Quantifying wildlife vehicle collisions and underreporting on Highway 33

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Front Cover image: ©Gayle Hesse: Highway 33, looking south from Hall Creek Rest Area, LKI Km 62.22.

EXECUTIVE SUMMARY

Wildlife vehicle collisions (WVCs) on British Columbia (BC) highways pose serious safety concerns for road users and result in human injury and death, economic costs, and wildlife losses. In BC, the British Columbia Ministry of Transportation and Infrastructure (BC MOTI) and the Insurance Corporation of British Columbia (ICBC) are the main sources of data on WVCs. BC MOTI reports that they capture between 25% and 35% of the actual number of WVCs and that ICBC captures approximately 75% of WVCs. Data regarding WVCs are also captured by the Conservation Officer Service (COS) of the British Columbia Ministry of Environment (BC MOE) and the Royal Canadian Mounted Police (RCMP). Presumably, if WVC data from police-attended WVCs and COS reports were combined with BC MOTI and ICBC data, then a better estimate of the baseline number of WVCs could be determined.

In this project, we integrated WVC data from these four agencies to establish the baseline number of WVCs that occurred on Highway 33, Segment 1324, and then documented patterns in WVC underreporting to establish the degree of WVC underreporting by agency. Data from WVCs with large mammals (deer, moose, bear, and elk) from January 1, 2008 to December 1, 2017 occurring on Highway 33, Segment 1324 were used in this project.

Wildlife vehicle collisions from each agency were examined and compared for commonalities, integrated into a union dataset, and then a baseline total number of WVCs (*Bt*WVCs) was calculated. From January 1, 2008 to December 31, 2014, WARS recorded the largest number of WVCs (1,133), followed by ICBC (993), COS (64), and RCMP (34), for a total of 2,224 discrete WVC records. These discrete agency records were combined into a union dataset of 2,055 *Bt*WVC records (a mean of 293.6 WVCs/year and 2.28 WVCs/km/year).

Out of 2,055 *Bt*WVCs, 1,893 WVCs (92.0%) were recorded by one agency, 84 WVCs (4.15%) were recorded by two out of four agencies, one WVC (0.05%) was recorded by three out of four agencies, and no WVCs were recorded by all four agencies.

There were 2,060 WVCs (2,055 *Bt*WVCs + 5 WARS WVC records with an incorrect date) involving 2,077 animals. The majority of WVCs (2,045) involved only one animal; however, 13 WVCs involved two deer, one WVC involved two elk, and one WVC involved four deer. Of the 2,077 animals involved in WVCs, 1,975 (95.1%) were deer, 33 (1.6%) were moose, 12 (0.6%) were elk, 11 (0.5%) were bear, and 46 (2.2%) were unidentified.

The number of WVCs recorded by each agency was compared to the *Bt*WVCs to determine the percentage of WVCs that were reported by each agency. The proportion of WVCs reported by each agency was calculated and tested for significance using a two proportion Z-test.

Out of 2,055 *Bt*WVCs, the proportions of *Bt*WVCs captured by each agency were all significantly different from each other. WARS captured significantly more WVCs (50.9%) than either ICBC (44.6%), COS (2.9%), or the RCMP (1.5%: as recorded in the Collision Information System).

Our results showed that out of 2,055 *Bt*WVCs, 55.4% of *Bt*WVCs were not reported to ICBC, 49.1% of *Bt*WVCs were not captured by BC MOTI, the COS was not called to attend 97.1% of *Bt*WVCs, and the RCMP did not attend 98.5% of *Bt*WVCs.

ICBC's WVC reporting rate of 44.6% of the known number of WVCs that occurred is considerably different than ICBC's estimate (as reported by BC MOTI) of capturing approximately 75% of WVCs involving vehicles from out-of-province, vehicles insured with other agencies, or vehicles where no claim was made. ICBC's WVC reporting estimates may need to be adjusted, particularly in areas where deer comprise the majority of WVCs.

BC MOTI captured 50.9% of the known number of WVCs that occurred (an underreporting rate of 49.1%). Therefore, on Highway 33, our results do not support BC MOTI's historical operating assumption that WARS captures between 25% and 35% of the actual number of WVCs (65% to 75% of WVCs were underreported). In fact, BC MOTI's WVC reporting rate between 2008 and 2014 on Highway 33 was higher (better) than had been traditionally assumed.

BC MOTI and RCMP WVC records were easily integrated because both were based on the Landmark Kilometre Inventory location system. The two datasets appear to have little overlap, meaning that each dataset was capturing different WVCs. Integrating RCMP WVC data with BC MOTI WARS data may provide a more robust WVC dataset for wildlife collision mitigation planning.

Between January 1, 2008 and December 31, 2014, the annual number of discrete WVCs from all agencies showed a slight decrease. Monthly trends showed a strong WVC peak in April and a smaller peak in October, reflecting the high percentage of WVCs that involved deer (95.1%). Over the entire length of Highway 33, using WARS data only, there was a mean of 1.26 WVCs/km/year, with 1.45 WVCs/km/year in BC MOTI District 4 (southern portion) and 0.83 WVCs/km/year in BC MOTI District 5 (northern portion).

We provide recommendations for all four agencies to improve the quality of WVC data (better locational accuracy, reduce missed WVCs, include species), and data collection/processing protocols (data recording consistency, reduction of errors in data handling). Specific situations where information sharing between agencies could improve the available WVC data are discussed.

Our results establish the underreporting rate for a known amount of WVCs for BC MOTI (49.1%) and ICBC (55.4%). This provides BC's highway managers with an improved understanding of the magnitude of the issue, the quality of BC's WVC data, and what, if any, limitations should be placed upon its use. With this understanding, highway mangers can confidently utilize WVC data for the identification of high risk stretches of highway, prioritize these areas for mitigation, develop appropriate mitigation strategies, and monitor mitigation results.

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INTRODUCTION

In British Columbia (BC), there is considerable overlap between animal habitat, wildlife travel corridors, and the provincial highway network, which means that motorists are likely to encounter wildlife while driving. When these encounters result in collisions with large mammals, they can result in human injury and death, economic costs, and wildlife injury and mortality. Road safety managers collect and use wildlife vehicle collision (WVC) data to mitigate these serious consequences.

There are four different agencies which collect data on WVCs in BC. The British Columbia Ministry of Transportation and Infrastructure (BC MoTI), through its highways maintenance contractors, records information on wildlife carcasses found on numbered highways in the Wildlife Accident Reporting System (WARS). The Insurance Corporation of British Columbia (ICBC) keeps records of vehicle property damage, human injury, and human fatality insurance claims caused by collisions with animals in the Corporate Data Warehouse and the Enterprise Data Warehouse. The Conservation Officer Service (COS) maintains records of officer-attended roadside incidents involving dead or injured animals in the Human Wildlife Conflict Violation Report (HWCR). The RCMP attends WVCs with resultant human injury or fatality, and their collision data are recorded in the Collision Information System (CIS). The information collected by each agency has both strengths and weaknesses (Hesse 2006, Hesse and Rea 2016).

BC MOTI reports a provincial annual average of 6,108 WVCs per year (five-year average 2003-2007: Sielecki 2010). ICBC reports a provincial annual average of 11,000 animal-related collisions per year resulting in three human fatalities and 650 human injuries (five-year average 2013-2017: ICBC 2018). BC MOTI and ICBC acknowledge that their records do not capture all WVCs that occur on BC highways (Sielecki 2010) resulting in systemic underreporting of WVCs.

On northern BC highways, WVC underreporting was quantified as 65.7% (BC MOTI) and 54.5% (ICBC) (Hesse and Rea 2016). Underreporting of WVCs on southern interior highways has not been investigated, even though ~55% of provincial WVCs occur in BC MOTI's Southern Interior region (Sielecki 2010). Southern interior highways traverse different types of terrain and wildlife habitat (supporting different species composition) than northern highways, as well as experiencing different weather patterns and variations in seasonal conditions, all of which may impact wildlife vehicle collision and underreporting rates.

Underreporting of WVCs on BC highways is of concern because identifying and prioritizing highway locations for WVC mitigation treatments is predicated on the magnitude of the WVC issue in particular locations. When the baseline number of wildlife collisions cannot be determined, mitigation treatment decisions and assessment of mitigation efficacy is compromised.

To quantify WVC underreporting on a southern interior highway, and using methodologies developed in Hesse and Rea (2016), we examined data on WVCs occurring Highway 33, Segment 1324, from January 1, 2008 to December 31, 2017 that were contained in four different databases, in order to: (1) establish a baseline number of WVCs, (2) document any patterns in WVC underreporting, and (3) establish the degree of underreporting of WVCs by agency.

Several specific questions about WVCs on Highway 33 form the basis of this report.

- How many WVCs were recorded by each agency from January 1, 2008 to December 31, 2017?
- How many of these individual (discrete) agency records referred to the same WVC incident?
- How often might a specific WVC be recorded by all four agencies, by three of the four agencies, by only two of the agencies, or by one of the agencies?
- Do all WVC records occurring on a specific date refer to the same incident?
- What percentage of the actual number of WVCs do the WVC records maintained by each individual agency represent?
- What is the magnitude of WVC underreporting, by agency?
- What factors might lead to the recording of a WVC by one agency and not another and under what circumstances might this occur?
- Are there ways to ensure that WVC records kept by each agency form a more complete representation of the actual number of collisions?
- Aside from WVC underreporting, what can be learned about WVCs on Highway 33?
- What species of animals are being hit and killed?
- Are WVCs increasing or decreasing through time on Highway 33?
- Are there annual or monthly WVC trends?

The scope of this project involved consultation with specialists in the collection and analysis of WVC data from BC MOTI, ICBC, and the COS, and then undertaking a comparison and analysis of relevant WVC records from each agency to create a unified and integrated WVC dataset. This project will provide a better idea of the actual WVC numbers and WVC underreporting rates on Highway 33. This will assist road safety managers with the identification and prioritization of highway locations for WVC mitigation and allow for more reliable monitoring and evaluation of mitigation measures.

BACKGROUND

Underreporting

Underreporting of WVCs is ubiquitous and has been documented in many jurisdictions including Australia (Rowden et al. 2008), Britain (Langbein 2011), Canada (Tardiff 2003, Sielecki 2010, Vanlaar et al. 2012, Hesse and Rea 2016), Finland (Niemi et al. 2015), Sweden (Almkvist et al. 1980, Seiler 2005), and the USA (Conover et al. 1995, Romin and Bissonette 1996, Huijser et al. 2007, Donaldson 2017).

Both BC MOTI and ICBC acknowledge that underreporting of WVCs exists and have attempted to describe the magnitude of the underreporting. Sielecki (2010) reports that BC MOTI: "… *estimates the number of wild animals recorded by the WARS system represents only about 25% to 35% of the actual number of wild animals killed*." This estimate of 25-35% underreporting is anecdotal (*pers. comm.* L. Sielecki, Wildlife and Environmental Issues Specialist, BC MOTI, March 2015) but has been historically used by BC MOTI to quantify underreporting of WVCs.

Sielecki (2010) also discusses the underreporting of WVCs to ICBC and reports that: "*ICBC estimates its accident claims capture 75% of the number of wildlife-related accidents that occur in British Columbia*. *Of the 25% of the number of British Columbia wildlife-related motor vehicle accidents ICBC estimates go unreported to it, ICBC estimates 10% involve out-of-province vehicles, 10% involve vehicles*

with less than $100 in damage, and 5% of the accidents are reported to other insurance companies in British Columbia."

Results from Hesse and Rea (2016) supported the historical (but generally anecdotal) BC MOTI WVC underreporting estimates and established that for northern highway segments (~100 km in length), 54.5% of WVCs were not reported to ICBC, 65.7% of WVCs were not captured by BC MOTI, the RCMP did not attend 89.8% of WVCs, and the COS was not called to attend 90.0% of WVCs.

As of March 2020, similar studies on WVC underreporting on highways in BC's southern interior had not been carried out. Highway 33, Segment 1324 was selected for this project because it is one discrete segment, (not part of a longer numbered highway with numerous segments) making data on WVCs easier to query from various databases and also because of its high numbers of WVCs. In BC MOTI's Rural Safety and Speed Review, Highway 33 was ranked as the ninth highest in the province for WVCs, with ~1.3 deer vehicle collisions/km/year occurring from 2004 to 2013 (BC MOTI 2014a). Previous WARS reports ranked Highway 33 as the fourth highest in the province for deer vehicle collisions (Sielecki 2001).

Databases

Information and data about wildlife vehicle incidents on Highway 33 from three agencies and four databases were used in this project: BC MOTI – WARS, COS – HWCR, BC MOTI – CIS, and ICBC – Corporate Data Warehouse and Enterprise Data Warehouse. Four types of WVC data were used: carcass counts (WARS), police-attended collision reports (CIS via RCMP), human-wildlife conflict occurrences (COS via HWCR), and insurance collision reports (ICBC). Data from all of these sources have traditionally been affected by underreporting and, therefore, the accurate (true) number of WVCs that occurred was not completely captured.

***BC MOTI – Wildlife Accident Reporting System*.** In BC, highway maintenance contractors are contractually obligated to remove carcasses found along numbered highways, and report information monthly about those carcasses to BC MOTI through WARS. BC MOTI administers WARS, and uses it for a variety of road safety and traffic related purposes. The WARS database is robust and dates back to 1978 (Sielecki 2010).

The WARS form (HO107) is designed to collect information on date of carcass pickup, estimated time of collision, highway number, carcass location using BC MOTI's Landmark Kilometre Inventory (LKI) system (required) and/or the Resource Feature Inventory (RFI) (optional), nearest town, presence of deer warning signs or wildlife reflectors within 100 metres of the carcass, and species, sex, and number of carcass removed. There is also a *Comments* field.

The carcass location (and by commonly accepted understanding and practice, the WVC location) in WARS is denoted using the LKI system and/or the RFI system. The LKI separates highways into discrete segments with defined start and end points that are typically located at the junction of other highways or major roads. Landmarks such as intersections and bridges along each segment are listed, along with their measured distance from the start of the segment. A carcass (WVC) location is recorded using a distance measurement or distance estimate from the nearest landmark recorded in the LKI. The RFI (based on a system of landmarks and offset distances) is occasionally used to record a carcass (WVC) location.

Accuracy of WVC locations using the LKI is directly related to the due diligence of the maintenance contractor (Sielecki 2010). No guidelines on the degree of kilometre accuracy (i.e., should the measurement be to the nearest kilometre, 100 metres, ten metres, or one metre) are provided on the form. During the term of this project, the Emcon Services Inc., Midway Area crew (responsible for Highway 33 LKI Km 0.00 to Km 13.32) recorded carcass locations to +/-50 metres, occasionally using a truck odometer to estimate distance (*pers. comm.* G. Spencer, November 2018). The Emcon Services Inc., Beaverdell Area crew (responsible for Highway 33 LKI Km 13.32 to Km 89.72) recorded carcass locations to the nearest 100 metres (*pers. comm.* D. Jamieson, Beaverdell Area Foreman, November 2018).

The WARS dataset is subject to some inaccuracy and incompleteness at the field data collection level resulting from errors and/or omissions in reporting of highway numbers, segment numbers, LKI location, and species. These inconsistencies in the WARS database result in difficulties for BC MOTI staff, and other users, when attempting to extract, sort, and manipulate the data. At the data management level, errors and omissions can occur during data reporting, transferring, and processing, and by procedural changes in these processes. Sielecki (2010) provides further discussion on WARS data quality.

An inherent difficulty with using carcass data is that the time and date of the WVC is not known, but is estimated based on the detection of the carcass by the maintenance contractor. How quickly an animal carcass is detected and removed from the travelled lanes, the shoulder, or the right-of-way (and therefore, what date is recorded in WARS) is a function of how frequently the highways is patrolled and the debris removal timeframes set out for the maintenance contractors. Highway patrol frequency and debris removal time frames are determined by the highway's maintenance classification.

Highways are assigned both a summer and winter road maintenance classification (Appendix 1). A default patrol frequency (Appendix 2) is established for both summer and winter highway classifications, and the patrol frequency is increased during periods of high water flow and snowfall. Debris removal timeframes (Appendix 3) are based on the summer highway classification.

BC MOTI – Collision Information System. The CIS contains data resulting from all vehicle collisions that are attended by police. Manpower and other operational constraints permitting, the RCMP in BC will attend the scene of a WVC if there is property damage over $1,000, or a human injury or fatality. The CIS data are initially captured on the Motor Vehicle Traffic Accident Police Investigation Report form (MV6020) by the attending police officer who completes the paper MV6020 form at the scene of a collision. The MV6020 is submitted to ICBC within ten days and entered into an electronic record database, the BC Traffic Accident System (TAS), which is maintained by ICBC. Data is transferred monthly from TAS into CIS which is maintained by BC MOTI. The CIS data are intended to be used internally by BC MOTI for transportation and safety related projects and purposes.

Collision location information on the MV6020 is recorded in several fields. The *Location Code* field captures the highway number, the LKI segment number, and the kilometre measurement of the collision. The *Collision Location* field captures a written narrative description of the location, and is used to supplement or clarify the data in the *Location Code* field. Latitude and longitude fields are present, but some data manipulation is required to extract the LKI locations if only a GPS latitude and longitude position is supplied (*pers. comm.* N. Nguyen, Highway Safety Engineer, BC MOTI, March 2015 and Sgt.

A.D. Steinhauser, North District – NCO Operations, Regional Provincial Traffic Services, RCMP, November 2015).

Conservation Officer Service - Human Wildlife Conflict Violation Report. The COS uses the Report All Poachers and Polluters (RAPP) hotline, a 24-hour toll-free phone number, for the public to report human-wildlife conflicts or other incidents involving wildlife. Calls to this hotline are directed to the Emergency Coordination Centre (ECC). The COS maintains a record of calls to the ECC from members of the public or other agencies calling to report WVCs or injured or dead wildlife on or near roads. These incidents are recorded in the electronic HWCR database by telephone operators. The same incident can generate more than one call to the ECC if different people report an incident independently. A call to the ECC generates a notification to a conservation officer, who may or may not attend a WVC depending upon occurrence priority, workload, and staff availability.

Prior to 2011/2012 fiscal year, the HWCR database contained only the information from the complaint as it was initially called in and recorded by the operator. A separate system, called the Human Wildlife Conflicts Ledger was maintained to keep track of the outcome of the call (i.e., what happened when the conservation officer attended the scene). Beginning in 2011/2012 fiscal year, the ECC records became fully computerized and searchable, and, in 2014/2015, ECC records were integrated into the Human Wildlife Conflicts Ledger so that incident outcomes could be more easily linked to the initial call.

The vast majority of data from the HWCR is from calls to ECC made by the public (the minority is from other agencies, primarily the RCMP) and is therefore subject to selection bias regarding which situations people feel compelled to report.

The HWCR database captures a considerable amount of information. Pertinent to this project are fields with pre-set, drop-down choices for *Species*, *Nature of Complaint*, *Action Taken*, *Complaint Outcome*, and *Occurrence Location*. Several fields are formatted for narrative text, where operators and officers can record details of the incidents, such as *Occurrence Notes*, *Location Description*, and *Incident Narrative*.

Calls to ECC cover a variety of situations, including:

- members of the public reporting an injured animal they see along the road
- members of the public self-reporting that they have been involved in a WVC
- members of the public who have seen another vehicle strike an animal
- members of the public reporting third-hand information about a WVC
- another agency requesting assistance from a conservation officer with an injured animal

These circumstances mean that the time and/or date of the WVC is not always known and it is possible that the time and date in the HWCR might be when the caller encountered an injured or dead animal rather than the time that the WVC occurred.

ICBC – Corporate Data Warehouse and Enterprise Data Warehouse. People who wish to initiate insurance claims as a result of a WVC self-report the details of the collision to ICBC. This information is housed in ICBC's Corporate Data Warehouse and Enterprise Data Warehouse. Requests for access to these data need to be vetted through various ICBC departments due to proprietary interests in the data. ICBC data must be viewed with the following caveats:

- due to the difficulty of accurately locating crashes along highway corridors with few landmarks, precise mapping of collision locations is not possible

- crash counts are determined based on the incident description fields and counts by location should not be considered comprehensive
- data include only those crashes where the vehicle owner had purchased optional comprehensive insurance coverage
- data exclude crashes in parking lots and crashes involving parked vehicles
- data exclude out of province crashes
- collisions are self-reported, so may not reflect incidents with incriminatory circumstances (i.e., impaired) (Brubacher et al. 2018) or distracted driving
- type of animal is based on driver reporting and is not verified by ICBC
- ICBC transitioned to a new system for reporting insurance claims in 2013. Although ICBC has made every effort to ensure that crash counts and location data from the new and old system are comparable, claims data from 2014 onward may not be directly comparable to prior data.
- data will continue to change, especially for the most recent time periods, because of late reporting, and corrections and adjustments.

The sources of WVC data for this project, and the strengths and weaknesses of that data, are summarized in Tables 1 and 2.

Table 1. BC WVC data sources and databases.

Agency	**BC MOTI**		**BC MOE (COS)**	**ICBC**
Database	**WARS**	**CIS**	**HWCR**	**Corporate Data Warehouse**
Who reports the WVC?	Maintenance contractors	RCMP (through MV 6020)	Public or other agencies	Public
Who receives the initial report?	BC MOTI	RCMP and ICBC (TAS)	BC MOE (through the RAPP hotline to ECC)	ICBC
Into what database does the information go first?	WARS	TAS	ECC call logs	Corporate Data Warehouse
Who manages the first database?	BC MOTI	ICBC	BC MOE (COS)	ICBC
Into what database does the data get transferred?	-	CIS	HWCR	-
Who manages the second database?	-	BC MOTI	BC MOE	-
What is the data type?	Carcass data	Police-attended collision data	Human-wildlife conflict reports	Insurance collision reports

Table 2. Comparison of WVC date, time, location, and species information obtained from four databases (bold font indicates known information).

	WARS	CIS (RCMP)	HWCR	ICBC
WVC date	Estimated	**Known**	Estimated or known	**Known**
WVC time	Estimated	**Known**	Estimated or known	**Known**: recorded in 3-hour increments up to March 31, 2014, and to the nearest minute after April 1, 2015
WVC location	**LKI km estimated from knowledge and experience**	**LKI km estimated from knowledge and experience**	Ranges from very specific (e.g., *Highway 33 at the 23 km mark out of Kelowna; north bound ditch*) to not specific (e.g., *Highway between Rock Creek and Westbridge, left side of the road*)	Most often not specific (e.g., *driving westbound on Highway 33* or *heading out of Kelowna to Beaverdell*)
Species involved	**Known**	Not identified	**Known if CO attends;** Caller may provide a correct species ID if they are knowledgeable	Claimant voluntarily self-reports a species ID. Claimant is not asked to provide species ID. Species ID is not verified by ICBC

METHODS

Study Area Highway 33, Segment 1324, Rock Creek to Kelowna

Administrative jurisdictions, boundaries, and historical revisions. Highway 33, Segment 1324 (Figure 1) lies wholly within BC MOTI's Southern Interior Region. The start of Segment 1324 (LKI Km 0.00) is the junction of Highway 33 and Highway 3 at Rock Creek and the end of Segment 1324 (LKI Km 128.82) is the junction of Highway 33 and Highway 97 in Kelowna (Figure 2). Its southern stretch (LKI Km 0.00 to 89.72) is contained within District 4 (West Kootenay) and Service Area 9 (Kootenay Boundary). Its northern stretch (LKI Km 89.72 to 128.82) is contained within District 5 (Okanagan-Shuswap) and Service Area 8 (South Okanagan). The boundary between BC MOTI Districts 4 and 5 and Service Areas 8 and 9 is located at LKI Km 89.72 (McCulloch Road) (Figure 3). During the term of this project, Service Area 8 was maintained by Argo Road Maintenance (South Okanagan) Inc., and Service Area 9 was maintained by Emcon Services Inc.

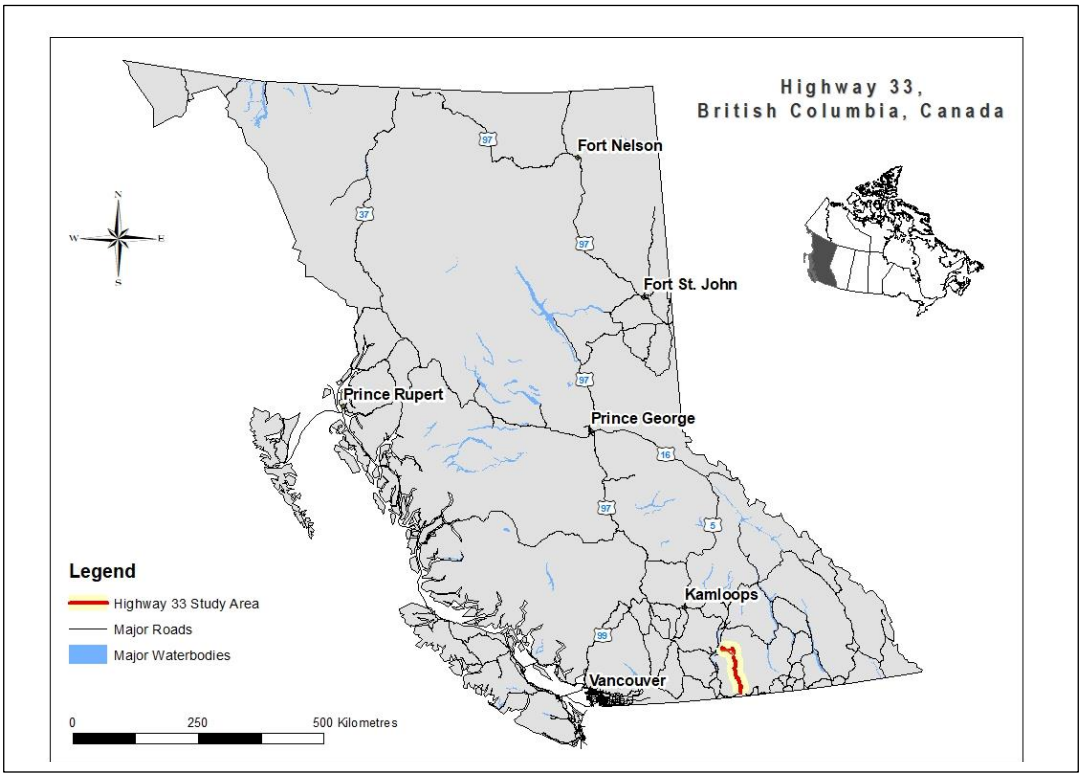

Figure 1. Highway 33, Segment 1324, for which WVC data from January 1, 2008 to December 31, 2017 was obtained and analyzed.

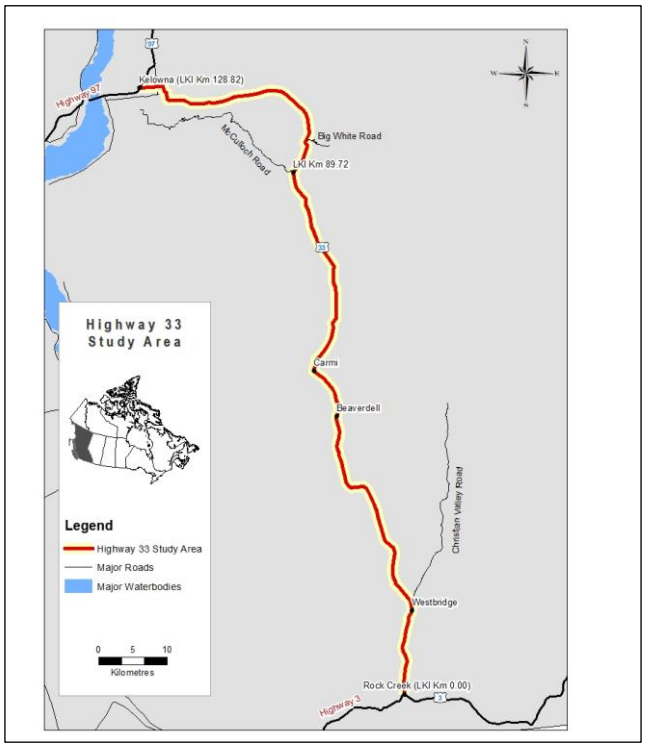

Figure 2. Highway 33, Segment 1324 study area, showing the start (Rock Creek: LKI Km 0.00) and end (Kelowna: LKI Km 128.82) of the segment.

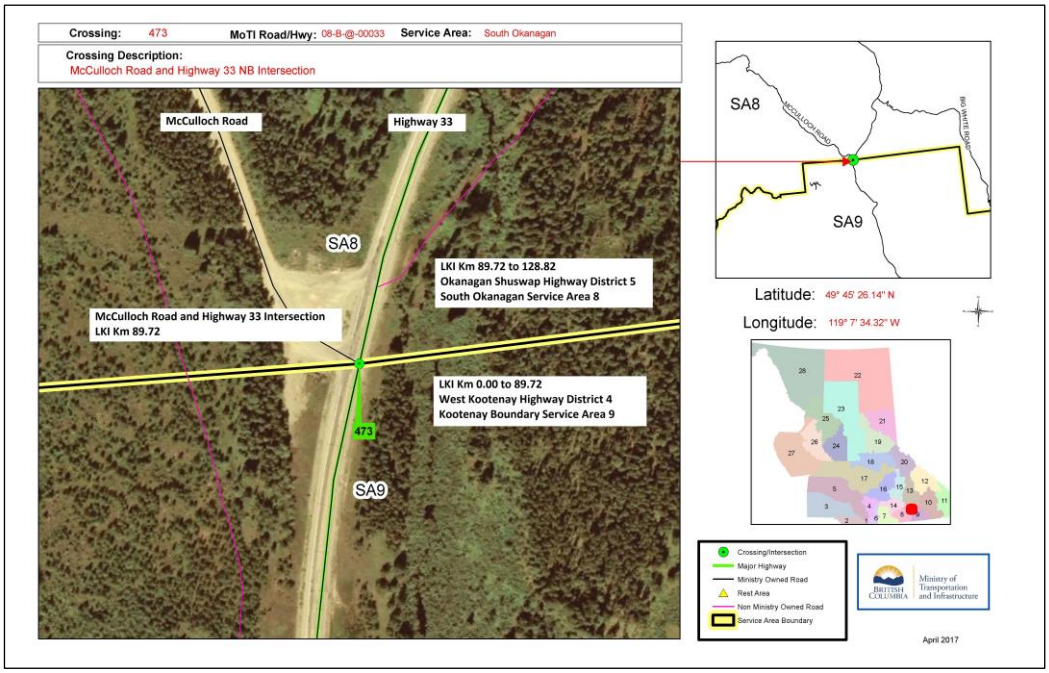

Figure 3. Intersection of Highway 33, Segment 1324 and McCulloch Road (LKI Km 89.72), marking the boundary between BC MOTI Districts 4 and 5 and Service Areas 8 and 9.
(Image adapted from BC MOTI 2019)

The entire length of Highway 33 is defined as one segment. In July 2015, the segment number was changed from Segment 1327 to Segment 1324 (Table 3) (BC MOTI 2017). Hereafter, we refer to the segment using its current designation as Segment 1324.

Segment 1324 was shortened from 128.88 km to 128.82 km and the BC MOTI District/Service Area boundary changed from LKI Km 89.80 to LKI Km 89.72 (Table 3) in July 2015 (BC MOTI 2015).

Shortening of the segment by 60 metres did not affect integrating agency WVC datasets or matching agency WVC records, as date and time were the primary comparative factors. Location was a secondary comparative factor as guidelines for locational accuracy are not specified on the WARS form (see **Integrating agency WVC datasets** section below for WVC matching protocols). Identifying specific WVC hotspots would require that locations be recorded consistently; however, hotspot identification was not within the scope of this project.

Table 3. Changes to Highway 33 segment number, length, and BC MOTI District/Service Area boundary between LKI Version 201407 and LKI Version 201507.

LKI Version	LKI Segment	Length (km)	BC MOTI District/ Service Area Boundary LKI Km	BC MOTI District	Service Area	Beginning of Segment Description (distance in km)	End of Segment Description (distance in km)
July 2014 (BC MOTI 2014b)	1327	128.88	0.00 to 89.80	4	9	JCT HWY 3 ROCK CREEK (0.00)	RTE 97 (128.88)
			89.80 to 128.88	5	8		
July 2015 (BC MOTI 2015)	1324	128.82	0.00 to 89.72	4	9	JCT HWY 3 / HWY 33 (0.00)	JCT HWY 97 / HWY 33 (128.82)
			89.72 to 128.82	5	8		

Highway classifications and traffic volumes. By planning/functional classification, Highway 33 is classed as a secondary arterial highway for its entire length. By design class, Highway 33 is undivided for its entire length and rural for the majority of its length, with two short stretches classed as urban (LKI Km 47.75 to Km 48.92 (Beaverdell) and LKI Km 125.72 to Km 128.82 (Kelowna)). The majority of Highway 33 is classed as "Up to 3 Lanes," with only LKI Km 121.68 to Km 128.92 classed as "4 or More Lanes." The terrain along Highway 33 is variously classed as mountainous or rolling.

Traffic volumes were higher (AADT 13,870 to 17,177) along the northern, more urban stretches of Highway 33 nearest to Kelowna and then decreased (average daily total 1,507 to 1,741) south of Big White Road intersection (provides sole access to Big White Ski Hill) to Rock Creek (Table 4).

Table 4. Highway 33 traffic volumes, from north to south.

Traffic count station	Location	Urban/ Rural	Time of Data Collection	Traffic count
25033S 25-33NS	LKI Km 126.48 W of Rutland Rd	Urban	2012	17,177 (AADT)*
57070S 25-016NS	LKI Km 124.62 E of Springfield Rd	Urban	2012	13,870 (AADT)*
25 101NS	LKI Km 81.1 14.6 km S of Big White Rd	Rural	Week of Sept 20-26, 2016	1,741 Average daily total**
25 102NS	LKI Km 17.53 660 m S of Blyth Rhone Rd	Rural	Week of Sept 20-26, 2016	1,507 Average daily total**
51500P P33-2NS	LKI Km 0.52 N of Rock Creek Cutoff Rd	Rural	2008-2016	1,678 (AADT)***

* Annual Average Daily Traffic (AADT) obtained from Short Count Stations (BC MOTI 2018a).

** Data collected for seven days and then averaged. Data provided by N. Nytepchuk, Traffic Operations Engineer, BC MOTI, October 2018.

*** Annual Average Daily Traffic (AADT) obtained from Permanent Count Stations (BC MOTI 2018a).

Differences in traffic volume and function result in different summer and winter maintenance classifications between the northern and southern portions of Highway 33 (Table 5) (iMapBC 2019 and *pers. comm.* S. Lain, Area Manager, BC MOTI, October 2018). This causes different patrol frequencies (Appendix 2) and debris removal timeframes (Appendix 3), both of which affect carcass detection and removal timeframes.

Table 5. Highway 33 Summer/Winter classification.

BC MOTI District	BC MOTI Service Area	LKI Km	Summer classification	Winter classification
4	9	0.00 to 89.72	3	B
5	8	89.72 to 128.82	1	A

Species of interest

Wildlife vehicle collisions with deer, moose, bear, and elk were selected as the focus of this project. Their large body size has a greater potential to cause personal injury, fatality, and property damage than do collisions with smaller animals resulting in the commensurate possibility of an insurance report to ICBC or attendance by the RCMP or conservation officers. Additionally, the large body size of these animals means that carcasses may be more readily detected by highways maintenance contractors and carcasses may be less easily removed by predators. These reasons facilitate comparison of WVCs among these agencies. Incidental records of WVCs with other species of interest such as eagle, bobcat, wolf, goat, or cow were noted but not included in the analysis.

Vetting WVC data: considerations and constraints

We requested Highway 33 WVC records from January 1, 2008 to December 31, 2017 from all four agencies. Each agency collected and stored data using different methodologies and systems, thus requiring considerable reorganization prior to the comparison, analysis, and integration of the datasets. The data from each agency database was examined and vetted to remove records that:

- contained missing, contradictory, or incorrect location information
- contained highway or segment numbers not included in our project
- did not involve one of the wildlife species of interest or involved a domestic animal
- did not involve an actual vehicle collision with wildlife

Additional agency-specific considerations that influenced the data vetting process are discussed below.

BC MOTI - WARS. Records from WARS were requested from BC MOTI using the following data parameters: highway number and name, LKI segment number and name, and BC MOTI Region, District, and Area. A data extraction was carried out by BC MOTI staff and the WARS records were provided in Excel Workbooks.

The WARS records from September 1, 2015 to December 31, 2017 were missing for BC MOTI District 4, Service Area 9 (LKI Km 0.00 to Km 89.72). Although we intended to use ten years of WVC records to establish agency underreporting rates (as per Hesse and Rea 2016), we limited our calculation

and analyses of underreporting rates to the January 1, 2008 to December 31, 2014 period, during which WVC data was available from all agencies. January 1, 2008 to December 31, 2017 data was used for other analyses.

Errors associated with segment numbers and LKI Kilometres in the WARS data were:

- use of an incorrect segment number (e.g., using Segment 1527 or Segment 1227 instead of Segment 1327, or using Segment 1325 instead of Segment 1324)
- use of a non-existent segment number (e.g., Segment 1119)
- use of a Segment number associated with another highway (e.g., incorrectly associating Segment 2224 with Highway 33 instead of correctly associating it with Highway 3)
- use of a clearly impossible LKI Kilometre (e.g., Km 13276, Km 476.6, or Km 9420)

We included or excluded WARS records with conflicting or invalid highway and segment numbers based on guidelines developed in discussions with the WARS database manager (*pers. comm*. L. Sielecki, Wildlife and Environmental Issues Specialist, BC MOTI, October 2015).

An inherent challenge of using carcass data is that the time and date when the WVC occurred is not known. When removing the carcass, maintenance contractors estimate the time of the WVC based on the time of the last patrol of the highway when the carcass was not present and the condition of the carcass at time of removal. Four general *Time of Kill* choices (dawn, day, dusk, and dark) are provided in WARS.

BC MOTI - CIS (RCMP). The CIS data can be linked to animal collisions via two fields captured from the MV6020 form. The *Type of Collision* field has a code for *Animal* and the *Contributing Factors* field has codes for *Domestic Animal* and for *Wildlife Animal*. The species of animal involved in the collision is not recorded on the MV6020. The CIS (RCMP) WVC records were queried and sorted by LKI segment, highway number, km marker, date, time, severity, contributing factors, and weather and road conditions. A data query was carried out by BC MOTI staff and the CIS (RCMP) records were provided in an Excel Spreadsheet.

Narrative comment fields on the MV6020, which may have included information on species, were not readily available for query in the CIS and, therefore, were not included in the data request.

COS - HWCR. Information about WVCs in the HWCR database is first captured by the ECC operator during the initial call when many types of information are recorded through a series of pre-scripted questions. The *Nature of Complaint* field has pre-set choices for *Wildlife Caused MVA* and *Roadkilled,* but ECC operators may also select *Injured* or *Distressed* or *Dead Wildlife* instead, because that helps conservation officers establish response priorities.

The HWCR was not designed to query for WVCs or to query by highway number. Therefore, to identify all calls in the HWCR database that might refer to WVCs, a query was designed to capture all occurrences under the *Nature of Complaint* field for entries concerning *Roadkilled*, *Injured/Dead/Distressed/Immobile Wildlife*, and *Wildlife Caused MVA* in the COS Southern Interior Region. The data query was carried out by BC MOE staff and results from the HWCR and Human Wildlife Conflicts Ledger were provided in a series of Excel Workbooks.

The broad parameters of the data query meant that each ECC call record was scrutinized to determine if:

- the call actually referred to a WVC (not all injured animals found along the road have been hit by vehicles)
- the call was for a WVC, did it occur on a highway included in our project?
- the call actually referred to a WVC, did it occur on a highway included in this project, and where along the highway did it occur?

The accuracy of any time, date, or location information in the HWCR depends on the caller, who may be reporting a WVC or injured animal with which they were directly involved, one that they witnessed, or one that had been reported to them third hand.

The HWCR was not designed to be a geographically-referenced database, so extracting the location relied on interpretation of information from several drop-down menu and narrative text fields. The HWCR does not have a separate field for highway, road, or segment. Location data is contained in several fields: administrative boundaries (*Region*, *District*, *Area*, *City*); address of the caller; *Occurrence Location* (has the incident occurred at the caller's home address or elsewhere?); and a narrative field for *Location Description*. Information in the *Location Description* field was anecdotal and ranged from detailed entries such as "*Hwy 33 heading towards Rock Creek (EB) at km change marker (from 60 km to 100 km) - at top of hill by truck stop (on shoulder of road)"* to anecdotal entries such as "*on the hwy by the big tree, south bound, at McCullogh Road*." The *Occurrence Notes,* written by the conservation officer, could contain further information on the incident location.

Narrative text in the *Location Description*, *Narrative*, and *Occurrence Notes* fields was examined to confirm that the WVC occurred on Highway 33 and then to determine, to the best extent possible, the specific spot on the highway where the WVC occurred.

ICBC – Corporate Data Warehouse and Enterprise Data Warehouse. All animal-related collision records along Highway 33 were requested using the following query parameters: date, year, month, incident identification number, vehicles, time category (recorded in three hour increments e.g., 15:01 – 18:00), number of injured victims, severity, road location, location description, incident description, street name, cross street name, latitude, longitude, direction of travel, city, and day of week. ICBC staff conducted the data query and provided the data in an Excel Workbook.

There were two areas of concern in capturing WVCs along a specific highway from the ICBC data. First, the S*treet Name* field where one would expect to find the name of the road or highway upon which the vehicle was travelling when the collision occurred is not always filled out, and second, it is difficult for the public to identify the specific point along a highway where the WVC occurred due to the lack of cross streets or landmarks recognizable to the general public.

The public may describe WVC locations in various ways. In order to capture all WVC locations provided in the *Incident Description* and *Location Description* fields, a list of geographic reference points and other recognizable names or features along the highway – that had been used by members of the public while reporting WVC incidents to the ECC – was developed from the narrative text descriptions provided in the HWCR. This list was provided to ICBC for inclusion in the data query. For example, some common reference points along Highway 33 that were used by callers reporting WVCs to the ECC included Westbridge, Beaverdell, Big White Road, Heartland Ranch, Joe Rich, or Function Junction, and these names were used to supplement the ICBC query.

The latitude and longitude coordinates associated with WVCs in the ICBC data were not provided by the caller. Rather, they were assigned by ICBC, based on the cross street name, so, in the absence of data in the *Cross Street Name* field (as was common in this query), the latitude and longitude fields were returned blank.

When the query results were received, the road location, location description, incident description, street name, cross street name, latitude, and longitude fields for each record were examined and locations that could not be established to have occurred on Highway 33 were excluded. For the remaining records, information in these fields was used to establish, as closely as possible, the specific location along the highway where the WVC occurred.

The ICBC reporting procedures did not include a separate field for species, so text in the *Incident Description* field was examined to ascertain the species and numbers of animals that were involved in the collision. Collisions with domestic animals were not differentiated from crashes with wild animals; therefore, records where domestic animals were referenced in the *Incident Description* field were excluded. Collisions involving non-target wildlife species were also excluded.

Integrating agency WVC datasets

The vetted WVC records from each agency were integrated into a union dataset, constructed in a calendar format from January 1, 2008 to December 31, 2017. For each agency, the number of WVC records was tallied and totalled for each month, year, and for the ten-year period.

Each discrete WVC record was examined to identify commonalties in date, time, location, species, numbers of animals, numbers of vehicles, road surface, weather, and collision severity that could match it with WVC records from another agency. The patrol frequency (Appendix 2) and debris removal timeframes (Appendix 3) were considered when determining whether a WVC reported in WARS was a match for a collision recorded by another agency.

Difficulties in matching WVC records from different agencies were primarily connected with the date, time, and location of the collision. As noted by Lao et al. (2012),

> *"Generally, collision data are reported on the same day when an AVC [animal vehicle collision] occurs; however, the carcasses are picked up by the WSDOT [Washington Department of Transportation] maintenance staff depending on when the carcass is found. Theoretically, the carcass pickup day should be the same as the day when the AVC is reported. In reality; however, a perfect match between two data sets rarely happens. The record of the same event typically looks different in time and/or location in each dataset."*

Following the protocols developed in Hesse and Rea (2016) and similar projects (Young and Vokurka 2007, Huijser et al. 2008a, Lao et al. 2012, Zink 2014), we used the following guidelines to establish proximity limits on WVC locations and temporal limits on estimated collision times in order to establish or exclude matches between agency WVC records.

- WVC locations recorded as LKI distances in WARS and CIS (RCMP) could vary by up to four kilometres and still refer to the same collision.

- if location data matched, WARS dates could vary from other agency collision dates due to highway patrol frequency and maximum debris removal time frames (Appendices 2 and 3) which were applied to each situation.
- WVC times (COS, CIS (RCMP), and ICBC) could vary by up to one hour and still be considered as the same incident.
- when ICBC or COS location information was insufficient, the WVC location was based on the best possible interpretation of the narrative comments.

These guidelines offered some flexibility in the integration of the four disparate datasets while still providing a conservative estimate of underreporting.

Using these guidelines, we classified each WVC record as having been reported by all four agencies, three of the four agencies, two of the four agencies, or only one agency. The WVCs that we confirmed as a match with other agencies were recorded in the union dataset as one incident, rather than as individual incidents.

Each WVC was further classified by species of animal involved. The number of WVCs in all these classifications was tallied and totalled by agency, month, year, and ten-year period.

We encountered three situations when it was not possible to determine whether individual agency WVC records that occurred on the same day referred to the same incident or not.

1. WARS data included some WVC records where the WVC was recorded in a specific month but the date of the collision was shown as zero or as 31 in a month when there were not 31 days. These data were included in the individual agency WVC totals, because a WVC had indeed occurred in that month, but were not used for comparison among agencies because the date could not be determined.
2. Some WVCS were recorded by an agency on one date and a WARS record showed that a carcass was removed on a date within several (later) days of the first date. The location information was insufficient to establish whether or not the records referred to the same incident. The date of carcass removal occurred during the contractual timeframes established for highway patrol frequencies and debris pickup. In this situation, the WVC could have occurred on one date and the WARS record could show another date and both records would be referencing the same incident.
3. Some WVCS were recorded as occurring on the same date and similar time by two or more agencies, but the location information was insufficient to establish that the records referred to the same incident.

The number of times these three situations occurred were also tallied and totalled by month, year, and ten-year period.

Baseline number of WVCs (*Bt*WVCs) calculation

The baseline total number of WVCs (*Bt*WVCs) in the union dataset was calculated by combining the total number of WVCs recorded by four agencies, three of four agencies, two of four agencies, only one agency, and the number of incidents described in points (2) and (3) above (i.e., WVCs were reported on different dates but WARS debris removal guidelines were within an allowable timeframe, and, WVCs were reported on the same date by two or more agencies but location information was insufficient for a match). The percentage of WVCs recorded by multiple agencies and by a single agency was calculated.

For each of the four agency databases, the total number of discrete WVCs recorded from January 1, 2008 to December 31, 2014 was compared to the *Bt*WVCs to determine the percentage of WVCs reported by each agency.

Proportion testing, by agency

We examined the difference between agency WVC reporting rates by calculating the proportion of WVCs recorded by each agency and testing for significance ($p \leq 0.05$) using the Z-test for proportions (Zar 1984).

WVCs, by species and by multi-animal collision

From January 1, 2008 to December 31, 2014, we aggregated the numbers of animals killed in WVCs, by species. We investigated whether more than one animal was involved in WVCs, how often that occurred, and aggregated the numbers and species of animals killed in collisions that involved more than one animal.

WVCs, by year and month

To show annual trends and monthly trends in WVCs, we aggregated discrete WVCs for all species, reported by all agencies, from January 1, 2008 to December 31, 2014, by year and by month.

WARS WVCs, by BC MOTI District, by year, and per kilometre

To show annual trends in WVCs by BC MOTI District, we aggregated WARS WVCs for all species from January 1, 2008 to December 31, 2017. We used WARS WVCs from January 1, 2008 to December 31, 2014 to obtain an average number of WARS WVCs per year and per kilometre in each BC MOTI District.

WARS WVCs, all species, by LKI Kilometre

We plotted the number of WARS WVCs of all species along the range of LKI Kilometres to provide a simple visual method to show where WVCs were occurring along Highway 33. We did not perform any model-based, density-based, or spatially-based analyses of WVC locations as a WVC hotspot analysis was outside the scope of this project.

WARS moose and elk collisions

We reviewed WARS WVC data for moose and elk collisions to provide the numbers of collisions for each species, the year that the collisions happened, and the LKI Km where the collision occurred.

RESULTS

WVCs, by agency

We examined 7,049 WVC records from carcass counts, human-wildlife conflict reports, RCMP-attended collision reports, and insurance collision reports (Table 6).

Table 6. Number of raw WVC records from each agency, from January 1, 2008 to December 31, 2017.

BC MOTI WARS	COS HWCR	BC MOTI CIS	ICBC Business Information Warehouse	Total
Carcass count	Human wildlife complaint	RCMP MV6020 report	Collision report	
1,321	3,734	52	1,942	7,049

After omitting records from January 1, 2015 to December 31, 2017 (due to missing WARS data), we aggregated the vetted WVCs for the seven-year period from January 1, 2008 to December 31, 2014, by agency, for a total of 2,224 discrete WVC records. WARS recorded the largest number of WVCs (1,133), followed by ICBC (993), COS (64), and CIS (RCMP) (34).

Using our established guidelines to determine commonalities of time, date, location, and species among WVC records, each discrete agency WVC record was classified as having been reported by all four agencies, three of four agencies, two of four agencies, or only one agency. This process integrated four agency datasets containing 2,224 discrete WVC records into a union dataset containing 2,055 *Bt*WVC records (Figure 4).

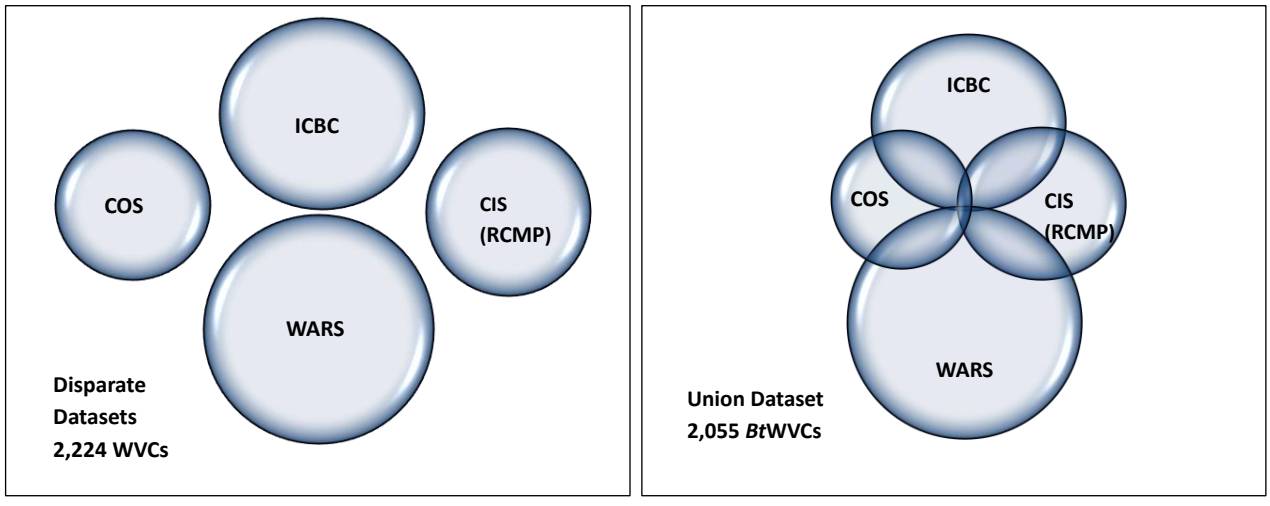

Figure 4. Combining four disparate datasets (*n*=2,224) into one union dataset (*n*=2,055).

Out of 2,055 *Bt*WVCs, 1,893 (92.0%) were recorded by only one agency, 84 (4.15%) were recorded by two out of four agencies, one (0.05%) was recorded by three out of four agencies, and zero WVCs were recorded by all four agencies (Table 7). The WVC records that were determined to be a match between agencies were counted as a single incident.

In WARS, there were five records when the day of WVC occurrence was unable to be determined (recorded as: Date=April 31, 2009 (non-existent); Date=0; or Date=unknown). These incidents were tallied, but were excluded from the *Bt*WVCs because it was not possible to determine if these incidents had occurred on the same date as other incidents, and their inclusion may have introduced duplicate incidents into the *Bt*WVCs.

Seventy-three WVCs were reported in WARS, and by at least one other agency, within a timeframe whereby it could have been the same incident if the carcass was retrieved within the debris removal timeframe. Four WVCs were reported by two or more agencies on the same day but with insufficient location or time-of-occurrence information to determine whether they were the same incident. Each occurrence of these two types was counted as one incident and included in the *Bt*WVCs because it was certain that at least one WVC had occurred on that date.

Table 7. Number and percentage of WVCs recorded by multiple agencies or individually from January 1, 2008 to December 31, 2014.

	# matching WVCs recorded													# discrete WVCs recorded					# possible matching WVCs			
	By 4 agencies	By 3 agencies					By 2 agencies							By 1 agency					By WARS date=0*	By WARS + 1 agency** (e)	By 2 agencies*** (f)	Baseline total WVCs (*Bt*WVCs) (a+b+c+d+e+f)
	WARS COS RCMP ICBC (a)	WARS COS RCMP	WARS RCMP ICBC	WARS COS ICBC	COS RCMP ICBC	Total (b)	WARS COS	WARS RCMP	WARS ICBC	COS RCMP	COS ICBC	RCMP ICBC	Total (c)	WARS	COS	RCMP	ICBC	Total (d)				
n	**0**	0	1	0	0	**1**	7	3	61	2	10	1	**84**	973	44	23	853	**1893**	5	73	4	**2,055**
%	**0.0**		0.05			**0.05**	0.3	0.2	3.0	0.1	0.5	0.05	**4.15**	47.3	2.1	1.1	41.5	**92.0**		3.6	0.2	**100.0**

* WARS date was recorded as non-existent, zero, or unknown. Not included in *Bt*WVCs.

** Time between the two incidents is within allowable debris removal timeframe. These agency records may, or may not, be referring to the same WVC. Included in *Bt*WVCs.

*** Two incidents were recorded on the same date, but the location or time of day information is insufficient to determine if they are the same incident. Included in *Bt*WVCs.

Proportion testing, by agency

The total number of discrete WVCs recorded by each agency was expressed as a percentage of the *Bt*WVCs (Table 8). WARS captured just over half (50.9%) of the *Bt*WVCs. ICBC captured 44.6% of the *Bt*WVCs, the Conservation Officer Service received ECC calls for 2.9% of the *Bt*WVCs, and the RCMP attended 1.5% of the B*t*WVCs.

Table 8. Percentage of *Bt*WVCs (*n*=2,055) by agency, from January 1, 2008 to December 31, 2014.

% of *Bt*WVCs, by agency			
WARS	**COS**	**CIS (RCMP)**	**ICBC**
50.9	2.9	1.5	44.6

The proportions of *Bt*WVCs captured by each agency were all significantly different from each other (Table 9). WARS captured significantly more WVCs (50.9%) than either ICBC (44.6%: $\hat{p} = 0.517$, $z = -4.370$, $p \leq 0.001$), COS (2.9%: $\hat{p} = 0.291$, $z = -36.701$, $p \leq 0.0010$), or CIS (RCMP) (1.5%: $\hat{p} = 0.284$, $z = -38.018$, $p \leq 0.001$).

Table 9. Number of discrete WVCs, by agency, from January 1, 2008 to December 31, 2014, showing Z-test for proportions significance (bold font indicates a significant result).

Agency	# WVCs captured by agency	$\hat{p}$	Z	p
COS	64	0.291	-36.701	**<0.001**
WARS	1133			
CIS (RCMP)	34	0.284	-38.018	**<0.001**
WARS	1133			
ICBC	993	0.517	-4.370	**<0.001**
WARS	1133			
CIS (RCMP)	34	0.024	-3.067	**<0.001**
COS	64			
COS	64	0.257	-33.154	**<0.001**
ICBC	994			
CIS (RCMP)	34	0.250	-34.552	**<0.001**
ICBC	993			

Underreporting

The percentage of underreported WVCs is obtained by subtracting the percentage of reported WVCs from the baseline total number of WVCs, and can be mathematically expressed as

% underreported WVCs = 100% BtWVCs – % reported WVCs

WARS did not capture 49.1% of *Bt*WVCs, 55.4% of *Bt*WVCs were not reported to ICBC, the RCMP did not attend 98.5% of *Bt*WVCs, and the COS did not receive calls about 97.1% of *Bt*WVCs (Table 10).

Table 10. Underreporting of *Bt*WVCs (*n*=2,055) by agency, from January 1, 2008 to December 31, 2014.

	WARS	COS	CIS (RCMP)	ICBC
Reporting rate (% *Bt*WVCs reported)	50.9	2.9	1.5	44.6
Underreporting rate (% *Bt*WVCs not reported)	49.1	97.1	98.5	55.4
	100	100	100	100

WVCs, by species, all agencies, type of collision

From January 1, 2008 to December 31, 2014, there were 2,060 WVCs (2,055 *Bt*WVCs + 5 WARS records with incorrect date) involving 2,077 animals. The majority of WVCs (2,045) involved only one animal; however, 13 WVCs involved two deer, one WVC involved two elk, and one WVC involved four deer. Of the 2,077 animals involved in WVCs, 1,975 (95.1%) were deer, 33 (1.6%) were moose, 12 (0.6%) were elk, 11 (0.5%) were bear, and 46 (2.2%) were unidentified (Table 11).

Table 11. Number and percentage of animals involved in WVCs, by species and type of collision, from January 1, 2008 to December 31, 2014.

Type of Collision	Species					Total animals
	Deer	Moose	Bear	Elk	Unidentified	
Single animal	1945	33	11	10	46	2045
Two animals	26	0	0	2	0	28
Four animals	4	0	0	0	0	4
Total	**1975**	**33**	**11**	**12**	**46**	**2077**
% of total	95.1	1.6	0.5	0.6	2.2	

WVCS, all species, all agencies, by year

For discrete WVCs (all species, all agencies, by year), a line of best fit (Figure 5) indicates a slight decrease in WVC numbers between 2008 and 2014. There was, however, a pronounced peak in WVCs in 2011 (Figure 5).

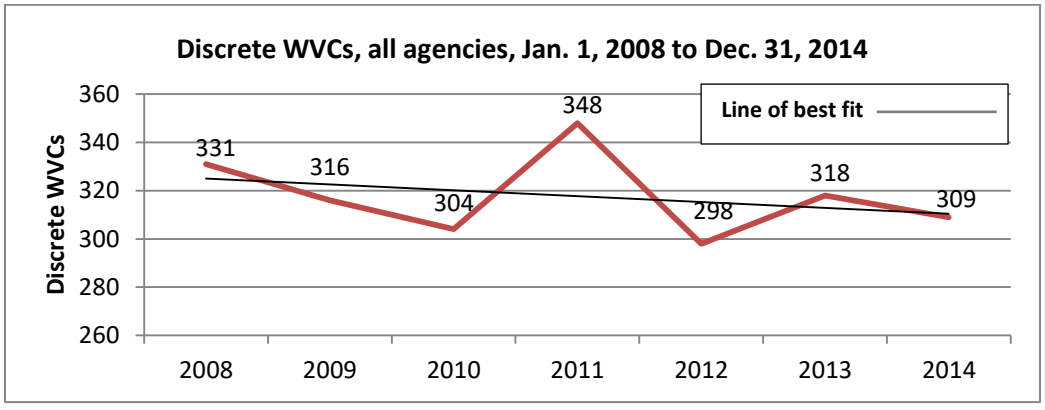

Figure 5. Number of discrete WVCs of all species (*n*=2,224), for all agencies, by year, from January 1, 2008 to December 31, 2014.

WVCs, all species, all agencies, by month

Monthly trends for discrete WVCs involving all species, for all agencies, showed a strong peak in April (spring) and a smaller peak in October (fall) (Table 12 and Figure 6).

Table 12. Number of discrete WVCs of all species, by agency, by month, from January 1, 2008 to December 31, 2014.

	WARS	COS	CIS (RCMP)	ICBC	Total
January	77	9	2	65	153
February	90	2	0	45	137
March	138	8	4	97	247
April	200	5	2	128	335
May	136	4	4	112	256
June	74	2	8	98	182
July	48	4	2	71	125
August	25	7	5	54	91
September	57	8	0	61	126
October	102	3	3	92	200
November	100	3	2	85	190
December	86	9	2	85	182
Total	**1,133**	**64**	**34**	**993**	**2,224**

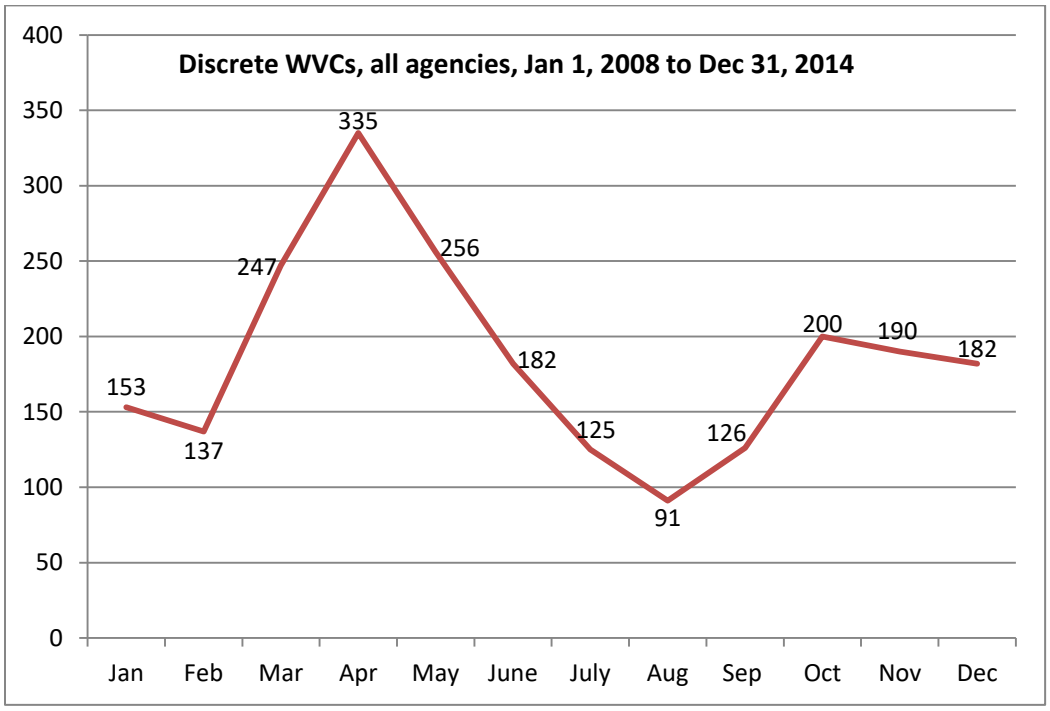

Figure 6. Number of discrete WVCs of all species (*n*=2,224), for all agencies, by month, from January 1, 2008 to December 31, 2014.

WARS WVCs, all species, by BC MOTI District, by year, and per kilometre

The majority of WARS WVCs (80.0%) were located in BC MOTI District 4, from Rock Creek to McCulloch Road (LKI Km 0.00 to Km 89.72) (Table 13 and Figure 7).

Table 13. Number of WVC records (all species) from WARS, by BC MOTI District, by year, from January 1, 2008 to December 31, 2014.

	BC MOTI District 4 LKI Km 0.00 to 89.72	BC MOTI District 5 LKI Km 89.72 to 128.82	Highway 33 LKI Km 0.00 to 128.82
	Number of WVCs	Number of WVCs	Total WVCs
2008	125	26	151
2009	116	39	155
2010	121	34	155
2011	144	35	179
2012	140	25	165
2013	124	50	174
2014	138	18	156
Total	**908**	**227**	**1135**
% of total	**80.0**	**20.0**	**100**

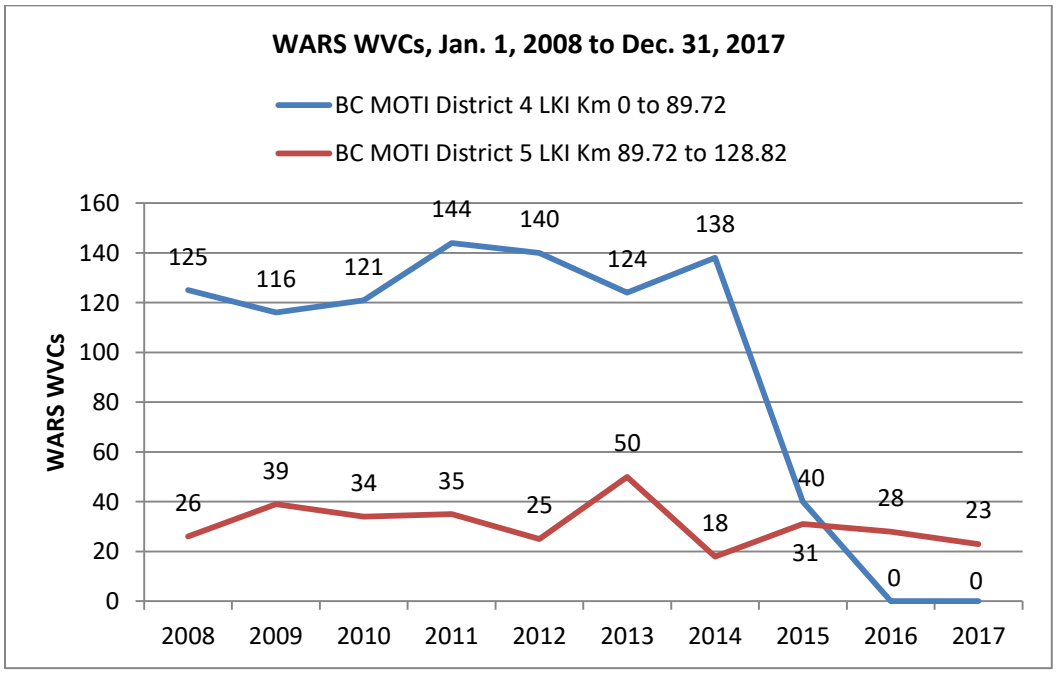

Figure 7. Number of WVC records (all species) from WARS, by BC MOTI District, from January 1, 2008 to December 31, 2017**.**

Note: The sharp decline in BC MOTI District 4 WVC numbers after 2014 results from missing WARS information after August 2015 and does not represent an actual decline in WVCs.

There was a mean of 129.7 WVCs/year in BC MOTI District 4, 32.4 WVCs/year in BC MOTI District 5, and 162.1 WVCs/year along the total length of Highway 33 (Table 14). Using the length of Highway 33 in each BC MOTI District, there was a mean of 1.45 WVCs/km/year in BC MOTI District 4 and 0.83 WVCs/km/year in BC MOTI District 5, with a mean of 1.26 WVCs/km/year along the total length of Highway 33 (Table 14).

Table 14. Mean number of WVC records (all species) from WARS per year and per kilometre per year, from January 1, 2008 to December 31, 2014.

	BC MOTI District 4 (89.72 km)	**BC MOTI District 5 (39.1 km)**	**Highway 33 (128.82 km)**
Total WARS WVCs	908	227	1135
Mean WARS WVCs/year	129.7	32.4	162.1
Mean WARS WVCs/km/year	1.45	0.83	1.26

WARS WVCs, all species, by LKI Kilometre

A simple distribution of WARS WVCs (all species) by LKI Km from January 1, 2008 to December 31, 2017 (Figure 8), shows the highest numbers of WVCs were located (from south to north) between LKI Km 4 and Km 5 (28 WVCs), between LKI Km 45 and KM 46 (39 WVCs), between LKI Km 52 and Km 53 (32 WVCs), and between LKI Km 118 and Km 119 (27 WVCs). Between LKI Km 15 and Km 44, WVCs ranged from 11 to 20. Lowest numbers of WVCs were located between LKI Km 69 and Km 102, where WVCs ranged from zero to seven.

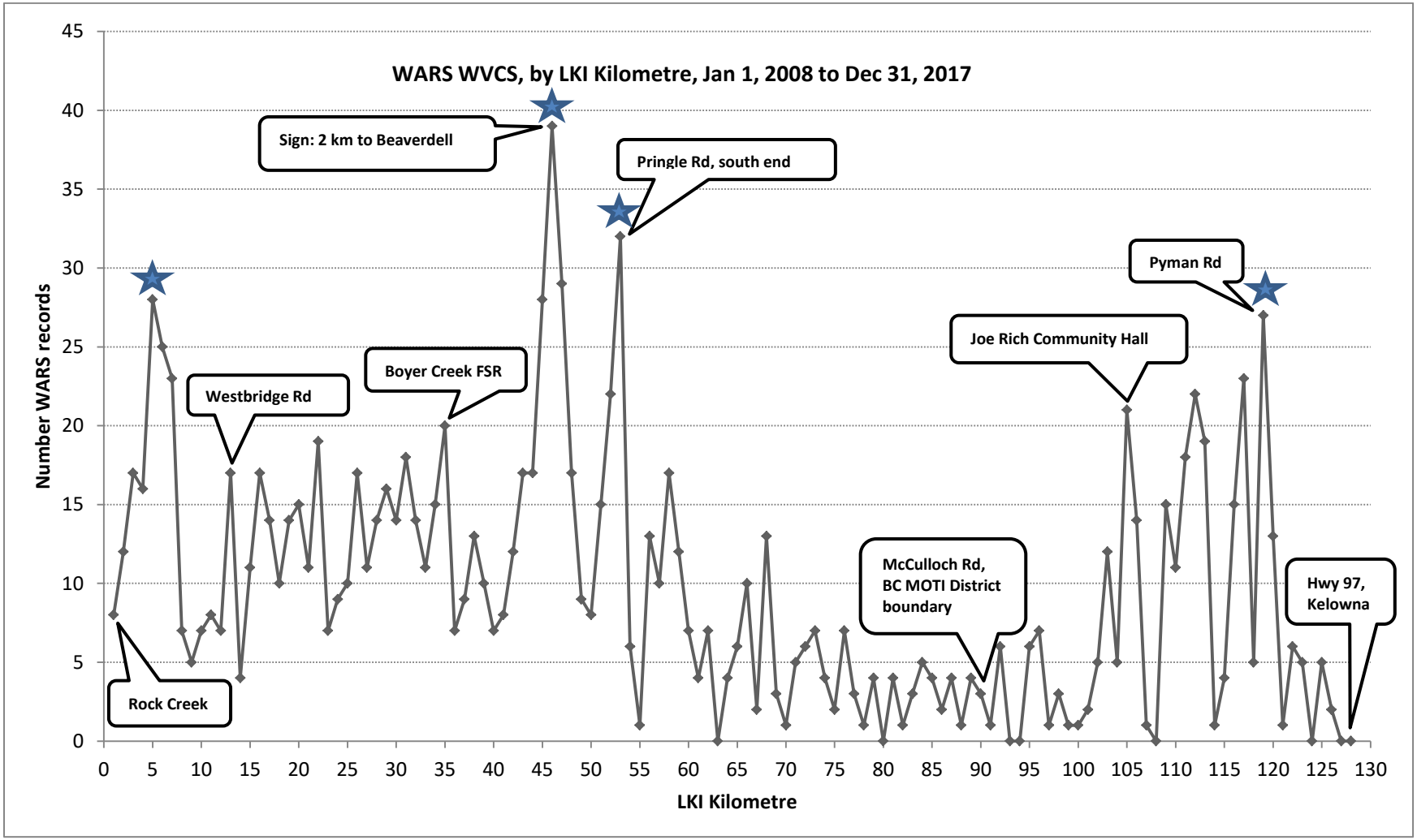

Figure 8. Distribution and numbers of WVC records (all species) from WARS, by LKI Kilometre, from January 1, 2008 to December 31, 2017. Locations indicate nearby recognizable landmarks. Stars indicate the four highest numbers of WVCs**.**

WARS moose and elk collision locations, numbers, and year of collision

From January 1, 2008 to December 31, 2017, there were 16 moose vehicle collisions (Table 15) and seven elk collisions (Table 16) recorded in WARS.

Table 15. Location, number, and year of moose collisions in WARS, from January 1, 2008 to December 31, 2017.

LKI Km	Nearby recognizable LKI Landmark	# moose collisions	Collision year
10.24	Zamora Road	1	2010
32	Sign: 90 km/hr	1	2012
37	Peanut Point Pit access	1	2012
37.5	Peanut Point Pit access	1	2012
40	Top of China Hill	1	2013
44	Driveway 5480	1	2014
57.5	Wilkinson Creek Bridge, south end	1	2014
68	North of Trapping Pit gate	1	2009
70	South of Arlington Lake FSR	1	2008
72.5	North of Arlington Lake FSR	2	2010 and 2011
75.5	McDonald Pit	2	2012 and 2013
86	North of Kallis Creek Pit	1	2013
88.87	South of McCulloch Road	1	2013
94.2	Brake Check Pullout, north end	1	2012
		16	

Table 16. Location, number, and year of elk collisions in WARS, from January 1, 2008 to December 31, 2017.

LKI Km	Nearby recognizable LKI landmark	# elk collisions	Collision year
4.06	Rock Creek Ranch	1	2012
4.5	Sign: BC Parks Kettle River 2 km	1	2008
4.71	Sign: BC Parks Kettle River 2 km	1	2010
8.75	James Lake Road	1	2009
101	Schram Road	1	2013
112.2	Goshawk Road	1	2015
115	Heartland Lodge	1	2015
		7	

DISCUSSION

WVC data and integrating datasets

Other researchers have compared WVC data from more than one dataset or agency to obtain the most complete set of WVC records. These combined datasets have been used to improve hotspot location accuracy, to monitor WVC mitigation efforts, and to improve predictive modelling.

Several studies have compared the locations of carcass count data with police or natural resource agency data, tried to derive "truer" locations of hot spots, or made observations about the "true" counts of WVCs (Clevenger et al. 2003, Gunson et al. 2009). Citizen-science WVC records have been compared and combined with carcass count datasets (Lee et al. 2006, Paul et al. 2014, Schilling 2014, Schilling and Waetjen 2015). Young and Vokura (2007) and Normandeau (2012) compared carcass counts and crash records before and after roadside projects to monitor impacts on WVC reduction. Various computer and manual methods of combining carcass and crash data have been used to identify WVC crash trends and hotspot locations (Baird 2010, Lao et al. 2011, Zink 2014) and to analyze differences in magnitude, locational patterns, and hotspot identification in different WVC records and datasets (Knapp et al. 2007, Yang et al. 2019, Zou et al. 2019). Lao et al. (2012) used fuzzy logic algorithms to compare and integrate carcass and crash data sets to improve the completeness of the datasets used for hotspot location modelling.

Notwithstanding our previous underreporting work on northern highways (Hesse and Rea 2016), this is still the only project we are aware of that integrates roadside human-wildlife conflict reports with carcass count records, police-attended WVC records, and insurance collision reports. The addition of the HWCR WVC records to the union dataset highlighted that the COS *Occurrence Notes* seldom include whether the carcass has been removed by the COS or that the maintenance contractor has been notified about carcasses that require removal. Further, incidents where the animal survived the collision are most easily captured in this dataset. For example, callers to ECC will report, "*I hit a fawn deer, but it ran away from the road. Unsure if it survived."*

A significant difficulty encountered in integrating HWCR data into the union dataset was our inability to confidently sort and filter WVC-related crashes in the HWCR database. Inconsistencies in the classification of WVC-related calls meant that ECC records had to be carefully screened to determine if the call record should be included.

The major difficulty encountered in the integration of the datasets was that any narrative-style location information resulted in considerable ambiguity and subjectivity in determining whether a specific record from one agency was referring to the same incident as the record from another agency. Geo-referencing of collision locations on rural roads continues to be difficult for ICBC (Brubacher et al. 2018). Location information provided by callers to ECC has also been inexact but, because one of the goals of the ECC operators is to obtain sufficient information so that a conservation officer could attend the scene, greater attempts are made to determine more accurate location descriptions from the caller. Matching LKI locations with incomplete narrative location information and the determination of time of collision associated with carcass removal data all proved problematic.

Defining Underreporting

Integrating disparate datasets from four different databases produced a union dataset containing 100% of the known WVCs that occurred on Highway 33. This union dataset (the baseline number of WVCs: *Bt*WVCs) is the best estimate of an accurate count of WVCs that can be achieved with the available data. Our estimates of underreporting are based on the number of WVCs not captured by each agency relative to this "known" baseline number of WVCs. However, there still remains an "unknown" number of WVCs that occur but are not captured by any of the agencies. British Columbia, and presumably all other jurisdictions, has no way to estimate this "known unknown" (Rumsfeld 2002) quantity. It is not possible to capture and record each and every incident between wildlife and vehicles, which would be the "absolute" number of WVCs.

Factors contributing to underreporting

Carcass data. Reasons for underreporting of carcass count data and specific data collection biases have been discussed by Sielecki (2010) for BC, and elsewhere by Conover et al. (1995), Romin and Bissonette (1996), Huijser et al. (2007), Lao et al. (2011), Boves and Belthoff (2012), Vanlaar et al. (2012), Snow et al. (2015), and Winton et al. (2019). These include, but are not limited to:

- animals are hit and injured by vehicles, but move away from the road and die outside the highway right-of-way (crippling bias)
- carcasses are removed by predation or scavenging (animal scavenger bias)
- carcasses are removed by passing motorists (general public scavenger bias)
- carcasses are removed by other agencies or permit holders (in BC: conservation officers, RCMP, or registered trappers) (agency scavenger bias)
- carcasses are concealed by snow, ice, vegetation, or roadside debris (search bias)
- carcasses are obliterated during the collision (search bias)
- errors, omissions, or changes in data reporting and/or processing
- lengthy time intervals between carcass collection activities
- carcass is not a species of concern (Olson et al. 2014)

Taking into account these biasing factors, Huijser and Begley (2016) state that *"… even carcass removal data should be regarded as a minimum count rather than an absolute count of the number of large animal-vehicle collisions that occur.*"

Police-reported or insurance claim-reported data. Reasons for underreporting of WVCs, either by the police or insurance companies, have been discussed by Sielecki (2010) for BC, and elsewhere by Romin and Bissonette (1996), Huijser et al. (2007), Rowden et al. (2008), Marcoux and Riley (2010), Lao et al. (2011), Sullivan (2011), Vanlaar et al. (2012), Tay et al. (2014), Snow et al. (2015), and Creech et al. (2019). On Highway 33, WVCs may be missing from either or both ICBC or CIS (RCMP) databases because:

Missing from ICBC Corporate Data Warehouse and Enterprise Data Warehouse

- not all WVCs are reported to ICBC (insufficient property damage; WVCs reported to other insurance agencies in BC; damaged vehicles belong to a fleet and repairs are carried out privately; WVC involved out-of-province vehicles; motorists reluctant to report WVC for unknown reasons)

Missing from CIS (RCMP) (as derived from MV 6020)

- not all WVCs are attended by RCMP (and less so after 2008) therefore an MV 6020 is not produced
- RCMP may be called to attend the scene of a WVC, or happen upon the scene as part of a routine patrol, but the vehicle involved has left the scene, therefore an MV 6020 is not produced
- RCMP may attend a WVC, but the attending officer decides that the collision does not merit reporting (i.e., insignificant property damage and no injuries)

Human wildlife conflict data. Reasons for underreporting of human-wildlife conflicts involving WVCs or dead, injured, or distressed wildlife on the road include:

- voluntary nature of call-in reports has an innate selection bias towards incidents which the public considers significant enough to report (Zink 2014)
- although there is a legislated requirement to report the accidental killing of wildlife (*Wildlife Act* Sec 75 (1)), this is seldom enforced with respect to WVC reporting
- inaccessibility or difficult terrain may preclude contact with authorities at the time that a WVC is detected (Goswami et al. 2015) and the incident may subsequently be forgotten or dismissed as unimportant
- public may be unaware of human-conflict reporting opportunities (e.g. Report All Poachers and Polluters hotline in BC: call goes to the ECC) for reporting injured or distressed wildlife or other human-wildlife conflict
- public may assume that others will report the WVC
- public may perceive that the animal or species is not of concern (Olson et al. 2014)
- encounters with or injured, distressed, or dead wildlife due to WVCs are opportunistic (2007), not systematic
- animal at the scene of a WVC is dead, so conservation officer is not required
- animal was hit, but not killed, in the WVC and left the area

Underreporting by agency

RCMP. In 2008, RCMP collision reporting in BC changed when the *Motor Vehicle Act* was amended, requiring RCMP to report police-attended collisions to ICBC. The provincial government and all BC police agencies arrived at an understanding that police attendance at "minor" collisions (loosely defined as collisions with no serious human injuries and where the vehicle is still driveable) was contingent upon manpower availability, staffing constraints, and operational consideration (*pers. comm*. Sgt. A.D. Steinhauser, North District – NCO Operations, Regional Provincial Traffic Services, RCMP, January 2016). This policy change broadly reduced RCMP attendance at WVCs, as the RCMP exercised their discretion whether or not to attend. This change also impacts the number of WVCs recorded in CIS (RCMP), and, therefore, affects the total number of WVCs that are known to occur.

RCMP and WARS. WARS and CIS (RCMP) datasets can be easily integrated because both locate WVCs by LKI landmark. However, on Highway 33, CIS (RCMP) and WARS records appear to have little overlap as only three WVCs were recorded by both agencies (Table 17). This indicates that there are

WVCs attended by the RCMP where there is either no carcass or no WARS record is submitted by the maintenance contractor. The goal of integration is to improve the size and robustness of the combined dataset. However, due to the small number of CIS (RCMP) records (*n*=34), integration only improved the WARS and CIS (RCMP) *Bt*WVC subset by 2.7% (Table 17). This differs from Hesse and Rea (2016), who found that combining WARS and CIS (RCMP) data from northern highways improved the union dataset by 27.5%. Despite only a slight increase (from 1,133 WARS records to 1,164 combined WVC records), highway managers should still consider integrating police-reported data with carcass removal data to build a more robust dataset that can be used in WVC mitigation planning, as each dataset has different and valuable attributes (Lao et al. 2012).

Table 17. Integration of WARS and CIS (RCMP) WVC data, January 1, 2008 to December 31, 2014.

# Discrete WVCs			# of matched WVCs (d)	*Bt*WVCs (e=c-d)	% improvement (change) in size of the integrated dataset (e-a)/(a)(100)
WARS (a)	CIS (RCMP) (b)	Total (c)			
1,133	34	1,167	3	1,164	2.7

ICBC and WARS. Our results showed that WARS captured significantly more WVCS (50.9%) than ICBC (44.6%). This differed from results on BC's northern highways where ICBC captured significantly more WVCs (45.5%) than WARS (34.3%) (Hesse and Rea 2016) and more closely resembles the situation in some US jurisdictions where carcass count records exceed police-reported WVCs (Donaldson and Lafon 2010, Lao et al. 2012, Donaldson 2017).

ICBC. The ICBC WVC reporting rate of 44.6% of the known number of WVCs, established in our results, is below ICBC's estimate (as reported in Sielecki 2010) of capturing approximately 75% of WVCs. A possible explanation for this might be the high incidence of deer vehicle collisions. Vehicle collisions with deer comprise 95.1% of WVCs along Highway 33, with 1.6% of WVCs involving moose. This contrasts with WVCs on northern highways, where 50.9% of WVCs involve deer and 34.6% involve moose (Hesse and Rea 2016). Although deer vehicle collisions can have serious repercussions in terms of human death and injury, vehicle damage, and animal mortality and injury, moose vehicle collisions present a more significant risk of severe outcomes and have much higher associated economic costs (Huijser et al. 2009). Because deer comprise the vast majority of the collisions along Highway 33, it may be possible that fewer of these collisions are reported to ICBC (compared to reporting of WVCs on northern highways) because less damage is incurred in deer vehicle collision than in moose vehicle collisions. Particularly for highways where deer comprise the majority of WVCs, ICBC may need to adjust its previous estimates of the percent of WVCs involving vehicles where no claim is made, vehicles from out-of-province, or vehicle insured with other agencies.

WARS. Highway 33 compared with northern highways. Various scenarios might explain why WARS captured more WVCs on Highway 33 (50.9%) than on the northern highways (34.3%) studied by Hesse and Rea (2016). The northern portion of Highway 33 (LKI Km 89.72 to Km 128.82), within BC MOTI

District 5, Service Area 8, and maintained by Argo Road Maintenance (South Okanagan) Inc., has a different summer and winter classification (1A) than all of the northern highways (3B), with subsequent increased highway patrol frequency and tighter timeframes for debris removal (Appendices 1, 2, 3 and Table 5). This results in less time for carcasses to be scavenged, or removed by any source other than the maintenance contractor, and, therefore, makes it more likely that the carcasses will be picked up by the maintenance contractor.

An unknown number of road-killed carcasses are removed by animal scavengers of all sizes, including grizzly bears. However, grizzly bears have been extirpated in the Kettle-Granby Grizzly Bear Population Unit (BC MOE and BC FLNRO 2017) which is traversed by Highway 33. It is possible that fewer carcasses scavenged by grizzly bears means there are more carcasses available to be picked up by maintenance contractors.

Removal of road-killed carcasses by conservation officers for carnivore baiting programs or meat-list distribution is seldom recorded in the COS *Occurrence Notes* or *Incident Narrative* for WVCs occurring on Highway 33, whereas a small but constant number of carcasses were removed by COS on northern highways (Hesse and Rea 2016). More carcasses that are not removed by the COS means more carcasses are available to be retrieved by maintenance contractor.

There are higher traffic volumes on Highway 33 than most of the northern highways in the Hesse and Rea (2016) project. More traffic means that people who wish to remove a road-killed carcass (which is illegal without a permit) without being noticed by other motorists have fewer opportunities to do so. Higher traffic volumes make the road and shoulder feel more unsafe, further discouraging people who may wish to stop and remove a road-killed carcass. Also, more traffic could mean that there are more people willing to report a carcass. Again, more carcasses reported or left on the road for pickup by the maintenance contractor increases the number of WARS records.

Registered trappers are allowed to pick up and use certain road-killed wildlife species as bait and must report such use monthly (BC FLNRO 2020). It is possible that there are fewer active trappers removing carcasses from Highway 33 than those removing carcasses from northern highways. Highway 33 traverses approximately six registered trap lines, but it is unknown how many of these are currently in use. From 2004 to 2010, 66 trapper-removed road-killed carcasses were reported in Region 8 (Okanagan) compared to 226 carcasses in Region 7 (Omineca Peace), 169 carcasses in Region 4 (Kootenay), and 53 carcasses in Region 5 (Cariboo) (unpublished data, M. Badry, BC FLNRO, 2010).

It was outside the scope of this project to compare maintenance contractor performance either along Highway 33 between Service Area 8 and Service Area 9, or with northern maintenance contractors. That said, Service Agreement standards regarding WARS reporting are consistent throughout BC and maintenance contractors are contractually obligated to record and report all wildlife carcasses that they remove from numbered highways. Maintenance contractors are subject to audit from BC MOTI regarding their carcass removal response times and other aspects of WARS reporting. This should provide consistency in maintenance contractor performance throughout the province.

WARS. Fate of the animal. The fate of the animal directly affects underreporting in WARS. For animals that are still alive but recorded by either COS or ICBC as having left the scene, there will be a WVC reported to ECC or ICBC but no carcass to be retrieved by the maintenance contractors. Similarly, for animals that have been killed in a WVC, but whose carcasses have been removed under varying

circumstances, there may be a WVC reported to ICBC but, again no carcass to recover. Each WVC for which no carcass can be recovered increases WARS underreporting.

Maintenance contractors will only record carcasses in WARS if the carcass is physically removed by their staff. If the carcass is sufficiently far from the travelled lanes so that it does not pose a hazard or if the carcass is in an unrecoverable location, the carcass is not removed by maintenance staff and therefore, the carcass goes unrecorded in WARS. If the carcass is obliterated in the collision and there are no remains to remove, there is no record in WARS of the event. Two specific situations were mentioned (*pers. comm*. D. Jamieson, Yellowhead Road & Bridge (Kootenay Boundary) Ltd., November 2018). During the time when the maintenance contract was held by Emcon Services Inc., D. Jamison was driving on Highway 33 and saw a dead doe. He drove to the yard to get the specific vehicle and equipment needed to retrieve the carcass. When he returned to the WVC location, the carcass was gone. Because he had seen the doe with his own eyes, he recorded that carcass in WARS. In situations where a carcass report is called in by the general public or other agency, and the maintenance contractor arrives but the carcass is gone, then that call-out is recorded on the maintenance contractor's time cards, but no carcass is recorded in WARS.

WARS. Reporting and underreporting rates. BC MOTI's estimate of WVC reporting rates has been traditionally considered to be about 25% to 35% of the actual number of animals killed (Sielecki 2010). Our results show that on Highway 33, WARS captured 50.9% of the known number of WVCs that occurred (an underreporting rate of 49.1%). These reporting and underreporting rates were calculated relative to the known number of WVCs that occurred. The proportion of animals struck by vehicles but not recorded in any agency database remains unknown. For Highway 33, just over half of the known number of WVCs was captured by WARS, which is a higher (better) WVC reporting rate than the current BC MOTI estimate.

Highway 33 underreporting compared with other jurisdictions

WVC underreporting rates have been variously estimated at 10-40% (Nova Scotia: Fudge et al. 2007); 39% (Sweden: Almkvist et al. 1980); 40-50% (Canada: Tardif 2003); 50% (Michigan: Marcoux and Riley 2010); 50% (Colorado: Romin and Bissonette 1996); 58% (New York: Decker et al. 1990); 66% (USA: Huijser et al. 2008b): 75-90% (Alaska: Bangs et al. 1989); 81-87% (Scotland: Langbein 2011); and 93.2% (Wyoming: Young and Vokura 2007) with many researchers concluding that the magnitude and implications of WVC underreporting are still largely unexplored.

These underreporting figures are variously based on carcass counts and police or insurance reports which may confound direct comparison with our underreporting results. In contrast to northern BC highways, for Highway 33, the carcass count dataset (WARS) was larger than the claimant-reported data-set (ICBC), similar to those analyzed in Virginia (Donaldson and Lafon 2010, Donaldson 2017) and Washington (Lao et al. 2012, Zou et al. 2019). Lao (2012) describes 76.9% underreporting (collision reports) and 16.3% underreporting (carcass counts) on ten state routes in Washington.

Our results show that WARS (carcass count) underreporting of 49.1% and ICBC (collision report) underreporting of 55.4% fit in the lower-range of underreporting found in these other jurisdictions.

Highway 33 general WVC trends

Although not the main focus of this project, we made some general observations about WVCs along Highway 33. In the seven years (January 1, 2008 to December 31, 2014) for which we had WVC data from all four agencies, we calculated that 2,055 *Bt*WVCs occurred along Highway 33 (a mean of 293.6 WVCs/year and 2.28 WVCs/km/year). This is over 3.5 times higher than the WVC rate on any northern highway in the Hesse and Rea (2016) study and reinforces Highway 33's rank as ninth on the list of BC's highways with high numbers of WVCs (BC MOTI 2014a).

The annual number of discrete WVCs of all species, and for all agencies combined, shows a slight decrease from 2008 to 2014 (Figure 5), although white-tailed deer and mule deer pre-season population estimates and trends in Region 8 (Okanagan) are noted as stable (BC FLNRO 2017). WVCs along Highway 33 exhibit spring and fall peaks (Figure 6), reflecting that over 95% of WVCs involve deer and that deer vehicle collisions peak in spring and fall (Sielecki 2010).

WARS data from BC MOTI District 4 (southern portion of Highway 33: length 89.72 km) captured 80% of all the WARS WVCs along Highway 33, while comprising 69.6% of the length of Highway 33. WARS data from BC MOTI District 5 (northern portion of Highway 33: 39.1 km) captured the remaining 20% of all WARS WVCs, with 30.4% of the length (Table 13). More WVCs per kilometre were being recorded in BC MOTI District 4 (Table 14), perhaps indicative of habitat differences between the Kettle River valley and the more mountainous and rocky stretches of Highway 33.

Significant wildfires occurred in 2015 along the Kettle River from Rock Creek (LKI Km 0.00) to north of Christian Valley Road (LKI Km 13.39) (4,417 hectares) (Figure 9: LKI Km 11.40) and, in 2017, in the Joe Rich area near Philpott Road (Figure 10: LKI Km 108.50) (465 hectares). Significant portions of roadside area adjacent to Highway 33 were burned in these wildfires, and wildlife habitat and movement patterns around the highway and WVC patterns and trends on the highway will have been affected.

Figure 9. Hillside adjacent to Highway 33, looking west, LKI Km 11.40 (G. Hesse, Sept. 2018)**.**

Figure 10. Philpott Road/Highway 33 junction, looking south, LKI Km 108.50 (G. Hesse, Sept. 2018)**.**

WVCs, all species. Model-based, density-based, or spatially-based analyses of WVC locations is required to determine WVC hotspots with more certainty and it was outside the scope of this project to conduct such analyses. However, we made some general observations.

The distribution of WVCs by kilometre (Figure 8) shows WVC peaks between: LKI Km 4 and Km 5 (agricultural fields near Kettle River); between LKI Km 45 and KM 46 (three kilometres south of Beaverdell); between LKI Km 52 and Km 53 (three kilometres north of Beaverdell); and between LKI Km 118 and Km 119 (southbound traffic travelling uphill on two lanes; northbound traffic starting downhill on one lane into Kelowna; highway changes from two lanes uphill to one lane uphill at LKI Km 118.57).

There are longer stretches of highway which appear to have high numbers of WVCs: between Westbridge and Boyer Creek FSR (LKI Km 13.32 to Km 33.97) and between Peregrine Road and the brake check located at the top of the hill before descending into Kelowna (LKI Km 109.62 to Km 119.33).

Lowest numbers of WVCs were located between south of Arlington Lake Forest Service Road and Schram Road (approximately LKI Km 69 to Km 102.77). This is anecdotally supported by BC MOTI District 5 staff who noted "there are many deer collisions in the Joe Rich area compared to higher up the mountain" (*pers. comm*. S. Lain, Area Manager, BC MOTI District 5, BC MOTI, October 2018).

Moose vehicle collisions. We were unable to determine any obvious identifiable common characteristics for moose vehicle collision locations, except to note that all but one occurred in BC MOTI District 4, south of the McCulloch Road/Highway 33 intersection (LKI Km 89.72), and south of the highest point of elevation noted on Highway 33 at LKI Km 94.18.

Elk vehicle collisions. Elk collision locations seem to be associated with the proximity of large agricultural fields adjacent to the Kettle River (*pers. comm*. G. Spencer, Yellowhead Road & Bridge (Kootenay Boundary) Ltd., November 2018 and WARS WVC locations at LKI Km 4.06, Km 4.71, Km 8.75), or further north, agricultural fields near Schram Road (LKI 101) (Figure 11: LKI Km 103.01), or extensive, south-facing grasslands on the slopes leading into Kelowna (LKI Km 112.2 - Goshawk Road; Heartland Ranch - LKI Km 115) (Figure 12: LKI Km 117).

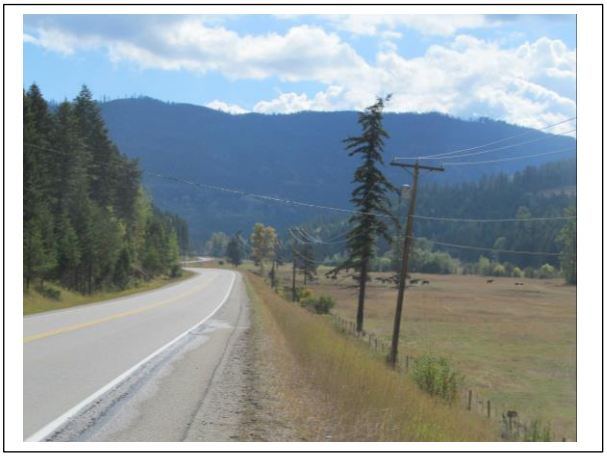

Figure 11. Fields adjacent to Highway 33, looking south, near LKI Km 103.01 (G. Hesse, Sept. 2018).

Figure 12. Grasslands adjacent to Highway 33**,** looking north, near LKI Km 117 (G. Hesse, Sept. 2018).

Highway 33 fatalities associated with WVCs

From January 1, 2008 to December 31, 2017, there were only two WVCs on Highway 33 that resulted in human fatalities and both WVCs involved motorcycles. Our primary data analysis objective was to determine if individual agency records for each WVC matched another WVC record from any other agency. For the first collision, there was a difference in the LKI Km noted in CIS and WARS, but other data proved sufficient to determine that the WVC records from both agencies were referring to the same collision. For the second collision, the WVC was only recorded in CIS. It was outside the scope of this contract to investigate specific WVC reports; however, we note that these extremely unfortunate collisions illustrate the challenges in reporting and interpreting WVC data.

RECOMMENDATIONS

BC MOTI

- ***Location reporting – LKI and RFI vs GPS.*** During the term of this project (January 1, 2008 to December 31, 2017), WARS carcass locations were recorded using the LKI or RFI systems, which lack easy geo-referencing capability. In 2018, BC MOTI began the staged rollout of new policy by implementing new Highway Maintenance Agreements and associated Schedules that mandate all highway maintenance contractors, in all Service Areas, to use GPS technology to mark WARS carcass locations. By 2023, all highway maintenance contractors will be using GPS for WARS locations (*pers. comm*. L. Sielecki, Manager, Wildlife Programs, BC MOTI, January 2020). This will improve the ease of locating WVCs along highways for analysis, hotspot identification, and mitigation planning and evaluation, although historical comparison with previous WARS records reported using the LKI Landmark system may be more difficult.
- ***Missing carcasses.*** Add a field to the WARS form to capture incidents where there is no carcass to remove, but the maintenance contractor knows that a WVC has occurred. This should include a field to note why there is no carcass (i.e., removed by RCMP, removed by COS, carcass obliterated, carcass unrecoverable). This data would not be used in any performance audit of the maintenance contractor.
- ***WVCs noted by another agency.*** Add a field to capture WVCs that are reported by another agency. This data would not be used in any performance audit of the maintenance contractor.
- ***Capture WARS data electronically in the field.*** Develop a WARS form app for mobile electronic devices so that maintenance contractors can quickly and accurately capture the required WARS information, geo-reference the location, and add a photograph of unusual circumstances where necessary, similar to that developed by Alberta (Alberta MOT 2017).
- ***Capture WARS data electronically at data entry.*** Until electronic data capture at the field level is implemented, develop an electronic system for data entry, either at the primary data reporting level where the maintenance contractor can enter the data directly, or at the secondary level, when the BC MOTI District office receives the data. Sielecki (2010) notes that in 2002, 28% of WARS entries lacked valid segments numbers and/or valid kilometre references, and although the amount of current similar errors is unknown, we noted a minimum of eight instances of incorrect Segment numbers or LKI Kilometres. An electronic system would prevent incorrect matches of

Highway and Segment (i.e., the system would not allow an entry on Highway 33 Segment 1325 because Segment 1325 does correspond with Highway 33). An electronic system would prevent non-existent LKI Km to be entered (i.e., the system would not allow an LKI Km entry of 1118.3 because the segment is only 128.82 km in length).
Currently, WARS forms are submitted to District staff and then vetted for obvious errors, but this process is not infallible. We encountered significant inconsistencies in WARS records (Segments recorded as 1325 and 1119, LKI KM recorded as 1658) from as recently as November 2016. An electronic data entry system at earlier stages in the process, before data arrives at the Branch level, would allow the maintenance contractors or BC MOTI District staff, who are familiar with the highway in question, to identify and correct errors. As previously noted by Sielecki (2010) "*a data quality feedback mechanism is required*."

- ***WARS database management*.** At the Branch level, ensure that WARS data entry errors are reduced and corrected and produce regular, published WARS reports, summarizing WVCs on a district, regional, and provincial basis.
- ***Use CIS (RCMP) data.*** Consider integrating the CIS (RCMP) WVC data with WARS data to obtain a more robust WVC dataset for wildlife collision mitigation planning.
- ***COS carcass removal.*** Initiate discussions with the COS regarding their removal of carcasses. It is difficult to quantify the magnitude of this activity but it may be more common in some BC MOTI Districts/Service Areas than others and could lead to increased WARS underreporting in those areas. Investigate ways whereby the COS could notify BC MOTI (or the maintenance contractor) when carcass removal occurs. In order for this to be most useful, more accurate carcass locations from COS are required. This notification of carcass removal ties into modification of the WARS form to allow the capture of WVCs that are reported by another agency.
- ***BC MOTI and COS cooperation.*** Promote discussion among COS and BC MOTI staff about WVCs so that each agency knows the strengths and limitations of the other. The resources that each agency manages are different; however, the goals and visions for both agencies include public safety. Opportunity exists for greater cooperation in working on WVC issues. This would provide long term benefits for COS by reducing the amount of WVCs that they may be called to attend and contributing to improved stewardship of the wildlife resource, and for BC MOTI by being able to identify and mitigate factors pertaining to WVCs with increased knowledge and efficiency.
- ***Maintenance contractor performance.*** Audit maintenance contractors in both Service Areas 8 and 9 for compliance to WARS recording and reporting requirements and response times to public concerns regarding wildlife to ensure completeness and accuracy of WARS records.
- ***WVC hotspot identification and mitigation.*** Carry out an analysis of WVC locations (using model-based, density-based, or spatially-based analyses) to determine WVC hotspots and allow for appropriate mitigation strategies to be implemented and evaluated.

RCMP

- ***Species identification.*** Make appropriate changes to the MV6020 so that the species involved in police-attended WVCs can be recorded. This could be accomplished by enhancement of the existing codes. The current Wild Animal - Code 70 could be expanded to include: Wild Animal Unknown - Code 700; Wild Animal Deer - Code 701; Wild Animal Moose - Code 702; Wild Animal

Bear – Code 703; Wild Animal Elk - Code 704; Wild Animal Other - Code 706. This, or a similar numbering system, would provide invaluable information on >90% of the WVCs that occur.

ICBC

- ***Location reporting.*** Implement changes to improve the locational accuracy of WVCs that occur on roads in rural settings, by building upon previous recommendations to ICBC (Rea 2006, Hesse and Rea 2016). It would be to ICBC's advantage to identify, more accurately, stretches of road (numbered highways, major roads, rural roads, and resource roads) where WVCs (and any other type of collision) occur so that any engineering or environmental factors that have contributed to the collision can be identified and mitigated, thereby reducing the number of collisions and resultant claims.
  Claimants currently identify the highway or road upon which they are travelling and the direction of their travel. In an urban setting, claimants can usually provide a cross street, thereby identifying the location where the collision has occurred, allowing for pinpointing of hotspot collision locations (intersections, etc.). In rural settings, the use of cross streets as WVC locators is difficult and different ways to determine the WVC location must be employed.
  What is missing in the current location description in rural areas is how far away, and in what direction, the WVC location is located from the closest landmark that the claimant can identify. The addition of three questions to the ICBC Dial-A-Claim dialogue with the claimant could assist with more accurate identification of the WVC (and any other type of collision) location.
  (1) What landmark have you just passed, how far away is it, and in what direction is that landmark?
  (2) If you proceeded further in your direction of travel, what is the next landmark that you would encounter? The intent of these two questions is to establish not just how far the WVC is located from an identified landmark but how far *and in what direction* the crash is located *in reference to that landmark.*
  (3) Did you record the collision location on a smart phone or other device?
  Improved geo-referencing of WVC locations either through gathering more information from the claimant or through the use of smartphone technology will help identify WVC hotspots and mitigate collision potential in a site-specific manner.

COS

- ***Carcass removal.*** Notify BC MOTI or the maintenance contractor when carcasses are removed. When carcasses are removed without notification, it leaves significant gaps in the information required by BC MOTI to make informed decisions for road safety planning.
- ***Location reporting.*** The HWCR was designed as a tracking system for calls, not as a database searchable by accurate location, and using this database for a purpose for which it was not intended made extraction of the appropriate information to complete this study very difficult. However, it would be an advantage for the COS to increase the accuracy of location reporting for all incidents. Ideally, there would be a separate field to geo-reference the location of the incident. If this is not currently possible, because the officers report out on each incident that they attend, a GPS location of the occurrence could be recorded in the narrative portion of the *Occurrence*

Notes. Whether the officer was called to a garbage bear complaint or a WVC, having a GPS location would simplify occurrence reporting for a variety of COS purposes.

- ***Designating calls as WVCs*.** Currently, *Wildlife Caused MVA* and *Injured Animal* are mutually exclusive selections in the *Nature of Complaint* field. Modifying the choices in the *Nature of Complaint* field so that a call can be designated as *Injured Animal - Wildlife Caused MVA* would allow for both the call prioritization required by COS for injured animals while still allowing for consistent classification and tracking of calls relating to WVCs.

CONCLUSIONS

The primary concern about WVC underreporting is that any conclusions drawn about WVCs, and the environmental and engineering factors associated with them, are based on a substantially incomplete dataset, and, therefore, subject to error. Snow et al. (2015) specifically studied the effects of underreporting on developing predictive models that were used to inform WVC management strategies. Their conclusions were that concerns about underreporting should not hinder the use of WVC data in the development of predictive models and management strategies, particularly in situations where the WVC data used in the analysis is derived from well-planned carcass collection, even if underreporting is very high (which they defined as ≥75%). The WARS underreporting rate on Highway 33 (49.1%) is well below this ≥75% threshold, meaning that WARS data can be used with confidence in predictive modelling, as was done by Rea et al. (2014) for moose vehicle collision hotspot identification in northern BC.

British Columbia's long-term, comprehensive, systematically-collected WARS data and CIS (RCMP) police-attended WVC reports provide location-based WVC data and ICBC data captures another sub-set of WVC information. The combination of these three sources of information gives BC an advantage over other jurisdictions in obtaining accurate estimates of the true numbers of WVCs and the underreporting associated with those WVCs.

Our results established the underreporting rate (WARS 49.1% and ICBC 55.4%) for a known number of WVCs in both of BC's major sources of WVC data. This provides BC's highway managers with a greatly improved understanding of the magnitude of the issue, the quality of BC's WVC data, and what, if any, limitations should be placed upon data use. With the level of WVC underreporting on Highway 33 established as lower than the historical standard previously used, highway mangers can confidently utilize WVC data for the identification of high risk stretches of highway, prioritize these areas for mitigation treatment, develop appropriate mitigation strategies, and monitor the results of mitigation.

Footnote:

There have been significant changes in highway maintenance, WARS reporting, and RCMP collision attendance and reporting that occurred after the term of this project. None of these changes affect the WVC data in this project, but they may affect WVC analysis in the future.

- On October 1, 2018, Yellowhead Road & Bridge (Kootenay Boundary) Ltd., assumed the highway maintenance contract in Service Area 9 (LKI Km 0.00 to Km 89.72), replacing Emcon Services Inc.
- On May 1, 2019, AIM Roads Inc., assumed the highway maintenance contract in Service Area 8 (LKI Km 89.72 to Km 128.82), replacing Argo Road Maintenance (South Okanagan) Inc.
- Both of these companies are operating under the 2018-2019 Highway Maintenance Agreement and 2018-2019 Schedules. Patrol frequencies and debris removal timeframes relative to summer and winter highway classifications have changed under the new schedules. WARS reporting of WVC locations has changed from the LKI landmark system to a GPS-based system.
- After March 8, 2019, police attendance and reporting at "minor" property damage collision changed. Police must file an MV6020 only if property damage in a collision exceeds $10,000. Attendance at "minor" collisions remains at police discretion. The previous reporting threshold was $1,000. This change will likely further reduce police attendance at WVCs.

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Appendix 1. Summer and winter classifications of British Columbia highways

Highway and Structure Maintenance Definitions

SUMMER CLASSIFICATION

Class	A.D.T. (average daily traffic) Vehicles per Day
1	over 10,000
2	5,000 - 10,000
3	1,000 - 5,000
4	500 - 1,000
5	100 – 500
6 *	10 – 100
7 *	0 – 10

8 a Highway, typically without a constructed road but for which maintenance responsibilities exist for such things as danger tree removal and drainage, and which may also have other improvements to maintain such as pedestrian and bicycle paths.

*Roads Classed 6 or 7 with heavy industrial use will be increased one Class in RIMS.

Winter Classification is generally based on but not limited to the following:

WINTER CLASSIFICATION

Class	Definition
A	high volume traffic (over 5,000 winter average daily traffic count) or commuter routes and certain expressways and Freeways through mountain passes, as determined by the Province. They are heavy commuter traffic routes extended to include the bulk of vehicles commuting daily to a center and cut-off where traffic drops below 2,500 winter average daily traffic count. Very high volume ski hill and commuter routes.
B	all trunk and main routes (or portion thereof as designated by the Province) not included in Class A, with a cut-off traffic volume of 1,000 winter average daily traffic count. Lower volume ski hill and commuter routes.
C	all school bus routes and industrial (truck) traffic routes (more than 25% trucks) not included in Class A and B.
D	all other regularly maintained winter routes.
E	all other irregularly maintained winter routes.
F	roads not maintained in the winter, or not open, or not maintained by the Minister.

2003-2004 Highway Maintenance Contracts
Schedule 21 Maintenance Specifications, Chapter 9 Definitions, Page 4
Accessed Feb 18, 2016 from
http://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/highway-bridge-maintenance/highway-maintenance/maintenance-agreements/maintenance-specifications/chapter_9_definitions.pdf

Appendix 2. Highway patrol frequencies on British Columbia highways

Maintenance Specifications Chapter 8-840
3.1 Routine Maintenance Services

The Contractor must:
a) **At all times** other than identified in 3.1 b), c), d) and e), patrol all Highways in accordance with the frequencies established in 3.1.1 a) i) 1;

i. Summer Highway Classification

	1 and 2	3	4	5	6 and 7
1. At all times	24 h	2 d	7 d	14 d	21 d

b) **during periods of high water flow**, patrol all Highways in accordance with the frequencies established in 3.1.1 a) i) 2; give appropriate attention to areas known to be impacted first by high water flow;

i. Summer Highway Classification

	1 and 2	3	4	5	6 and 7
2. During periods of high water flow	2 h	4 h	8 h	16 h	32 h

c) **when freezing temperatures and/or snow fall are not present or forecast,** patrol all Highways in accordance with the frequencies established in 3.1.1 a) ii) 1;

ii) Winter Highway Classification

	A	B	C	D	E
1. At all times	24 h	2 d	7 d	14 d	21 d

d) **during periods of snowfall,** patrol all Highways in accordance with the frequencies established in 3.1.1 a) ii) 2;

ii) Winter Highway Classification

	A	B	C	D	E
2. Winter patrols during snowfalls	4 h	8 h	16 h	24 h	36 h

2003-2004 Highway Maintenance Contracts
Schedule 21 Maintenance Specifications
Chapter 8 Inspections,
Maintenance Specification Chapter 8-840 Highway Patrol, Page 1-3
Accessed Feb 18, 2016 from
http://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/highway-bridge-maintenance/highway-maintenance/maintenance-agreements/maintenance-specifications/chapter_8_inspection.pdf

Appendix 3. Debris removal timeframes on British Columbia highways

3. DETAILED PERFORMANCE SPECIFICATIONS

3.1 Routine Maintenance Services

The Contractor must:

a) remove Debris in accordance with the Performance Time Frames set out in Section 3.1.1;

b) if the Debris is too large for immediate removal, secure the area in accordance with the Maintenance Specification for *Highway Traffic Control*;

c) establish additional patrols through the area when Debris over 1000 cc on the Travelled Lanes, Shoulders, and Sidewalks is detected or reported to the Contractor more than once in a 24 hour period so that Debris is removed within the Performance Time Frames specified in Section 3.1.1, and discontinue the additional patrols when the frequency of Debris over 1000 cc falling on the Travelled Lanes, Shoulders, and sidewalks is less than 2 in a 24 period;

d) dispose of dead animals in a manner acceptable to local regulatory agencies.

Note: For volumes of Debris on Travelled Lanes or Shoulders that are greater than 10 cubic metres per location, the Maintenance Specification for *Mud, Earth and Rock Slide Response* will apply.

3.1.1 Performance Time Frames

The following table establishes the maximum time, from the time the Debris was detected by or reported to the Contractor, within which the Contractor must start the removal of Debris:

	Summer Highway Classification				
Obstruction	1 and 2	3	4	5	6 and 7
Debris or spilled material over 1000 cc on the Travelled Lanes and sidewalks	60 min	60 min	3 hr	5 hr	24 hr
Debris or spilled material equal to or less than 1000 cc on the Travelled Lanes and sidewalks	60 min	3 hr	5 hr	24 hr	2 days
Dead animals on the Shoulders and sidewalks	60 min	3 hr	5 hr	24 hr	2 days
Dead animals on the Right-of-way, excluding Travelled Lanes, Shoulders and sidewalks	3 hr	5 hr	24 hr	2 days	3 days
Debris or spilled material more than 1000 cc on the Shoulders	3 hr	24 hr	2 days	3 days	7 days
Debris or spilled material equal to or less than 1000 cc on the Shoulders	24 hr	24 hr	3 days	7 days	14 days

2003-2004 Highway Maintenance Contracts
Schedule 21 Maintenance Specification
Chapter 1 Surface Maintenance, Maintenance Specification Chapter 1-190 Debris Removal, Page 1 – 3
Accessed Feb 18, 2016 from
http://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/highway-bridge-maintenance/highway-maintenance/maintenance-agreements/maintenance-specifications/chapter_1_surface_maintenance.pdf

Appendix 4. List of Acronyms

AADT	Annual Average Daily Traffic
BC MOE	BC Ministry of Environment
BC FLNRO	BC Ministry of Forests, Lands and Natural Resource Operations
BC MOTI	BC Ministry of Transportation and Infrastructure
*Bt*WVCs	Baseline total number of known WVCs in the union dataset
CIS (RCMP)	Collision Information System - database managed by BC MOTI, police-attended collisions
COS	BC Conservation Officer Service
ECC	Emergency Coordination Centre – coordinates wildlife-related calls reported to COS
HWCR	Human Wildlife Conflict Violation Report - database managed by COS
ICBC	Insurance Corporation of British Columbia
LKI	Landmark Kilometre Inventory - highway location system, managed by BC MOTI
MV 6020	Motor Vehicle Traffic Accident Police Investigation Report form
RAPP	Report All Polluters and Poachers - reporting hotline for assorted wildlife-related issues
RCMP	Royal Canadian Mounted Police
RFI	Resource Feature Inventory, highway location system - managed by BC MOTI
TAS	Traffic Accident System - database managed by ICBC
WARS	Wildlife Accident Reporting System - database managed by BC MOTI
WVCs	Wildlife vehicle collisions