABLE OF CONTENTS

INTRODUCTION

Wildlife-vehicle collisions (WVCs) represent a growing safety, conservation, and financial concern across North America, and particularly the West. As wildlands are increasingly fragmented by urban sprawl and expanding transportation infrastructure, the natural and built worlds are literally crashing together on roads – to the detriment of wildlife and humans, alike. WVCs have typically been studied and managed for in rural environments, but as this rapid development continues human-wildlife conflict (HWC) will more frequently occupy the urban and suburban landscape. Urban areas are expected to hold 6.3 billion people by 2050, absorbing all the population growth of the next 35 years[1]. The swelling of cities also means greater traffic volume, road use, and accident risk across larger areas, and indeed reports of collisions in suburban and urban areas are already on the rise[2]. Very few cities, however, are equipped to assess or mitigate WVCs as an issue. Knapp and Witte (2006) argue this is in part because transportation agencies have no access to cost-benefit data or tools for comprehensive analysis to do so, which requires management decisions be made with incomplete data.

To inform policies and practices that appropriate and effective, this appraisal aims to assess the costs, significant environmental conditions, and policy gaps associated with wildlife-vehicle collisions (WVCs) in the City of Calgary, in the Province of Alberta, Canada. The anticipated outcomes of the appraisal are immediate and long-term structural, wildlife management, and policy recommendations that seek to decreases the amount of urban WVCs, thereby (i) enhancing safety of drivers along roadways, (ii) reducing the economic burden associated with these collisions, and (ii) mitigating harm to deer and other urban wildlife. The ultimate objective is to explore a diverse set of potential solutions that are rational, morally justifiable, and politically achievable based on the data provided and City of Calgary's political environment.

Assessment of WVCs as a problem in Calgary will be done through three different but complimentary technical approaches: statistical, financial, and spatial. Deer and deer-vehicle collisions will be the focus of this analysis, as they represent the highest proportion of large road kill collected in Calgary, the most commonly reported species involved with AVCs both nationally and locally, and are responsible for the greatest financial and safety risks. Statistical analyses will be conducted on two data sets to identify significant trends and environmental conditions associated with animal collisions. Covering 9 years (05/2005-05/2014) worth of road kill data, and 4 ½ years (2010-07/2014) worth of vehicle accident records, these data sets individually provide information critical to understanding overlying trends in AVCs. Comparing these two datasets also illuminates patterns in underreporting to more accurately quantify annual AVCs and costs. Financial analysis using information gathered from a variety of organizations and individuals will be conducted to calculate the annual and per-collision and cumulative cost burden of AVCs to society. Understanding the "cost to society" is an important decision tool to assess and justify implementation of mitigation strategies. Finally, spatial analysis using GIS

---

[1] United Nations 2011

[2] Schrank et al. 2012

[3] Alberta Transportation 2013

[4] A note on acronyms: The terms wildlife vehicle collision (WVC) and animal-vehicle collision (AVCs) are related tc[2]Schrank et al. 2012:h term is used to denote a specific meaning. WVCs refer to collisions where only unknown or wild species are considered, while AVCs refers to collisions where domestic animals (such as dogs or cats) may be

data from collected road kill will visually identify and display “hot-spots” of collisions that result in animal death throughout the city. Taken together, the findings of these analyses will help identify which structural and wildlife-management strategies from the literature are appropriate for the City of Calgary.

Standpoint Clarification

As a visiting academic researcher not from the area, it is important to identify potential biases that may influence the analysis and recommendations laid out in this work. This appraisal is the first permutation of research conducted in partial fulfillment of requirements for the Master’s of Environmental Science degree at the Yale School of Forestry and Environmental Studies. The project was conducted with financial support from the Hixon Center for Urban Ecology at Yale University, and in partnership with the Miistakis Institute – a private research organization in Calgary – and the City of Calgary Natural Areas Management government agency. To use terminology specific to the Policy Sciences, my current role in this very young policy process was partially as an Initiator, primarily as an Estimator, and in part as a Selector. This arrangement kept me autonomous as a researcher, but allowed for critical access to government resources and personnel without which this work would have been much more difficult. Acknowledgement of WVCs as a policy issue is mostly contained within this government agency and private research institutions, so this appraisal was partly motivated by consolidating, analyzing, and making information relevant to WVCs accessible to different government agencies as a decision making tool.

Coming from a liberal arts academic background in wildlife management, political ecology, and development studies, I adhere to the guidelines of Pragmatism to solve real-world problems, but often find the rigidity of Positivism’s structure helpful for organizing theoretical concepts. My professional experience is mostly comprised of socio-ecological human-wildlife research in the developing world, and as a policy researcher for regional environmental issues. Partnered with my personal background growing up abroad as an American citizen, these experiences have made me globally minded, socially conscious, and terribly aware of my privilege as a researcher and outsider in almost all communities. My instinctual approach to problem solving in a form of Functional Accounting – where local perspectives, preferences, and world-views are considered in the process of identifying appropriate and socially-acceptable solutions – but I am also inclined to categorize issues within the Conventional Accounting framework. I am not an architect or engineer, nor an urban planner or transportation expert, but instead identify as an interdisciplinary problem solver, bridging these fields with the natural sciences in pursuit of a more holistic problem definition. My personal goal in this research, therefore, is to avoid recommendations that are purely technical, but rather provide insights and recommendations that illuminate the magnitude and nature of WVCs in Calgary in pursuit of effective action.

WILDLIFE-VEHICLE COLLISIONS: A PROBLEM?

The goal of this appraisal is to provide analysis and identify trends that inform policies for the City of Calgary in the Province of Alberta, Canada. Over the last ten years roughly half[3] of all rural collisions in the Province have involved an animal (AVC[4]). In 2013 this accounted for 11,835 accidents resulting in 433 injured people and 3 fatalities. As a whole, however, vehicle collisions in urban areas are responsible for the vast majority in the Province, accounting for 84% of accidents that result in property damage and 74% that result in human injury. In contrast to the City of Calgary, where no formal evaluations of animal collisions as an issue have been undertaken, the Province's capital, Edmonton, has gone to great lengths to financially and spatially quantify their AVC problem. Their efforts have resulted in a number of studies supporting the construction of urban animal crossing structures and the implementation of specific wildlife-management procedures to minimize animal collisions[5]. As Alberta's largest, most populated, and only other major city, Calgary has an opportunity to build on Edmonton's experience. Together accounting for 83% of the Province's population[6] and half of all registered drivers[7], addressing WVCs in these urban centers will have huge positive implications for reducing both urban and rural WVCs as the public becomes more educated on the issue.

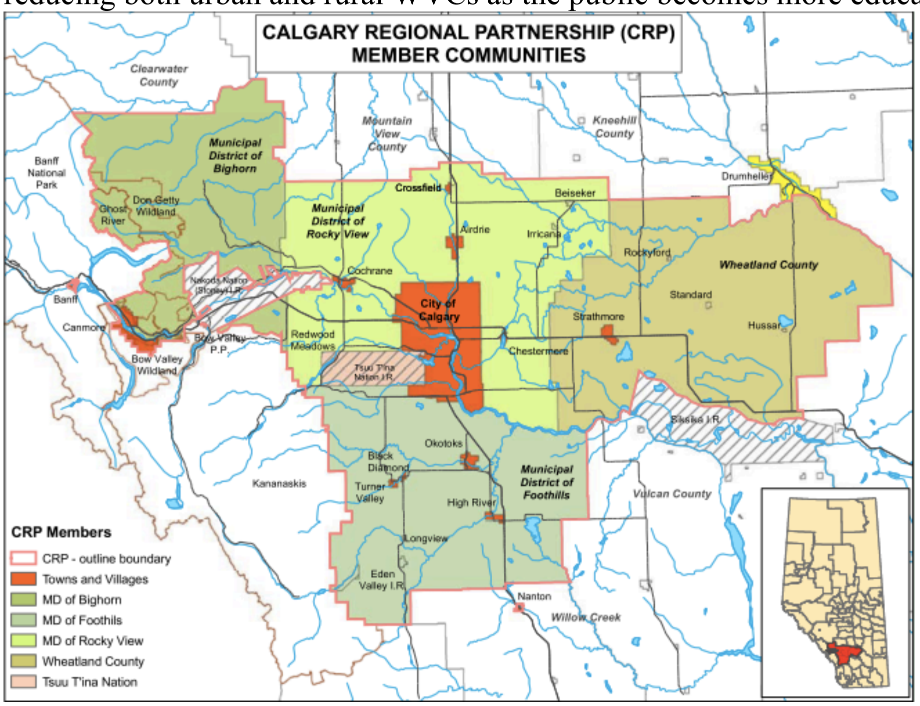


Figure 1. Calgary metropolitan area. *Source: MDP 2013*

---

[3] Alberta Transportation 2013

[4] A note on acronyms: The terms wildlife vehicle collision (WVC) and animal-vehicle collision (AVCs) are related to each other, but each term is used to denote a specific meaning. WVCs refer to collisions where only unknown or wild species are considered, while AVCs refers to collisions where domestic animals (such as dogs or cats) may be involved. For the most part AVCs are cited when referring to total numbers or distributions extracted from the data, while WVCs are cited in reference to specific policy that should target wild rather than domestic species.

[5] Alberta Transportation 2013

[6] Stats Canada

[7] Based on 2012 reported numbers (Alberta Transportation).

Calgary provides an interesting case study for the assessment of AVCs because of its geographic position, physical layout, and rapid rate of development. Situated in southern Alberta.[8] Calgary is part of large metropolitan area bisected by the Trans-Canada Highway,[9] the country's only coast-to-coast motorway. As a result, Calgary has become a major commercial transportation hub, the title bringing with it an increase in traffic volume as well as booming economic and physical growth. Located in the prairies, Calgary's outward sprawl has largely been unhindered, and at the current population growth rate of 4.3% a year the city is expected to double its physical size[10] in less than 40 years.[11]

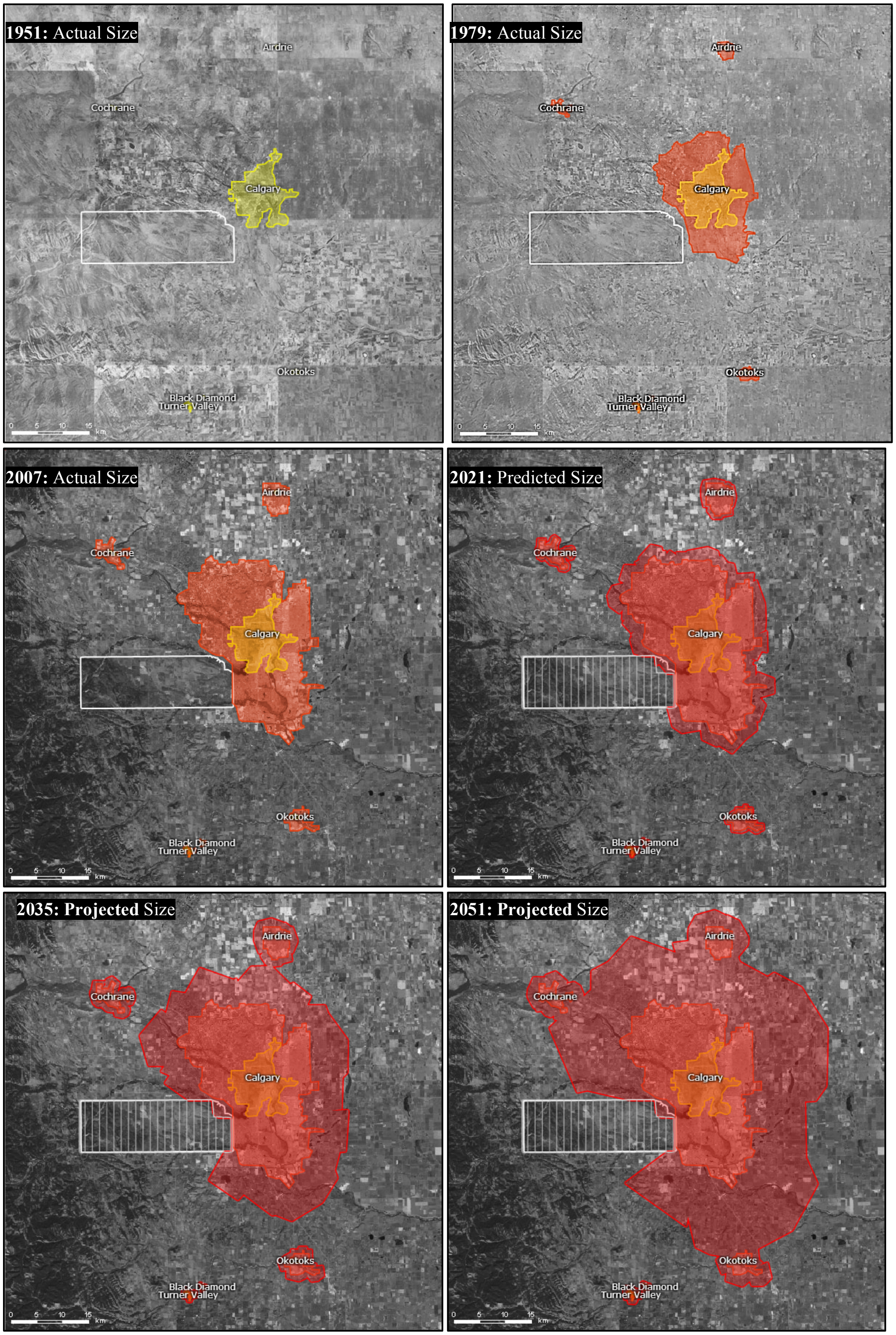
The city is characterized by one major, densely developed commercial center surrounded by expansive low-density suburbs, necessitating an extensive transportation network to keep the city connected[12]. Despite a large public transit system, Calgarians overwhelming rely on and prefer personal vehicles; in 2014 there were 972,193 registered cars[13] and 897,943 registered drivers[14] in Calgary. The addition of more cars on urban roads is expected as the population grows, and will likely impact the nature and magnitude of WVCs in the city[15].

Revealing the policy gaps that facilitate the conditions causing WVCs requires a review of how the City of Calgary's urban wildlife and natural habitat management policies interact and overlap with city planning and development standards. Such an evaluation is timely given the city's current political landscape. In addition to overhauling a number of policies relevant to development and natural space management, last year marked the beginning of the final building stages for the City's Transit and Utility Corridor (TUC) - commonly referred to as the Calgary 'Ring Road'. Initiated in 1970, Calgary's Ring Road project sought to reduce East-West traffic by connecting the urban transportation network to the larger provincial North-South travel corridor. Now in its last stage of development in Calgary's Southwest corner, concerns have been raised about the intended alignment through an undeveloped natural area and wetland recently acquired from the adjacent Tsuu T'ina First Nations Reserve.[16] Better understanding the magnitude and pattern of animal-vehicle collisions along existing roadways may help inform construction decisions for this new portion of the road, offer solutions for decreasing AVCs where they currently occur most often, and contribute to Calgary's developing land and wildlife-management policies.

---

[8] See Figure 1
[9] Referred to as "Highway 1" in Alberta"
[10] See Figure #2 for one possible projection of growth
[11] The City of Calgary (2013). *Municipal Development Plan*. Bylaw 24P2009, Adopted April 2010.
[12] Knapf 2010
[13] Alberta Transportation 2014
[14] Alberta Trasportation 2014b
[15] Leonard Sielicki, Personal Communication 06/14/2014; The City of Calgary (2013).
[16] CITE

Figure 2. Historical (1951-2007) and projected growth (2007-2051) based on population growth rate.



Data Source: Government of Alberta Municipal Affairs

*The marked out region is Tsuu T'ina First Nations land.
Simulation conducted using *ALCES Community Growth Simulator Version 2.0*

The most substantial existing documents regarding urban flora and fauna management are Calgary's *Municipal Development Plan* and the 1994 *Natural Areas Management Plan*. The adoption of the Municipal Development Plan in 2009 was the result of a policy shift that sought to integrate and update the *Go Plan* of 1995 and *The Calgary Plan* of 1998, documents that outlined the City's transportation and land use development guidelines, respectively. The resulting MDP, and its partner document - the Calgary Transportation Plan – outline a 60-year development strategy for sustainable growth and complimentary transportation networks, a 30-year strategy for making land use and public investment decisions as the city expands, and a 10-year corporate planning guideline for integrating private interests with sustainable growth[17]. The MDP was also charged with managing the environmental, physical, and social issues related to the city's physical growth. In the most recent *Municipal Development Plan,* published in 2013, one of the stated citywide sustainability goals recognizes "the need to partner with adjacent municipalities and regional neighbors to develop strategies for protecting watersheds, habitats and biodiversity and to establish ecological networks that benefit the region as a whole."[18] One of the 4 policy recommendations is to "Identify and protect strategic parcels, blocks, and corridors that increase ecosystem connectivity" to minimize "disruption and fragmentation of natural habitats."[19]

The initial recognition of the importance of habitat protection was officially noted however, in Calgary's *Natural Areas Management Plan*[20]. Created and adopted by the municipal government in 1994, this document is currently under review for the first time in 20 years. The original document has some very progressive and thoughts and findings, and while much of it deals with issues surrounding public perception and definition of green/open spaces, there is mention of the importance of habitat quality and connectivity a handful of times:

> "Urbanization has had and does have major impacts on the functioning of ecological units. Adequate habitat size, diversity, connectivity and healthy condition must be maintained in order to conserve viable areas for future use for people and wildlife."[21]

If such a goal is to be achieved, the diversity and abundance of wildlife in these areas will inevitably increase. Until recently, however, strategies for managing wildlife in the city have been mostly limited to handling "pest" animals; species like coyote and raccoons that cause disturbance. The term "urban wildlife" seems almost oxymoronic, and while many species that occupy urban landscapes are semi-domesticated, wildlife biologists have attested to the fact that these animals occupy their own natural micro-ecosystems within the city[22].

[17] The City of Calgary 2013, MDP, CTP
[18] The City of Calgary, 55
[19] Ibid, 57-58
[20] Calgary Parks and Recreation (1994). *Natural Area Management Plan.* The City of Calgary.
[21] Ibid, 22
[22] Personal correspondence: 06/14/2014 and 06/26/2014 (Contact author for name of these persons)

As the largest species in the city, deer are a particular challenge to manage. According to a local wildlife biologist[23] and team lead for the South Saskatchewan Region Habitat, Calgary's deer insulate themselves in the city year-round, rather than migrate like other deer populations in the region. A senior wildlife biologist and researcher[24] for British Columbia's WVC data collection system speculated that Calgary's deer do so to seek refuge from the hunting areas which encompass the city on all sides[25]. As the isolated population grows, however, young fawns disperse and stake out their own territory[26] - a task obviously limited by space, and one that requires traversing roads.

It is this biological process that brings deer onto urban and rural highways, but the where and why collisions happen (or don't) are poorly understood. Only when these biological and physical trends are understood can effective steps be taken to mitigate WVCs. A preliminary analysis of some spatial, environmental, and financial trends is one first step in this direction.

.

ANALYSIS

STATISTICAL ANALYSIS: WVC & ROAD KILL TRENDS AND CONDITIONS

While WVC reports provide important "official" data to elucidate trends, road kill data proves equally important - showing not only where collisions occurred, but where they are fatal to animals.

METHODS

Nine years of road kill collection data and 4 ½ years of vehicle accident reports were used to evaluate the magnitude and nature of wildlife-vehicle collisions in Calgary. Taken together these data provide valuable information about the extent of unreported collisions, allowing for a more precise understanding of spatial and temporal patterns than either of these data sets can provide alone.

Deer and other large animals were the focus of analyses in both of these data sets, as they represent the highest proportion and most costly species involved in wildlife-vehicle collisions. Other large wildlife include moose, a bear (!), and coyotes.

I. ROAD KILL

Road kill data was attained from the City of Calgary's Roads Department and Carmacks Enterprised, a private maintenance company contracted by the City of Calgary. The City of Calgary's Roads database provided road kill records from May 2005 through May 2014 and Carmacks Enterprised provided records from January 2012 through February 2014. Data collection and storage methodologies for each provider was different, and required reorganization to be compatible for compilation and analysis.

---

[23] Personal correspondence 06/26/2015 (Contact author for name of this person)
[24] Personal correspondence 06/14/2015 (Contact author for name of this person)
[25] PC (06/14/2014)
[26] [26] Personal correspondence 06/26/2015 (Contact author for name of this person)

The City of Calgary's Roads Department is responsible for all roadway maintenance within the city boundary. Road kill locations and initial species identification are collected through the City of Calgary's 3-1-1 call-in center - a government service responsible for responding to non-emergency concerns, general local government policy, and city-wide contact information. When road kill are reported, a script requires operators to ask for a (i) description of the animal and **species** (when possible), (ii) whether the carcass is on **public or private property**, and (iii) an approximate location that includes the **road's name** and direction of travel. At the time of reporting GPS coordinates are generated for exact addresses, and pre-designated spots throughout the city are automatically assigned to less specific locations based on road name or nearest landmark. Crews from the Road Department are then dispatched to confirm location and species (if possible), and their comments are incorporated into the original 3-1-1 report. These crews are also ultimately are responsible for collecting and disposing of all animal carcasses.

Carmacks Enterprised is a private maintenance company contracted by the city to patrol two of Calgary's major roadways - Stoney Trail and Deerfoot Trail - for debris and carcass collection. Carmacks is sometimes dispatched in response to 3-1-1 reports, but largely keep their own records from twice-daily highway patrols made at dusk and dawn. In regards to road kill, crews record: (i) the date and time road kill is encountered, (ii) a description and **species name** (when possible) of the animals picked up, (iii) and a description of the location including the **road's name,** direction of travel, and nearest overpass or significant road feature.

Every line of data across both datasets was assigned an ID number and then combined into one worksheet. Once amalgamated, the data had these final relevant variables:

1. **Time & Date** – The time, day, month, and year that the carcass was reported/encountered, as well the time, day, month and year it was ultimately removed.
2. **Location** – Input as "Address" by 3-1-1 operators or Road crews, the accuracy of these locations are highly variable.
3. **Species** – Entered as "Flex Question" in the datasheet, this column recorded caller responses to 3-1-1 operators' questions about the species involved, or Road crews' comments on the scene. Species were identified from these entries to the extent possible, and all blank or non-specific entries were labeled as "unidentified."
   In 2011 the 3-1-1 script moved away from asking for specific species in favor of "Large" or "Small to Medium" Animal.
4. **Road Type** - This category was assigned to each listed locations based on the Road Classifications used by the City of Calgary government. These classifications are based on daily traffic volume, number of lanes, commercial vs. residential use, and speed limit (See Appendix #3 for Road type information.)

Sources of Error and Questionable Points

The major challenge to marrying these two data sets was the discrepancies in reporting methodologies between Carmacks contractors and the Roads Department. The variables most affected by this were species identification and the accuracy of location information.

For entries that contained a species description or name, inconsistencies exist in how they were recorded between and within each data set. Species identification from Carmacks patrol logs required reading through entry "Comments" to ascertain the number and type of species found. While the Roads dataset had a column entry for species, how these species were recorded changed a number of times between 2005 and 2014. In 2011, for example, the 311 road kill reporting script moved away from asking for species-specific information, and instead recorded road kill as either “Large Animal” or “Small to Medium Animal.” This change was made in order for operators to communicate which size vehicle the Road’s Department required to respond to the call. Therefore, limited species-specific data is available from the City of Calgary from 2011 through 2014, although it is assumed that large unidentified animals are likely deer, as evidenced by an apparent drop in deer carcasses collections during this time.

Ultimately, each line of data was assigned a species name based on the best interpretation of entry comments (See Appendix #1 for table of species). In both data sets there was a significant amount of entries where animal descriptions were insufficient to determine species, or no identification is made. To the best extent possible these entries were placed into the “Large” or “Small Animal” categories, and otherwise were marked as “Unidentified”. Entries that were left blank were also classified as “Unidentified.” Unidentified entries were not included for the majority of statistical tests.

Accuracy in location reporting is also highly variable within and between the datasets. The majority of Carmacks’ entries specify the road and nearest landmark only, while Road’s reports range from specific street addresses to road name only. Many of the 3-1-1 entries generated location coordinates based on street names or specified addresses, but there is high level of spatial uncertainty for these locations. The 3-1-1 systems has a number of pre-determined location coordinates throughout the city, and these coordinates were often assigned to entries where street intersections or specific sections of the city were generated. It is assumed, therefore, that locations are generally accurate on the road section level.

Lastly, it is important to note that the majority of the road kill data – from 3-1-1 call-ins – were based on reports from the public, and therefore subject to selection bias. The nature of this partiality isn’t entirely evident, but we can assume that it influences the distribution of the data. Driver are more likely to report large animals on highways, for instance, than a bird or

Another concern regards the recorded dates for these entries. It has been noted that many animals are injured in collisions but manage to get off the road before they die of their injuries. This can be a problem during the winter, for large animals in particular, as many of these carcasses are not seen or reported until the snow melts in the summer (Personal communication). The exact date the animal was killed, therefore, has a high level of uncertainty. For the most part we assume accuracy at the month level.

With all these limitations in might, we assume these data are not representative of all animals killed on roadways, but rather provide an important first glimpse into the distribution and abundance of species that are involved in vehicle collisions.

I. WILDLIFE-VEHICLE COLLISIONS

Data pertaining to WVCs in Calgary were obtained from the Calgary Police Department through a Freedom of Information and Protection of Privacy (FOIP) request. The Police provided requested collision report data for all vehicle accidents involving an animal within the city limits from January 2010 through July 2014. For each report, the following information was provided:

1. **Location** – There is a range of spatial certainty for each of these entries. Some reports simply list the name of the major street the accident took place on, others identify an intersection or cross street, and still others list exact street addresses. Given how often some of these exact addresses/intersections are cited, it is likely some addresses are pre-designated and assigned based on proximity.

2. **Date & Time** – This includes the time, day, month, and year that the accident occurred.
3. **Time of Day** – These categories were assigned to each entry based on levels of light[27] during each month: (i) darkness, (ii) dawn, (iii) daylight, and (iv) dusk.
4. **Severity of Collision –** Designates whether the collision resulted in (i) Property Damage, (ii) Injury, or (iii) Fatality.
5. **Primary Event –** This indicates whether the accident was caused by a direct head-on collision, swerving action to avoid contact, or by the animal striking the vehicle.
6. **Environmental Conditions –** Lists weather conditions on roads during the time of the accident, such as: (i) clear, (ii) cloudy, (iii) fog/smoke/dust, (iv) hail/sleet/rain, (v) high wind, (vi) snow, or unknown (vii).
7. **Scene Visit by Police –** Yes or No
8. **Damage over C$2,000** – Yes or No[28]
9. **# Fatalities / # Injured**
10. **Vehicle Style –** The type of vehicle involved in the collision: (i) emergency vehicle, (ii) motorcycle, (iii) passenger car, and (iv) pickup van <4500 kg, or (v) Other (minivan/van & utility vehicle).
11. **Light Conditions –** (i) daylight vs. darkness and (ii) no artificial light vs. artificial light.
12. **Unsafe Speed –** Yes or No
13. **Animal Species –** This column indicated which animal species was involved in the collision, if known. A new column was created to interpret the comments/entries for this data.
14. **Animal Type –** A column created and filled based on interpretation of species type entered in order to allow comparisons between (i) deer, (ii) other large animals, and (iii) small animals. Large animals included moose, deer, a grizzly bear (!), wolves, coyote, and dogs and were chosen based on their ability to potentially inflict damage to a vehicle. Small animals included badgers, birds, cats, porcupines, rabbits, raccoons, and squirrels.
15. **Point of Impact –** Area of impact or damage on the vehicle: (i) front (left and right), (ii) left side, (iii) right side, (iv) undercarriage, (v) top of vehicle, (vi) rear (left and right), (viii) rollover.
16. **Road Type –** This category was assigned to each listed locations based on the Road Classifications used by the City of Calgary government. These classifications are based on daily traffic volume, number of lanes, commercial vs. residential use, and speed limit (See Appendix #3 for Road type information.)

Police vehicle collision reports are a mix of required and voluntary accident reports. Collision reports are legally required when a police officer attends the scene of an accident, as well as when the costs associated with property damage, injury, or death exceed C$2,000. Citizens can file reports at police stations after the fact. The same Report Form is used for each. (See Appendix #4 for a copy of the form filled out for each collision report).

Sources of Error and Questionable Points

The limiting factor for statistical analysis of these data is the absence of information for *all* vehicle collisions in the Calgary area. Unfortunately, funding only allowed for the collection of wildlife-vehicle collision reports between 2010 and July of 2014. Obtaining information for all vehicle collisions during this period was prohibitively expensive. This certainly limits the scope of potential analyses that can be done on this data, but still provides important information about the distribution and abundance of WVCs over the last 4 ½ years.

Prior to January 2011 the provincial government required that all collisions resulting in more than C$1,000 worth of damage or costs associated with injury or death.[29] After January 2011,

[27] Gaisma.com
[28] As of January 2011 the provincial government required that all collisions resulting in more than C$2,000 worth of damage or costs associated with injury or death. Prior to January 2011 the required value was C$1,000.

this value was raised to C$2,000. Citizens are still able to submit report collisions under this value voluntarily. Since this data set includes data ranging from 2010-2014, it is likely the data is affected by the public response and transition to this new legislation.

TRENDS

I. ROAD KILL

Between May 2005 and May 2014 exactly 24,963 animal carcasses were removed from Calgary roadways. Of the 29 different species represented the majority were small mammals; rabbits, alone, accounted for 41% of all carcasses - the single most represented species.[30] While small animals like rabbits, squirrels, and birds accounted for the largest abundance of carcasses, deer were the focus of particular safety and financial concern.

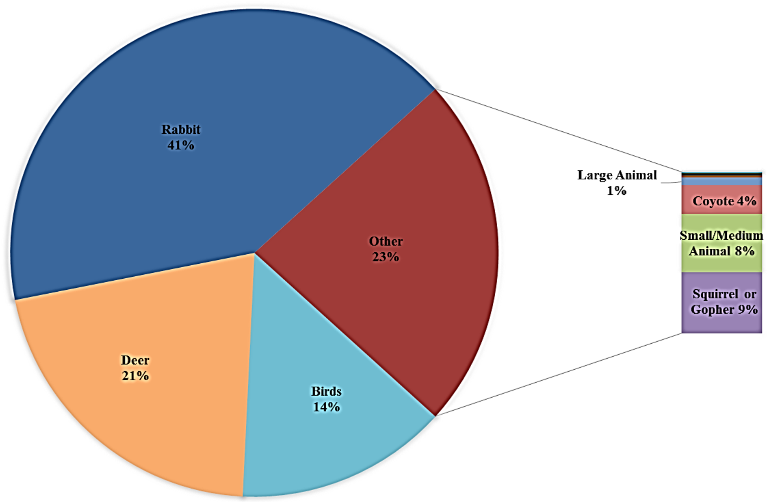


Figure 3. Species Breakdown of Calgary's Identified Road Kill

The mean number of deer and large animal[31] carcasses collected on any given month from 2005-2014 was 40, with evident peaks in June-July and November.

[29] Alberta Transportation 2013

[30] See Figure 3.

[31] When the script for identifying animals in the 3-1-1 system changed in 2011 the annual count of deer carcasses collected went down as a new category – "Large Animal" – went up. These species were labeled as such to designate the need for a truck with a 'lift' to haul the animal off the road. Since there are few other species where such a measure might be needed, for the purposes of this analysis it is assumed the majority of carcasses identified as "Large Animal" are deer.

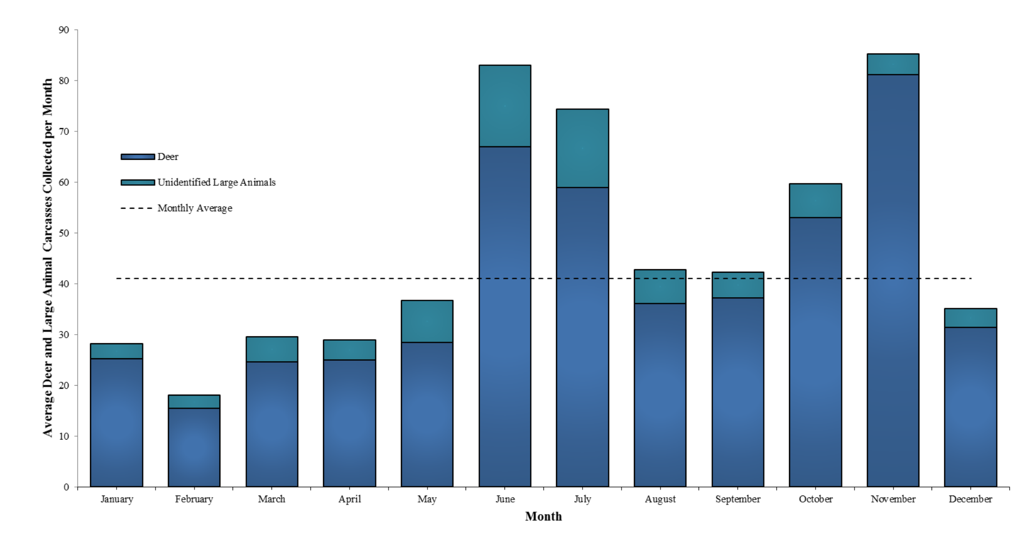


Figure 4. **Average Number of Collected Deer and Large Animal Carcasses per Month in Calgary, AB (2010-2014)**

II. DEER-VEHICLE COLLISIONS

Between 2010 and July of 2014 the Calgary Police Department filed 1,601 vehicle accident reports citing collision with an animal as the primary event. Only 108 of 920 deer-vehicle collisions were attended by the police, meaning that 812 (88%) of these reports were filled by drivers after the fact. These DVCS resulted in property damage for 916 vehicles, injuries for 3 drivers/passengers, and one fatality[32].

Over the course of this 4 ½ year period, collisions with deer were cited in 86% of reports where species were identified, and 57% of all reports. An average of 17 DVCs were reported per month (See Figure 1.). November was the peak for reports, accounting for 15% of all collisions, and averaging the most DVCS with roughly one occurring per day (28). Most collisions during the week happened on Friday (18%), and the vast majority of collisions took place at night (54%).[33]

[32] This particular incident involved a motorcycle.
[33] See Appendix #3 for details on when "night" occurred in each month."

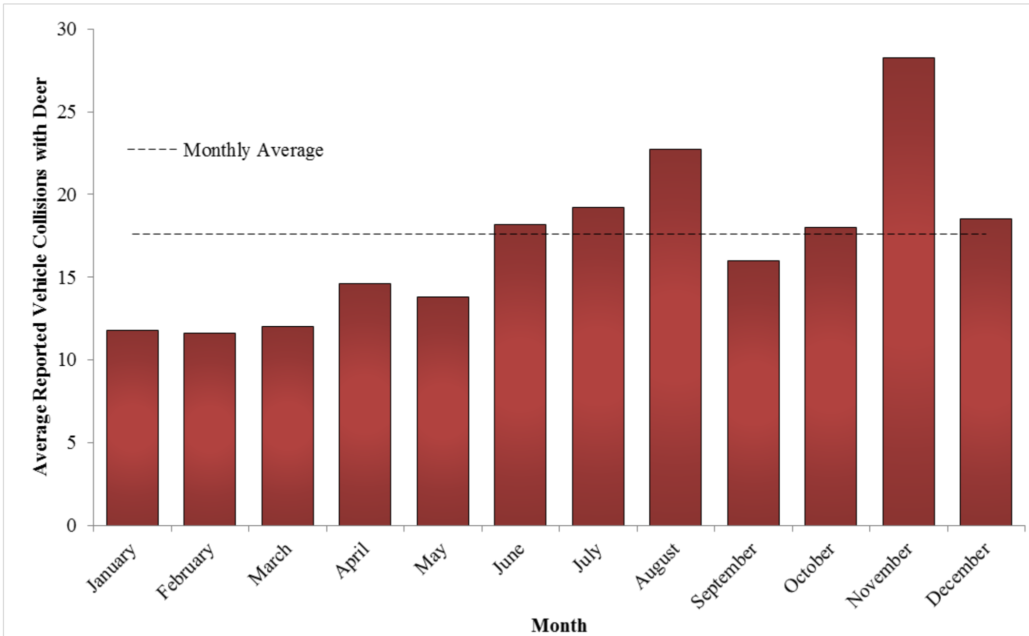


Figure 5. Average Reported Deer-Vehicle Collisions per Month in Calgary, AB (2010-2014)

III. DEER CARCASSES VS. DVCS

Studies in Alberta and throughout the peer-reviewed literature estimate the number of unreported WVCs as equal or greater to the number of reported ones,[34] which is exactly what these data demonstrate. Comparing trends and averages over the last 4 years, there are over twice as many deer carcasses collected per month as there are reported collisions with them.

This disparity in reporting has huge consequences for how WVCs are problematized and managed. If a deer carcass represents a single collision, this means that roughly half of all collisions are going unreported.[35] This has repercussions not only for how seriously WVCs are prioritized as an issue to manage for, but also for how costs associated with these collisions are calculated. Without this 2:1 correction factor, the economic burden would be presumed to be half of the actual value – limited which mitigation strategies are deemed feasible or worthwhile.

[34] Imran, "RAFIA"
[35] See Figure #

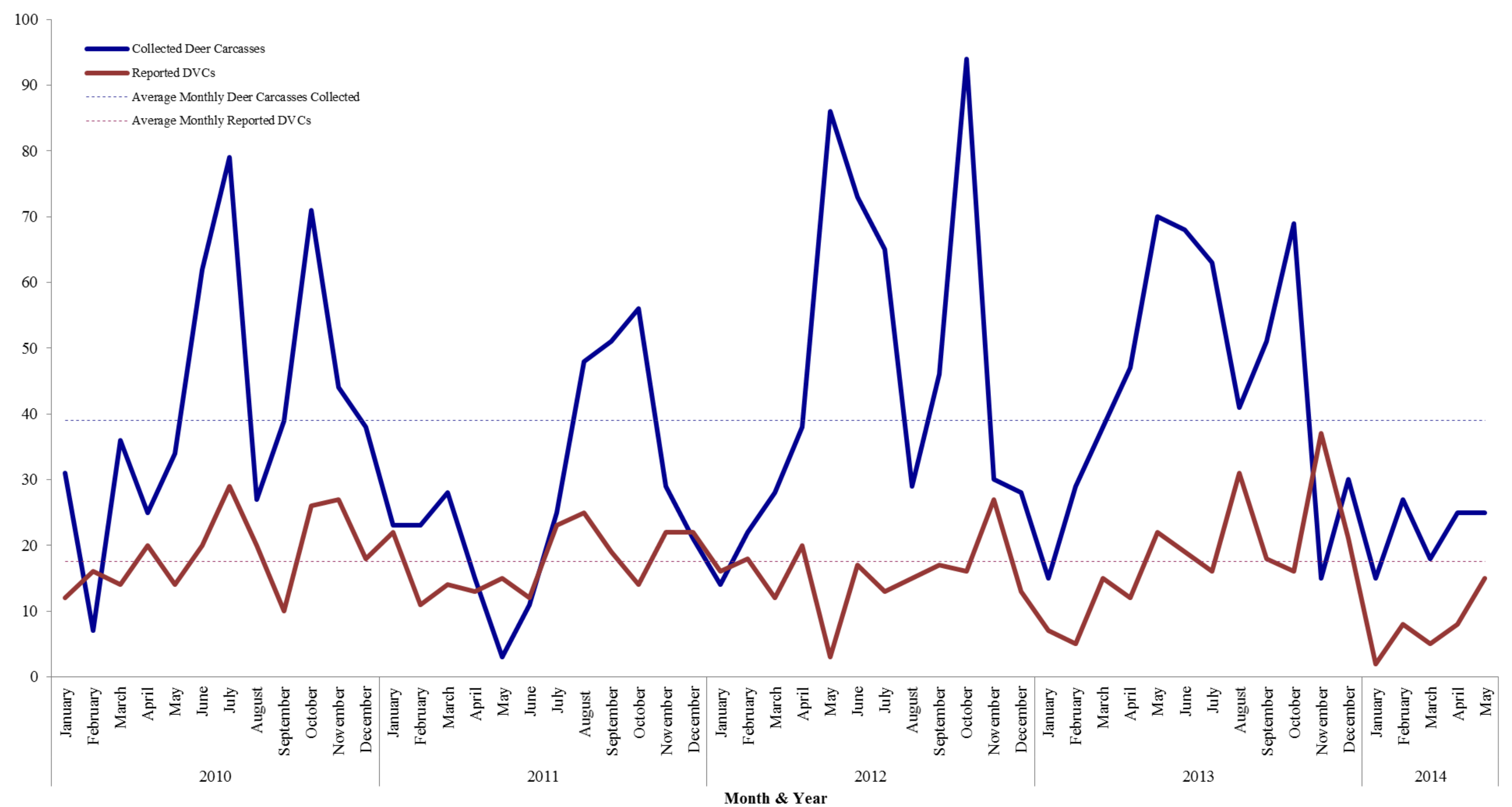


Figure 1. Disparity between Collected Deer Carcasses and Reported DVCs per Month (2010-05/2014)

CONDITIONS

Statistical analyses on WVC data were conducted using MINITAB 17 Statistical Software. A number of statistical tests were performed to measure which temporal and environmental conditions were significant predicts of when WVCs were most likely to occur. As there was no way to determine when road kill were hit, statistical analysis was only done on the WVC data set.

A Binary Logistic Regression measured which variables were significantly associated with deer collisions vs. all other collisions. A number of iterations of the regression were performed, and the following variables were found to be significant predictors of deer collisions (vs. collisions with other animals):

- Time of Day (p-value=0.001)
- Artificial Light (p-value=0.000)
- Unsafe Speed (p=0.037)

Taken together, these variables indicate that a collision with a deer is more likely to occur at 2.15 times more likely at Dusk that during the daylight, is 1.6 times more likely to occur when travelling at an unsafe speed.

SPATIAL ANALYSIS: IDENTIFYING COLLISION HOTSPOTS

METHODS

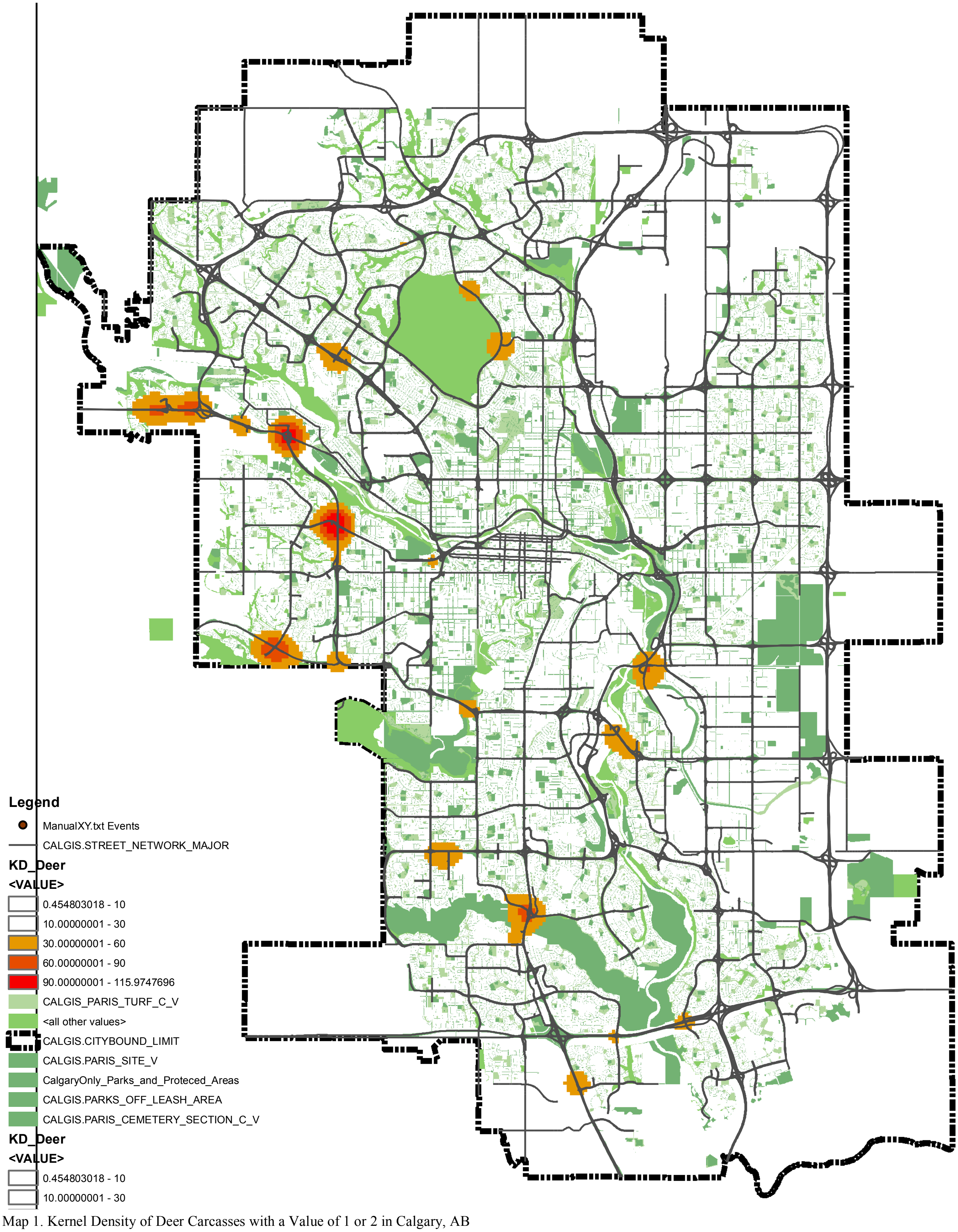
In the road kill data set provided by the Roads Department, many entries had coordinates already assigned. Coordinates were manually input for the remaining Roads data, and all Carmacks data using descriptions of locations to identify coordinates on Google Maps. Depending on the level of addresses or location descriptions' accuracy, a Confidence Level was assigned using the following criteria:

1. **Confidence Level #1:** Highest level of confidence and accuracy. Coordinates ascribed to this confidence level were exact reported addresses, or described locations with sufficient detail to indicate accuracy within several feet of the animal.
2. **Confidence Level #2:** Coordinates displayed given cross-street information, or assigned to pre-designated spots along a road in the absence detail. *The 311 system has assigned coordinates for roads, so in the absence of sufficient detail, 311 operators would assign these coordinates for mentioned streets or landscape features. These points are assumed to be accurate to the street level.
3. **Confidence Level #3:** Lowest level of confidence and accuracy.
   This confidence level is primarily comprised of Carmacks data, which only provided information relative to the nearest intersection, overpass, or major road feature. Coordinates for these points were assigned to mentioned features, and therefore have a low level of accuracy.

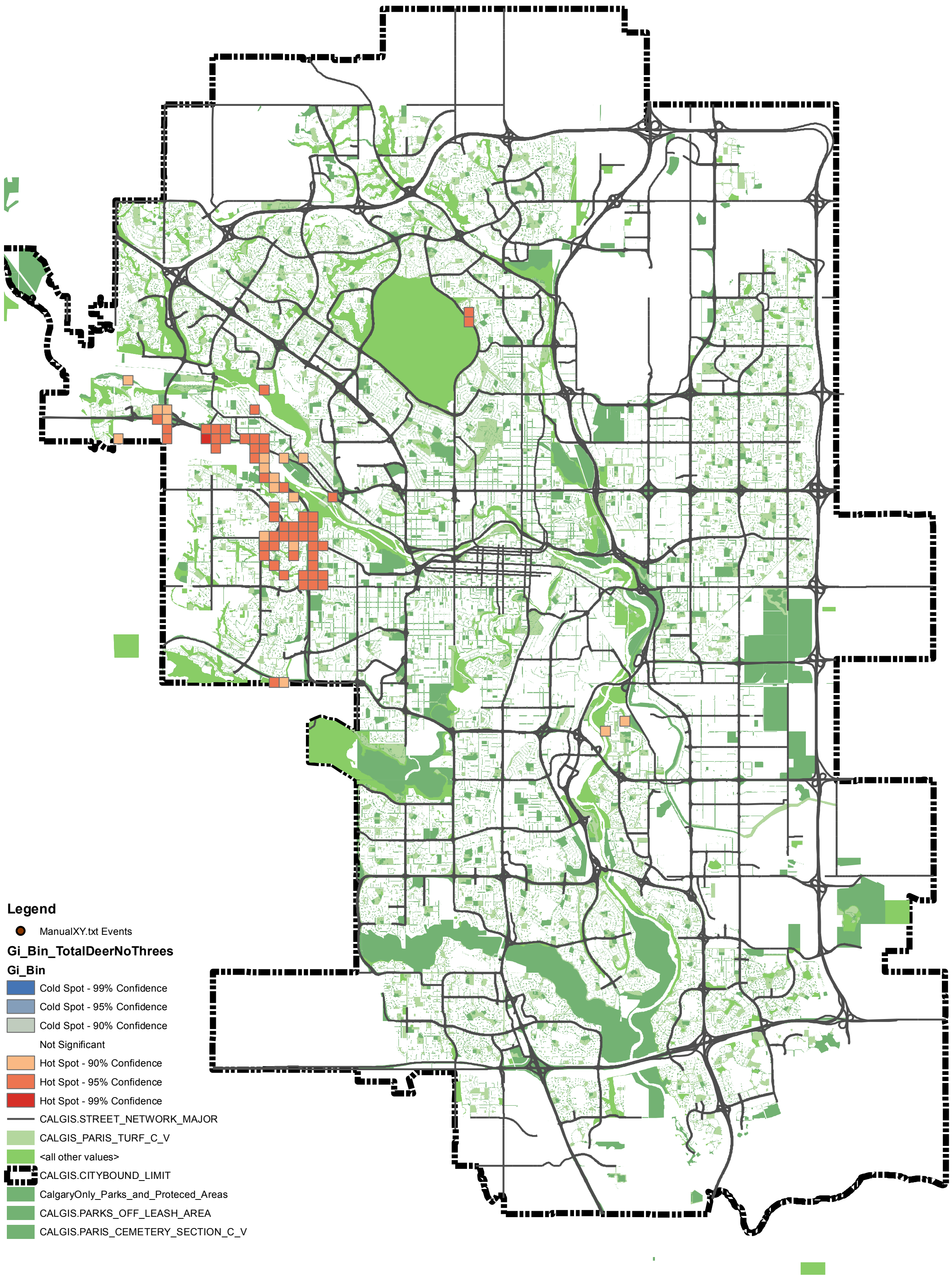
These coordinates were sorted imported into ArcMap and then all deer carcass locations with a Confidence Level of 1 and 2 were projected as points onto a map containing various layers specific to Calgary. Two major tests were performed to identify where road kill “Hotspots” occurred.

TRENDS

Map 1. shows hotspots as a function Kernel Density, where grouping parameters were set manually. Map 2. shows hotspots as calculated by the Getis-Ord Gi* statistic, which calculates a p-value based on whether clustering of points is greater or less than would be expected under a normal distribution.



Map 1. Kernel Density of Deer Carcasses with a Value of 1 or 2 in Calgary, AB



Map 2. Statistically Significant Deer Road Kill Hotspots in Calgary, AB

COST TO SOCIETY OF DVCS

Collision with an animal can inflict serious damage to a vehicle, and cause injury – even death – to those inside it. Acar travelling at 60 km/hr, for example, would have 0.8 tons of force exerted on the vehicle – that is about the average weight of a cow - for hitting a small *deer*.[36]

Understanding the economic burden, or "cost to society" of these collisions is a crucial tool for decision making and selecting feasible mitigating measures. Although the cost is spread out among different stakeholders – citizens, the government, and private insurance agencies – amalgamating these costs serves to quantify the issue financially.

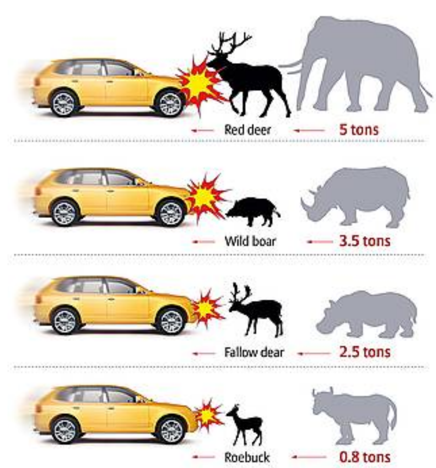


Figure 2. Relative Force of Hitting an Animal at 60 km/hr (Allianz)

METHODS

The economic burden of deer-vehicle collisions was calculated using a variety of information from organizations, individuals, and peer-reviewed literature. Methodology for calculating the "cost to society" was developed using frameworks and variables outlined in Huijser et al.'s (2009) peer-reviewed paper published in the journal *Ecology & Science*.

Only "direct" costs that were specific to Calgary were used to calculate the cumulative and per-collision cost to society of DVCs, so this estimate is an extremely conservative and incomplete. Data was amalgamate to consider costs for collisions that only resulted in injury or property damage.

TRENDS

According to these calculations, each time a deer is hit in Calgary it carries an economic burden of C$11,775.42. This puts the cost of recorded deer-vehicle collisions over the last 4 ½ years at a whopping **C$10,833,386.40.**

[36] http://knowledge.allianz.com/?2465/Crash-with-nature

Table 1. Costs Associated with Deer Vehicle Collisions in Calgary, AB

Cost Category	Description	Source (s)	Assumptions	Cost Methodology	COST
Vehicle Repair Costs	Vehicle Repair Costs	Alberta Motor Association; Insurance Corporation of British Columbia; CRISP	Before 2010 Alberta drivers were required to report collision damage exceeding $1000. On January 2011 this value changed to $2000. We are assuming that all reported collisions, therefore, are at least $1000 and that this substantiates repair.	A different cost methodology was used to calculate values for the three severity levels of collisions: (i) Property Damage Only (PDO), (ii) Injury, and (iii) Fatality. The value for Property Damage is an average of two values: the average insurance payout provided	$11,198.28
Towing	Towing costs reflect the (i)initial price charged for vehicle hookup, and (ii) the charge per kilometer to haul the vehicle from the crash site to an automechanic shop	City of Calgary Parking Authority; Alberta Motor Association	-	The average towing costs for Calgary were determined by averaging the towing costs deduced from data provided by AMA and the Calgary Parking Authority. For each of these sources the 'average kilometers towed' per vehicle was multiplied by the 'price charged per kilometer' then added to the initial hook-up cost, which is generally a flat-rate. This average price was determined for Calgary in general (Parking Authority), suburban Calgary (AMA), and the city proper (AMA). The average of these three costs was used for the final value.	$123.14
Animal Pickup & Disposal	The costs incurred by the Calgary Roads Department and Carmacks Enterprises to collect and dispose of road kill carcasses along roadways, including (i) hourly manual labor and (ii) gas and equipment cost.	Carmacks Enterprised; City of Calgary Roads Department	Costs were averaged for all animals.	Quoted price from Bill Croteau, General Manager of Carmacks Enterprised	$285.00
Accident Attendance & Investigation	Costs incurred by the Police Department for visiting the scene.	CRISP Report	-	Taken from CRISP Report.	$169.00

RECOMMENDATIONS

Unlike rural connectivity and WVC mitigation projects that rely primarily on structural elements to conserve species and habitats, the complex social and ecological context of the urban environment requires interdisciplinary solutions the employ both infrastructural and behavior-changing management strategies. Policies aimed at mitigating WVCs need to be informed by understanding empirical trends, functions of ecological principles and systems, social values specific to the community, and must integrate environmental goals with economic ones.

Using the trends illuminated above, and supplemented from case studies across Canada and the US, a number of short- and long-term recommendations can be made to help Calgary reduce WVCs. Strategies need to encompass actions to mitigate existing conditions causing WVCs and to integrate findings into policy to adapt for future growth.

1. *Create an Urban Wildlife Management Plan*

It has been shown that formalized policies to manage urban wildlife and human-wildlife conflicts are more effective than ad-hoc methods[37] and currently Calgary has no such policies. The most important step the City can take is to (i) establish specific management goals and acceptable thresholds for each present wildlife species, (ii) integrate the perceptions and preferences of the public[38], and prepare pre- and post-development strategies.

Focusing on creating a management plan for deer, specifically, should be a high priority for the city, not only because they represent the largest species in the city, and the one most involved in WVCs, but also because there is a breadth of examples and literature on urban deer management (some from neighboring cities and provinces) from which to draw from. Deer are also one of the species most impacted by development, because they establish their yearlong home ranges on the "urban-rural interface" – where most development is occurring.[39]

In choosing which management strategies to employ, McCance (2012)[40] argues that "wildlife managers much consider not only the biological and ecological aspects of an urban wildlife population, but also the associated social dynamics" given the complexity of having numerous stakeholders and perspectives. As Aldo Leopold famously said, "wildlife management is primarily the management of people," so Plans need to create strategies that change human behavior (e.g. driving behavior, plant choice for gardens, treatment of wildlife and pets, etc.) as well as animal behavior.[41] In creating strategies that "manage humans," Elmauer (2012) advocates the use of Community-Based Social Marketing (CBSM), which "deals directly with the interests and perceptions of the target audience regarding benefits and barriers for the promoted behavior" by identifying the community's values, motivations, and public perception. By operating on the community level first, policies for urban wildlife management can be tested by Community Action Plans and Neighbourhood Plans – smaller scale management

---

[37] Hall, M. (2012). "The process of solving urban wildlife conflicts at the community level." *Urban Wildlife: Challenges and Management*. Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC Canada.
[38] Ibid
[39] The City of Calgary 2013; Hesse, G. & R.V. Rea (2012). "Considerations for mitigating human-moose conflict in moose habitats undergoing urban development." *Urban Wildlife: Challenges and Management.* Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf
[40] McCance, E. (2012). "Understanding urban white-tailed deer movement in a Canadian metropolitan center." *Urban Wildlife: Challenges and Management*. Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC Canada.
[41] Hesse & Rea 2012

organizations throughout Calgary that have some decision-making power – and potentially be scaled up.[42]

2. *Engage the Public in Decision-Making and Policy Creation*

Engaging Calgary's citizenry will be a crucial step for ensuring the acceptance and sustainability of citywide policy. This can be achieved by increasing the amount of citizen-science programs opportunities for communities to engage more fully with the topic of urban wildlife, while simultaneously determining social values, problem perceptions, and management preferences on a citywide scale.[43]

One way to involve the public in urban wildlife management is through citizen-science programs. A prominent example in Calgary is the Living With Coyotes project, a collaborative initiative between local universities, research institutions, and private corporations that "aims to understand the relationship between humans and coyotes within the city of Calgary and promote their co-existence through research, citizen engagement and outreach programs". [44] A big portion of their work is an interactive city map where citizens can report sightings of coyotes around the city.

Researchers involved in this project have also tried to determine social attitudes and beliefs about coyotes by analyzing the content and tone of local media sources that reference coyotes in the City of Calgary. In one study, Alexander & Quinn (2011) cataloged 215 articles in local media sources between 1995 and 2010 that contained content about coyotes or references human-coyotes interactions. They determined that 26% of the articles – a majority - revolved around a concern for property, pet, and child health.[45] Taking results of inquires like these could be incredibly valuable in directing education programs, mitigating human-wildlife techniques, and incorporating social values and preferences into wildlife management policy.

An illustrative example of this comes from the city of Winnipeg in the Canadian province of Manitoba, where in 2009 a Masters student conducted a randomized mail-out questionnaire on civilian white-tail deer tolerance and preferred management strategies.[46] This study helped determine citizens' notions of human-wildlife conflict, perception of urban wildlife (specifically deer), and evaluated preferences for urban wildlife management techniques. Results found, for example, that 43% of respondees enjoyed the presence of deer but worried about HWC, 34% knew someone who had been involved in a deer-vehicle collision, and that among citizens the

---

[42] Elmauer, K. (2012). "Changing human behavior as part of wildlife management: Adopting a Community-Based Social Marketing (CBSM) approach." *Urban Wildlife: Challenges and Management.* Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf

[43] Alexander, S.M. and M.S. Quinn (2011). "Coyote (Canis latrans) Interactions with Humans and Pets Reported in the Canadian Print Media (1995-2010)." *Human Dimensions of Wildlife* **16**: 345-359.

[44] CITE

[45] Alexander & Quinn 2011

[46] McCance, Erin (2009). "Resident opinions concerning urban deer management in the Greater Winnipeg Area, Manitoba, Canada." Master of the Environment Thesis University of Manitoba, CANADA: 200 pages. http://proquest.umi.com/pqdlink?did=1919661251&Fmt=7&clientI%20d=79356&RQT=309&VName=PQD

most supported[47] urban deer management techniques were public education on wildlife and an increase in road safety signs.[48] The survey results also indicated that citizens believed the deer management plan should be created by both government and citizens, rather than by citizens or government, alone.[49]

Conducting a similar survey in Calgary would help policy-makers get a better grasp of citizens' perception of urban wildlife, and inform them on which approaches and management techniques are most supported by the public. It also has the added benefit of engaging citizens with these issues, and to make them feel involved in the problem-solving process.

3. *Incorporate Connectivity Planning into Existing and Future Urban Landscape*

This policy step may be the most legislatively difficult to employ because of the existing power dynamics in Calgary. In Alberta, the acquisition and designation of land for the purpose of a habitat corridor ("Environmental Reserve") can only be done with consent of all land owners of the area agree, and cannot be formalized as permanent protection.[50] This requires multi-stakeholder agreement, and most likely the involvement of conservation-easements to private owners, which are very costly and require substantial funding sources.[51] Municipal rezoning of land as protected is therefore the only practical means of establishing corridors because it is a legally mandated designation, but this, too, is extremely difficult given that "municipal politicians and the community as a whole must regard wildlife as an appropriate and valuable component of a community" in order to rezone land.[52] Navigating these bureaucratic hurdles will be the first major step required to integrate habitat connectivity into development plans.

The actual mechanisms for planning, however, are quite easily accessible with modern GIS and connectivity modeling technology, and multiple approaches exist for different scales of operation and landscape features.[53] These programs provide the benefit of not only helping plan for future development, but can also aid planners in identifying WVC hotspots and quantifying the existing level of connectivity in a given city. This, in turn, can help direct park development and connectivity management within the existing urban boundary. In 2002, a municipality in Vancouver - a city in the neighboring province of British Columbia – conducted such an analysis of their urban green spaces to calculate the required size and number of habitat patches necessary to facilitate biodiversity conservation within the city. Using 3 different connectivity and mapping approaches, researchers produced 13 possible networks of habitat linkages to facilitate their

---

[47] The survey also collected information on the least supported management methods, which were "Trap & Euthanize", "Surgically Sterilize Deer", and "Chemical Repellents." McCance 2009
[48] McCance 2009
[49] Ibid
[50] Buxton, G. & S. de Keijzer (2012). "Wildlife corridor planning in a rapidly growing community: Town of Canmore." *Urban Wildlife: Challenges and Management.* Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf
[51] Ibid
[52] Ibd, pg 104
[53] Snow, N.P., Williams, D.M., & W. F. Porter (2014). "A landscape-based approach for delineating hotspots of wildlife-vehicle collisions*." Landscape Ecology* **29**:817-829.

desired level of biodiversity.[54] They determined that a network of 325 total linkages was required, and recommended these linkages be achieved by utilizing matrices of urban backyard spaces and "beautifying" transportation right-of-ways and roads with desired native plants.[55]

An important part of habitat connectivity efforts is the continued monitoring and protection of habitat quality; increasing the level of connectivity between habitat nodes in the city is not sufficient if those patches are not of suitable quality to provide shelter, food, and passage for targeted species.[56]

4. *Incorporate Wildlife Conservation in Transportation Planning*

Institutionalizing the consideration of wildlife species' movement patterns and behavior in the planning states of transportation projects maybe the most impactful of all adopted changes as it is a preventative rather than reactionary measure. Given Calgary's rate of growth into currently undeveloped areas, the opportunity to incorporate ecological factors into road planning and design is an extremely valuable WVC mitigation tool.

The Town of Golden, a city 3 hours due West of Calgary on the other side of Banff National Park, is currently developing a wildlife-friendly road design plan for the portion of the Trans-Canada Highway that passes through their urban boundary and is in the process of being twinned.[57] This project is currently underway, and the "urban" road landscaping is set to start later in 2014. Golden's Trans-Canada Highway plans employ a number of different structural and landscape designs, placed at strategic locations, expressly to decrease the occurrence of WVCs; one-way escape structures for animals, wildlife crossings, jump-outs, fences, and ungulate guards (similar to cow guards) are suggested for different portions of the road.[58] This project recognizes that "unless properly designed, fencing systems" and other structural elements "designed to reduce animal-vehicle collisions can fragment wildlife populations and jeopardize their viability" [59], so they have employed other strategies such as planting vegetation unpalatable to deer and other ungulates on the side of the road as a deterrent.

The project also recognizes that road planning for WVC mitigation needs to have strategies specific to urban areas. Specifically, they cite an "increased focus on addressing potential public safety and liability concerns" and choice of structural elements based on resident preference.[60] Methods used by Golden as they unroll their plan, and lessons learned once construction is complete in Golden's urban section of the Trans-Canada Highway could serve as a useful tool for guiding Calgary's own transportation planning. Drawing on the experience of other cities and

---

[54] Rudd, H., Vala, J., & V. Schaefer (2002). "importance of Backyard Habitat in a Comprehensive Biodiversity Conservation Strategy: A Connective Analysis of Urban Green Spaces." *Restoration Ecology* **10** (2): 368 – 375.
[55] Ibid
[56] Bailey, S. (2007). "Increasing connectivity in fragmented landscapes: An investigation of evidence for biodiversity gain in woodlands." *Forest Ecology and Management* 238: 7-23.
[57] Harper, B. & C. Morley (2012). "Wildlife exclusion fencing in urban areas – Issues and solutions." *Urban Wildlife: Challenges and Management*. Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC Canada.
[58] Ibid
[59] Ibid, 64
[60] Ibid

rural projects will be valuable for Calgary, but there will be a fair amount of innovative and creative thinking to apply structural methods and planning strategies that fit the social and ecological context of the City. Comprehensive planning that marries sound design with ecological needs will require collaboration between city planners, wildlife specialists, landscape ecologist, transportation officials, park managers, construction teams, and private landowners.

5. *Conduct Cost-Benefit Analyses of WVC Mitigation Strategies*

Having focused primarily on integrating the social and ecological components of WVCs into problem solving, it is important to also recognize that there is a financial burden. With 920 collisions with deer happening in the last 4 ½ years alone Calgary's city limits a year, at C$11,774.42 per collision, the economic burden is estimated at well over C$10 million.

Cost-benefit analyses of WVC mitigation strategies are becoming more common in rural areas, but such models need to be adjusted to be applicable for the urban context, where costs and damages may need to calculated or weighed differently. Generating figures for these costs and solutions may be somewhat dangerous in that it simplifies the complexity of these issues to a number, but it also may benefit the decision process by providing participants and decision-makers with a sense of scale of the issues, and how much of an impact they have in an economic capacity.

6. *Increase Intelligence Function*

Lastly, none of the above actions can be achieved without first gathering more information on the ecological, social, and economic factors involved in WVCs and habitat connectivity planning. The methods employed to determine relevant factors and their impact greatly influence how they are integrated into policy, so an important first step is identifying holistic and appropriate measures for them. For WVCs, in particular, understanding an assessing the problem requires a more fundamental understanding of the scale and quantity of collisions occurring, as well as more comprehensive data on the types and gender of species being hit and conditions of roads where WVCs are occurring. A basic step in the right direction would be to reverse the 2011 decision to catalogue 311 road-kill reporting calls as "large" or "small-medium" animal, and take more detailed information on the species and, ideally, demographic information on the individual animal. This will determine not only which species are most prone to being involved in WVCs, but which subsets of those populations, so that management approaches can be more targeted and effective.

CONCLUSION (1 PAGE)

Bennett et al. (2003) describe protected areas as the "islands of conservation in an ocean of destruction".[61] This sea of devastation no doubt refers to the land touched by the force of human development, of which cities are the pinnacle antithesis of nature. What this characterization forces us to question is not only how to best protect these islands, but perhaps to recognize that

---

[61] Bennett, A.F. (2003). *Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation.* IUCN Forest Conservation Programme. Conserving Forest Ecosystems Series No. 1. Gland, CH: IUCN (The World Conservation Union)

destruction can be mitigated, reversed, and innovatively transformed into a new landscape that integrates built and natural landscapes. The philosopher Henri Lefebvre describes the concept of Second Nature as the space in which human labor transforms natural space, creating juxtaposition between land that is touched and land that is untouched by nature.[62] Sustainable development is a field that strives to find ways of "meeting fundamental human needs while preserving the life-support systems of planet Earth,"[63] arguably integrating these two spaces into one.

In cities like Calgary, where urbanization and population growth are a strong force, and human wildlife-conflicts in the form of WVCs keep pace with the rate of growth, it is time to acknowledge the need to create an urban development strategy that facilitates economic expansion while valuing the presence and protection of wildlife and natural areas. As a whole, this paper seeks to present arguments worthy of persuading government representatives and park managers of the financial and social value of increasing and enhancing urban habitat connectivity. Evaluating the state of habitat connectivity could come at no better time for the City of Calgary; the government is currently in the process of revising their 20 year-old *Natural Areas Management Plan*, as well as creating 60-year future urban development plan. By creating an urban wildlife management plan

---

[62] Soja, Edward W. (1989). *Postmodern Geographies: The Reassertion of Space in Critical Social Theory.* London: Verso.

[63] Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grübler, A., Huntley, B., Jäger, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H., Moore III, B., O'Riordan, T., & U. Svedin (2001). "Sustainability Science." *Science* 292 (5517): 641-642., 641.

LITERATURE CITED

Bailey, S. (2007). "Increasing connectivity in fragmented landscapes: An investigation of evidence for biodiversity gain in woodlands." *Forest Ecology and Management* 238: 7-23.

Beckmann, J.P., Clevenger, A.P., Huijser, M.P., & J.A. Hilty (2010). *Safe Passages: Highways: Wildlife, and Habitat Connectivity."* Washington, D.C., USA: Island Press

Bennett, A.F. (2003). *Linkages in the Landscape: The Role of Corridors and Connectivity in Wildlife Conservation.* IUCN Forest Conservation Programme. Conserving Forest Ecosystems Series No. 1. Gland, CH: IUCN (The World Conservation Union)

Buxton, G. & S. de Keijzer (2012). "Wildlife corridor planning in a rapidly growing community: Town of Canmore." *Urban Wildlife: Challenges and Management.* Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf

Calgary Parks and Recreation (1994). *Natural Area Management Plan.* The City of Calgary.

D'Eon, R.G., Glenn, S.M., Parfitt, I., & M.J. Fortin (2002). "Landscape Connectivity as a Function of Scale and Organism Vagility in a Real Forested Landscape." *Conservation Ecology* 6 (2): 1-10.

Elmauer, K. (2012). "Changing human behavior as part of wildlife management: Adopting a Community-Based Social Marketing (CBSM) approach." *Urban Wildlife: Challenges and Management.* Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf

Gonser, R.A., & J.S. Horn (2007). "Chapter #5: Deer-Vehicle Collisions Along the Suburban-Urban Fringe." n *Geo-Spatial Technologies in Urban Environment*, Pg. 177-196. Springer Link: New York, NY < http://link.springer.com/chapter/10.1007%2F978-3-540-69417-5_9>

Harper, B. & C. Morley (2012). "Wildlife exclusion fencing in urban areas – Issues and solutions." *Urban Wildlife: Challenges and Management*. Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC Canada.

Hall, M. (2012). "The process of solving urban wildlife conflicts at the community level." *Urban Wildlife: Challenges and Management*. Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC Canada.

Hesse, G. & R.V. Rea (2012). "Considerations for mitigating human-moose conflict in moose habitats undergoing urban development." *Urban Wildlife: Challenges and Management.*

Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf

ImagineCALGARY. *Plan It Calgary.* The City of Calgary. http://www.imaginecalgary.ca/

Imran, Muhammad. "Road Animal Fatality Information Application (RAFIA)." Edited by Moh Lali. *TSB Newsletter* 8, No. 2 (2010): 3-6 <http://www.transportation.alberta.ca/Content/docType256/Production/Marchfin2010TSBNewsletter.pdf>

Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Lowe, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grübler, A., Huntley, B., Jäger, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P., Mooney, H., Moore III, B., O'Riordan, T., & U. Svedin (2001). "Sustainability Science." *Science* 292 (5517): 641-642., 641.

Lamy, K. "Resident coyotes in the City of Calgary, Alberta: Function connectivity of urban natural spaces." *Urban Wildlife: Challenges and Management.* Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC CANADA. http://cmiae.org/wp-content/uploads/Urban-wildlife-summary-2012.pdf

McCance, Erin (2009). "Resident opinions concerning urban deer management in the Greater Winnipeg Area, Manitoba, Canada." Master of the Environment Thesis University of Manitoba, CANADA: 200 pages. http://proquest.umi.com/pqdlink?did=1919661251&Fmt=7&clientI%20d=79356&RQT=309&VName=PQD

McCance, E. (2012). "Understanding urban white-tailed deer movement in a Canadian metropolitian center." *Urban Wildlife: Challenges and Management*. Columbia Mountains Institute of Applied Ecology Conference, April 18-19: Cranbrook, BC Canada.

Rudd, H., Vala, J., & V. Schaefer (2002). "importance of Backyard Habitat in a Comprehensive Biodiversity Conservation Strategy: A Connective Analysis of Urban Green Spaces." *Restoration Ecology* **10** (2): 368 – 375.

Schrank, D., Bisele, B., & T. Lomax (2012). *TTI's 2012 Urban Mobility Report: Powered by INRIX Traffic Data.* Texas A&M Transportation Institute. <http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/mobility-report-2012.pdf>

Snow, N.P., Williams, D.M., & W. F. Porter (2014). "A landscape-based approach for delineating hotspots of wildlife-vehicle collisions." *Landscape Ecology* **29**:817-829.

Spellerberg, I.F. (2002). *Ecological Effects of Roads.* Volume 2, The Land Reconstruction and Management Series Science Publishers, Inc: Enfield (NH), USA.

The City of Calgary (2013). *Municipal Development Plan*. Bylaw 24P2009, Adopted April 2010. www.calgary.ca/MDP/

APPENDICES

Appendix 1. Animal Carcasses Collected on Calgary Roads (2005 - 07/2014)

Species Identified	Year										Total
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	
Badger	-	-	-	-	-	-	-	10	7	-	17
Beaver	-	-	-	-	-	-	3	4	-	-	7
Birds	222	307	276	265	274	255	288	508	402	74	2871
Blackbird	-	-	-	-	-	-	-	1	-	-	1
Crow	-	-	-	-	-	-	-	1	5	-	6
Duck	-	-	-	-	-	-	7	30	44	3	84
Falcon	-	-	-	-	-	-	-	1	-	-	1
Goose	-	-	-	-	-	-	5	4	1	2	12
Hawk	-	-	-	-	-	-	-	2	1	1	4
Magpie	-	-	-	-	-	-	-	22	3	-	25
Owl	-	-	-	-	-	-	-	1	1	-	2
Pigeon	-	-	-	-	-	-	-	8	4	2	14
Raven	-	-	-	-	-	-	-	1	-	-	1
Seagull	-	-	-	-	-	-	-	5	1	-	6
Sparrow	-	-	-	-	-	-	-	1	-	2	3
Unidentified	222	307	276	265	274	255	276	431	342	64	2712
Cat	-	-	-	-	-	-	-	4	5	-	9
Coyote	-	-	7	200	257	212	57	74	31	9	847
Deer	334	376	603	505	497	493	312	546	534	115	4315
Dog	-	-	-	-	-	-	-	7	3	1	11
Fox	-	-	-	-	-	-	2	2	2	-	6
Moose	-	-	-	-	-	-	1	-	-	-	1
Muskrat	-	-	-	-	-	-	-	25	13	-	38
Opossum	-	-	-	-	-	-	-	1	-	-	1
Porcupine	-	-	-	-	-	-	2	7	5	-	14
Rabbit	-	28	918	1117	1097	1174	1185	1332	1290	311	8452
Raccoon	-	-	-	-	-	-	-	2	-	-	2
Rat	-	-	-	-	-	-	-	-	-	1	1
Skunk	-	-	-	-	-	-	35	3	8	2	48
Small/Medium Animal –	-	-	-	-	-	-	548	664	412	105	1729

Unidentified[+]											
Squirrel / Gopher	-	5	201	285	315	304	26	183	421	73	1813
Unidentified	812	1292	415	344	409	416	330	262	204	58	4542
Large Animal - Unidentified[+]	-	-	-	-	-	-	125	50	50	13	238
Total	**1368**	**2008**	**2420**	**2716**	**2849**	**2854**	**2914**	**3684**	**3387**	**762**	**24962**

Source: Calgary Roads Department & Carmacks Enterprised

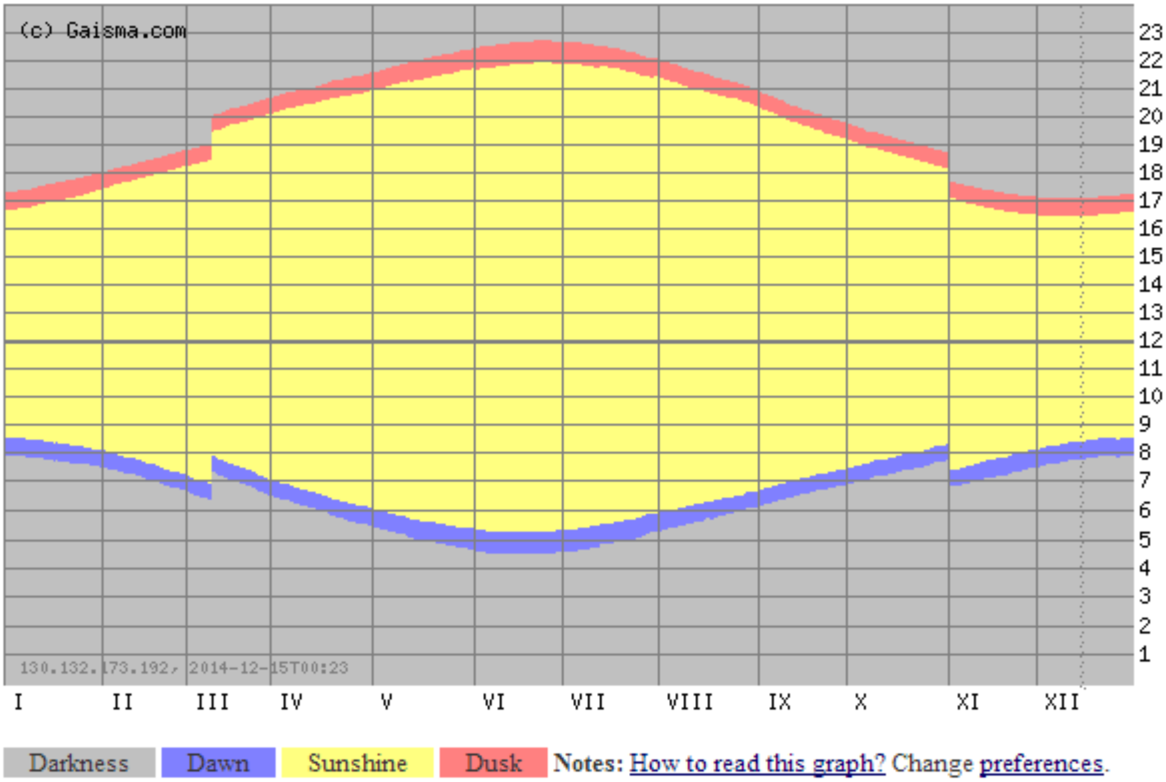
[+]In 2011 the 311 reported system introduced "Large Animal" and "Small to Medium as a new species category, so many

Appendix 2. Animal Species Reported in Police Vehicle Accident Reports in Calgary (2005 - 07/2014)

Species Identified	Year					Total
	2010	**2011**	**2012**	**2013**	**2014**	
Badger	-	-	1	-	1	**2**
Bear	1	-	-	-	-	**1**
Bird	2	1	1	-	-	
Goose	-	-	1	-	-	1
Owl	2	-	-	-	-	2
Cat	-	-	1	1	1	**3**
Coyote	17	11	17	7	5	**57**
Deer	226	212	187	219	76	**920**
Dog	13	12	13	10	4	**52**
Moose	1	6	1	2	1	**11**
Porcupine	1	2	1	2	-	**6**
Rabbit	7	3	1	2	2	**15**
Raccoon	-	1	-	-	-	**1**
Squirrel	-	1	-	-	-	**1**
Unidentified	136	115	132	100	34	**528**
Wolf	-	-	-	1	-	**1**
Total	**404**	**364**	**366**	**344**	**124**	**1602**

Source: Calgary Police Department

Appendix 3. Dawn, Night, Dusk, and Daylight times in Calgary January-December



Sourece; Gaisma.com

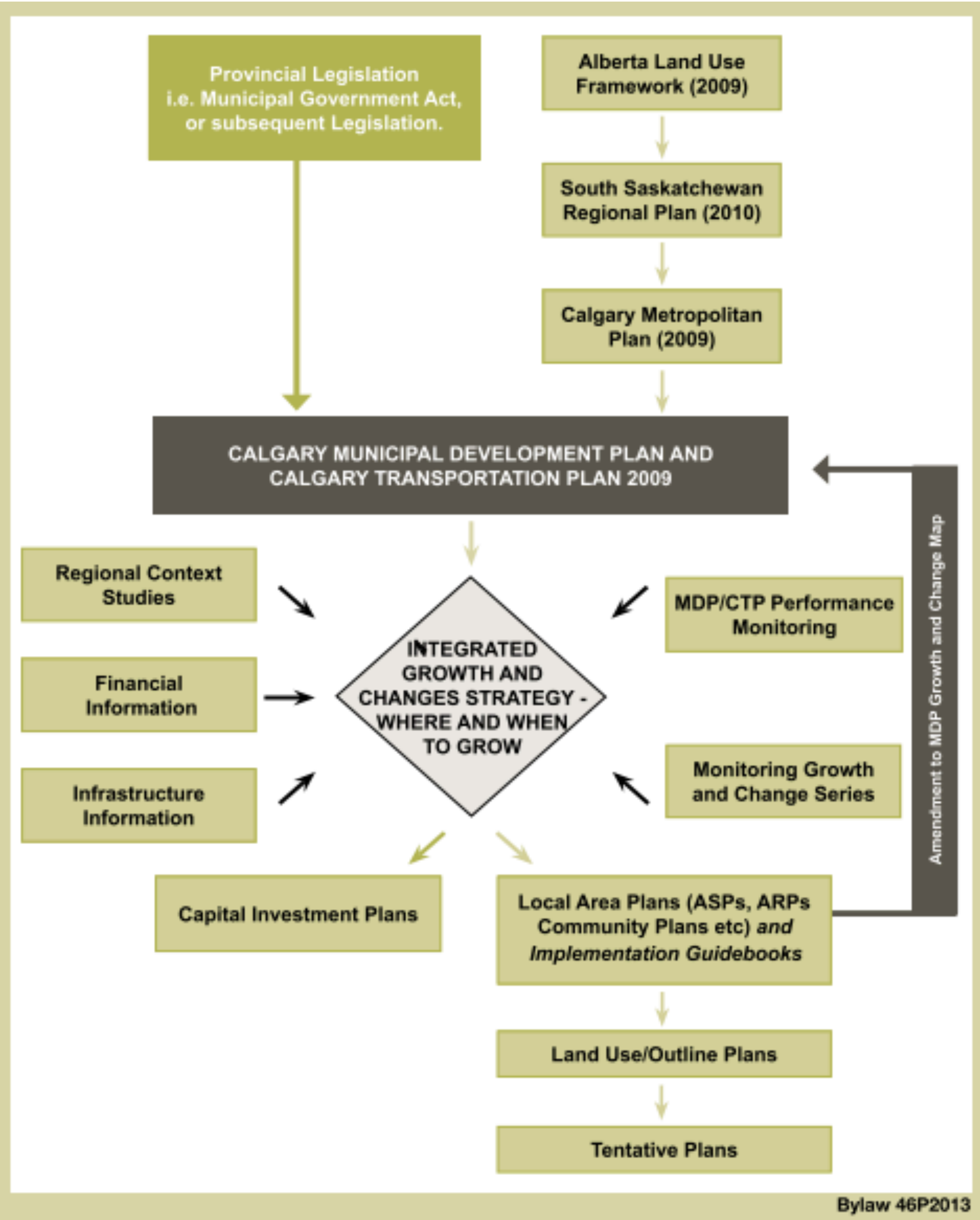


Figure 5-1: A Strategic Framework for Growth and Change
*South Saskatchewan Regional Plan and Calgary Metropolitan Plan are not approved.

Source: CRP (5-4)