Use of Infrared Camera Video Footage from a *Wildlife Protection System* to Assess Collision-Risk Behavior by Deer in Kootenay National Park, British Columbia

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Disclaimer

Summary

We used video footage from infrared and conventional video cameras within a *Wildlife Protection System* (*WPS*) installed along a flat, level 2-km stretch of Highway 93 in Kootenay National Park, BC, Canada to assess collision-risk behaviors by deer during autumn, 2002. We recorded 1131 deer-minutes of behavior (number of deer multiplied by the time they were present during the sampling period). Based on marked breaks in hourly totals of deer-minutes, we stratified the 24-hour period into night (midnight to 7 AM), midday (7 AM to 7 PM) and evening (7 PM to midnight). Both the number of deer and the duration of their stay in the highway right-of-way were greatest during the night, intermediate during the evening, and lowest during midday, so the number of deer-minutes per hour was over 2x higher at night than evening, and over 15x higher at night than midday. Similarly, the peak in hourly rates of most collision-risk behaviors occurred during the night. However, all of the risk behaviors measured showed higher per-deer rates during midday than during the evening or at night, including presence at roadside, approaches to highway, running approaches to highway, presence on the highway surface, attempted highway crossings, running highway crossings, crossing in front of oncoming cars, and aborted highway crossings. The hazard created by higher per-deer rates of risk behaviors during midday is likely compounded by greater traffic volumes during midday than evening or night. Driving in daylight undoubtedly increases deer visibility, but being within the line-ups of cars more typical of midday presumably decreases the driver's field of view and may increase the collision hazard associated with a driver swerving or making a sudden stop. Thus, the net risk of wildlife-related accidents during midday may be much higher than raw animal numbers would initially suggest. No reliable data are available for the test section indicating timing of wildlife-related accidents. In fact, "swerved-to-miss" accidents are not recorded as wildlife-related unless an animal collision occurs, making any available data potentially suspect. Systems such as the *WPS*, which are designed to work at all times of the day and are triggered by animal presence, offer the greatest ability to prevent wildlife-related accidents in situations similar to those we studied.

Introduction

Wildlife-vehicle accidents result in substantial personal, environmental, and economic losses, including human injuries, fatalities, loss of wildlife, and vehicle damage. In 2002, the Insurance Corporation of British Columbia (ICBC) received over 9,000 claims for wildlife-vehicle collisions in BC, at a total cost of roughly CDN$25,000,000, with claims averaging CDN$2,650 in property damage alone (G. Gilfillan, ICBC, Kamloops, BC, personal communication). This did not include collisions in which an animal was injured or killed but only minor vehicle damage occurred, vehicles were from out of province, or drivers had insurance from other companies. Similarly, it did not include accidents in which an animal's presence caused an accident, but the animal was not actually hit. The loss of wildlife also represented a major cost through lost hunting and viewing opportunities, in addition to being a general environmental concern (Province of British Columbia 2001). From 1987 to 2001, an average of about 2.5 people were reported killed annually in wildlife collisions in BC (L. Sielecki, Ministry of Transporation, Victoria, BC, unpublished data). As Farrell (2002) observed, the problems associated with wildlife-vehicle collisions are global, pervasive and increasing, yet most of the literature suggests that many mitigation techniques have limited utility because they are ineffective at reducing collisions or have large impacts on natural wildlife movements. In addition, few prevention techniques have been developed from a clear understanding of animal behavior.

The *Wildlife Protection System* (*WPS*) is now being developed by InTransTech (owned by the Rainbow Group of Companies) in cooperation with the Insurance Corporation of British Columbia and other partners. Initial prototypes used infrared (IR) cameras with *Quantum Well Infrared Photodetector* (*QWIP*) focal plane arrays (QWIP Technologies, Altadena, California) to detect wildlife on or near highways. When animals are detected, flashing lights on road signs are triggered, warning drivers to reduce speed and anticipate wildlife on the highway. The potential benefits of this system are that it is portable, it does not affect wildlife movement patterns, there are no issues of animal habituation, and it is activated only when animals are actually present, reducing the chance of driver complacency. In addition, the WPS is capable of collecting video footage, thereby providing a unique opportunity to investigate wildlife locations, numbers and behavior on and near road systems. As part of *WPS* testing conducted in the summer of 2002, we analyzed conventional and IR video footage. The purpose was to assess deer behaviors that are relevant to developing more effective strategies for preventing wildlife-vehicle collisions.

Study Area

The test section was situated on Highway 93 in Kootenay National Park, BC, Canada, immediately north of the Dolly Varden Day-Use Area. This 2-lane highway had average daily traffic volumes in 2001 ranging from about 1200 in November to 4400 vehicles in August (Parks Canada, Radium Hot Springs, BC, unpublished data). It was a straight, level 2-km stretch, with open, grassy roadsides and ditches extending about 18 m on each side, followed by abrupt transitions to mature lodgepole pine forest (Figure 1). Minimum numbers of roadkilled animals on this test section from 1992 to 2001 included 24 white-tailed deer, 3 moose, 2 mule deer, 1 elk and 4 other species (Parks Canada, Radium Hot Springs, BC, unpublished data). Based on informal observations made during research, virtually all large mammals within the test section during our study period were white-tailed deer. Kootenay National Park falls within the Rocky Mountains. Deer, elk and moose in this region typically live at higher elevations during the summer and early fall, moving to lower elevations in winter and early spring. The test section occurs at an intermediate elevation, and has significant populations of large mammals year-round.

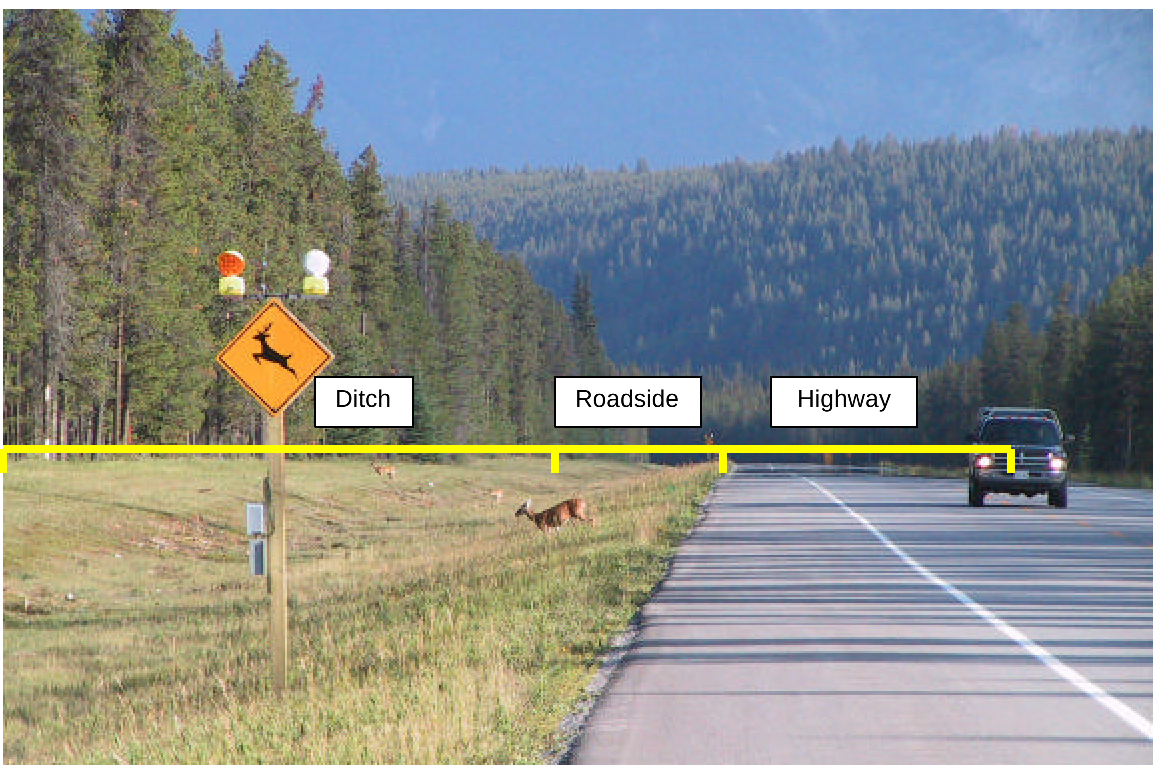

Figure 1. Cross-sectional view of one side of the test section right-of-way along Highway 93 in Kootenay National Park, British Columbia, Canada. It includes the highway surface, the roadside (slope leading up to highway) and ditch (remainder of right-of-way, to edge of forest). Ditch and roadside combined are 18 m wide on each side of highway. Photo courtesy Alan Dibb, Parks Canada.

Methods

A *QWIP* IR camera was mounted on a 6-m pole in the ditch at each end of the test section, facing oncoming traffic. Adjacent to each pole was a trailer containing a generator, computer (with tracking software), 2 radar guns, radio controls for wildlife-activated signs, and a conventional digital video camera (Figure 2). Continuous infrared (digital) and conventional (VHS) video footage was recorded. In addition, an event log was generated in an *Excel* spreadsheet that recorded traffic speeds before and within the test zone, and animal detections within the zone. A number of technical difficulties prevented the system from becoming fully operational in 2002. However, we were able to view video footage of deer behavior in the highway right-of-way (ROW) on 16 days between 29 August and 7 October, 2002.

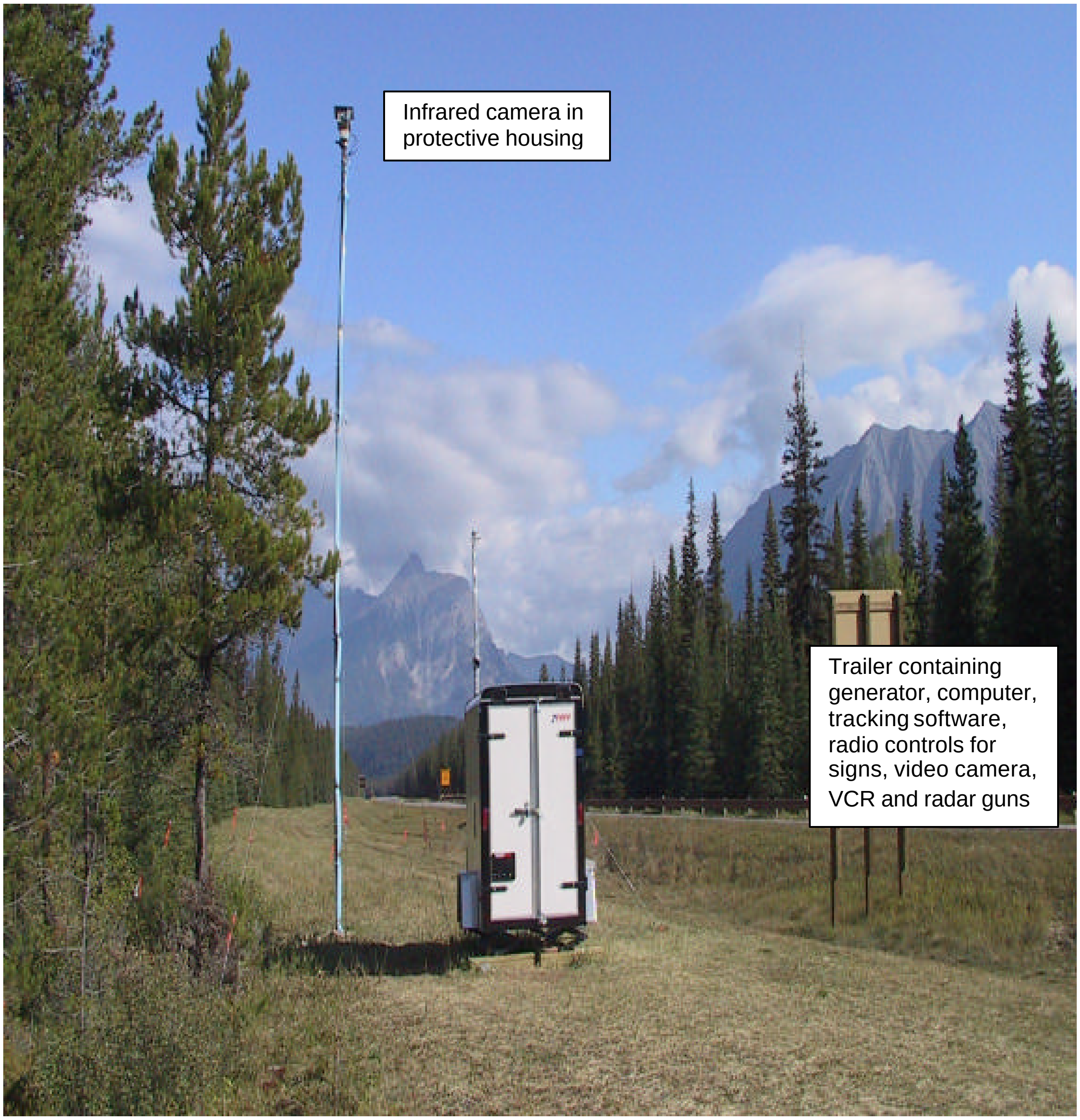

Figure 2. Layout of Wildlife Protection System equipment tested along Highway 93 in Kootenay National Park, British Columbia, Canada. Photo viewing northward, the same direction that camera is aimed. Test section extends approximately 2 km north from trailer, with identical equipment directed southward at north end.

We viewed the videos from either the north or south end of the test section on a computer monitor, observing 5-minute samples at the beginning of every half-hour of video. We recorded the number of vehicles entering the test section, along with the following measures of deer presence and behavior that are presumed to relate to collision risk:

- number of deer present within the entire right-of-way (ROW)
- location of deer within the ROW, i.e. on the paved highway surface, at the roadside, or in the ditch (Figure 1)
    - if on the roadside, whether (a) approaching the highway or alternatively (b) remaining stationary or retreating from the highway
        - if on the roadside approaching the highway, whether running
    - if on the highway surface, whether attempting to cross
        - if attempting to cross, whether running
        - if attempting to cross, whether crossing in front of an oncoming vehicle
        - if attempting to cross, whether the attempt was aborted
        - if attempting to cross, whether a deer-vehicle collision occurred.

The rationale for recording the above risk behaviors is as follows. It is assumed that deer presence anywhere in the ROW creates a collision risk, and that this risk is progressively greater from the ditch to the roadside to the highway surface. This considers both the likelihood of deer being in a vehicle's path and the potentially unpredictable behavior of drivers when a deer is on or near the highway surface. It is further assumed that, within the roadside segment, deer approaching the highway present a greater risk than those standing still or retreating from it, particularly if the deer is running during the approach. Finally, those deer on the highway surface are assumed to pose a greater risk if attempting to cross than if stationary on the shoulder, and pose the greatest risk if crossing in front of a vehicle. Aborted highway crossings (i.e. those in which a deer reverses direction part way through the crossing and returns to its roadside of origin) are assumed to indicate a greater collision risk than successful crossings, because aborted crossing might be followed by additional crossing attempts.

Based on availability, we used video from the northern cameras for dates through 9 September, and from the southern cameras thereafter. Observers could detect deer on video footage to a range of about 1 km, so data are representative of deer present within about 1 km of highway. The northern and southern 1-km portions of the test section were immediately adjacent and in identical habitat, so we do not expect that the source of video footage affected the results. Regardless, we did not analyze data based on date, so there should be no systematic bias. It was not possible to accurately classify deer to species (white-tailed deer versus mule deer) from the videos, but based on roadkill records and observations made at the site, it appears that > 90% of records would have been of white-tailed deer.

Results

During 624 5-minute sampling periods (Table 1), we recorded 1131 deer-minutes of behavior, i.e. number of deer present multiplied by the time they were present.

Table 1. Dates and times from which deer behavior and vehicle count samples were taken, Highway 93, Kootenay National Park, British Columbia, 2003. Start time indicates beginning of 5-minute samples. Missing data due to lack of file storage capacity or corrupt files.

start	Data from north cameras											Data from south cameras				
time	29-Aug	30-Aug	31-Aug	1-Sep	2-Sep	3-Sep	4-Sep	6-Sep	7-Sep	8-Sep	9-Sep	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct
0:00		X	X	X	X	X	X		X	X	X		X	X	X	X
0:30		X	X	X	X	X	X		X	X	X		X	X	X	X
1:00		X	X	X	X	X	X		X	X	X	X	X	X	X	X
1:30		X	X	X	X	X	X		X	X	X	X	X	X	X	X
2:00		X	X	X	X	X	X		X	X	X	X	X	X	X	X
2:30		X	X	X	X	X	X		X	X	X	X	X	X	X	X
3:00		X	X	X	X	X	X		X	X	X	X	X	X	X	X
3:30		X	X	X	X	X	X		X	X	X	X	X	X	X	X
4:00		X	X	X	X	X	X		X	X	X	X	X	X	X	X
4:30		X	X	X	X	X	X		X	X	X	X	X	X	X	X
5:00		X	X	X	X	X	X		X	X	X	X	X	X	X	
5:30		X	X	X	X	X	X		X	X	X	X	X	X	X	
6:00		X	X	X	X	X	X		X	X	X	X	X	X	X	
6:30		X	X	X	X	X	X		X	X	X	X	X	X	X	
7:00		X	X	X	X	X	X		X	X	X	X	X	X	X	
7:30		X	X	X	X	X	X		X	X	X		X	X	X	
8:00		X	X	X	X	X	X		X	X	X		X	X	X	
8:30		X	X	X	X	X	X		X	X	X	X	X	X	X	X
9:00		X	X	X	X	X	X		X	X	X	X	X	X	X	X
9:30		X	X	X	X	X	X		X	X	X	X	X	X	X	X
10:00		X	X	X	X	X	X		X	X	X		X	X	X	X
10:30		X	X	X	X	X	X		X	X	X		X	X	X	
11:00		X	X	X		X	X		X	X	X	X	X	X	X	
11:30		X	X	X		X	X		X	X	X		X	X	X	
12:00		X	X	X	X	X	X		X	X	X	X	X	X	X	
12:30		X	X	X	X	X	X	X	X	X	X		X	X	X	
13:00	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
13:30	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
14:00	X	X	X	X		X		X	X	X			X	X	X	
14:30	X	X	X	X		X		X	X	X			X	X	X	
15:00	X	X	X	X		X	X	X	X	X			X	X	X	
15:30	X	X	X	X	X	X	X	X	X	X			X	X	X	
16:00	X	X	X	X		X	X	X	X	X			X	X	X	
16:30	X	X	X	X		X	X	X	X	X			X	X	X	
17:00	X	X	X	X		X	X	X	X	X			X	X	X	
17:30	X	X	X	X		X	X	X	X	X			X	X	X	
18:00	X	X	X	X		X	X	X	X	X			X	X	X	
18:30	X	X	X			X	X	X	X	X		X	X	X	X	
19:00	X	X	X	X		X	X	X	X	X		X	X	X	X	
19:30	X	X	X	X		X	X	X	X	X		X	X	X	X	
20:00	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
20:30	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
21:00	X	X	X	X	X	X		X	X	X		X	X	X	X	
21:30	X	X	X	X	X	X		X	X	X		X	X	X	X	
22:00	X	X	X	X	X	X		X	X	X		X	X	X	X	
22:30	X	X	X	X	X	X		X	X	X		X	X	X	X	
23:00	X	X	X	X	X	X		X	X	X		X	X	X	X	
23:30	X	X	X	X	X	X		X	X	X		X	X	X	X	

Based on the daily pattern of relative deer presence (Figure 3), we stratified the day into “night” (0:00 to 6:59), “midday” (7:00 – 18:59) and “evening” (19:00 – 23:59). Deer activity was greatest at night, intermediate in evening, and lowest in midday, whether measured as number of deer in the ROW, the mean duration of stay in the ROW per deer, or the total deer-minutes of activity within the ROW (Table 2).

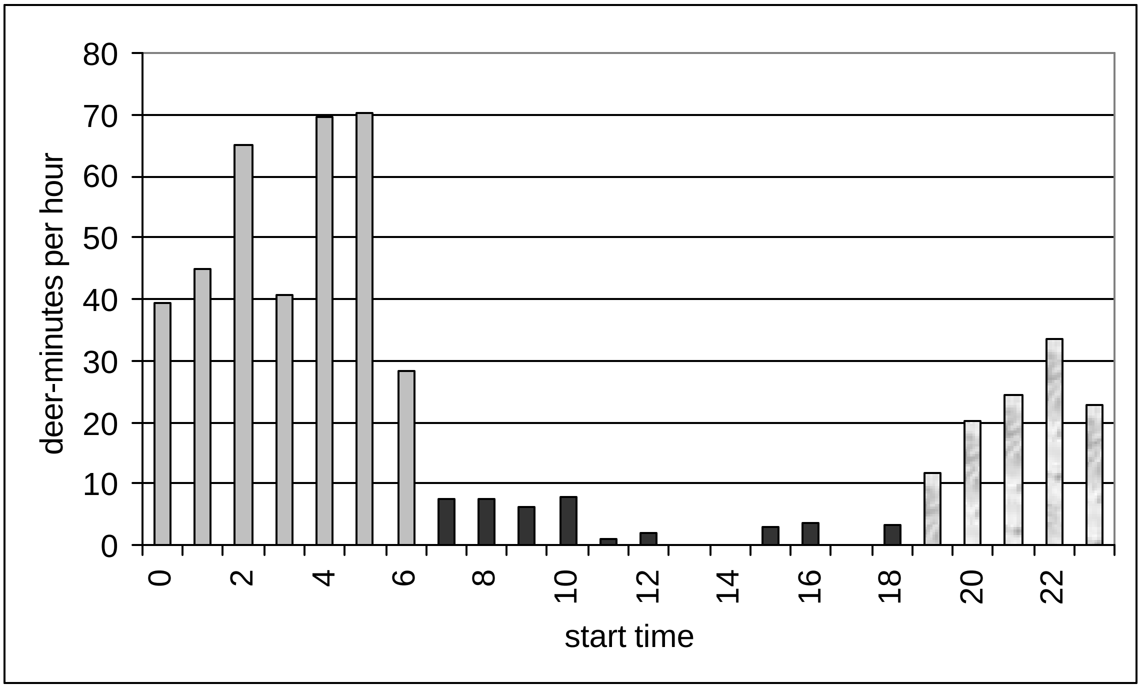

Figure 3. Deer-minutes (number of deer present multiplied by minutes each was present) per hour from Highway 93, Kootenay National Park, British Columbia on 16 days from 29 August to 7 October, 2002. Values extrapolated from 5-minute samples taken at the beginning of each half-hour, with data from approximately 1-km segments of the test section. Data stratified into night (0:00 – 6:59), midday (7:00 – 18:59), and evening (19:00 – 23:59) periods.

Table 2. Deer activity along Highway 93, Kootenay National Park, British Columbia on 16 days from 29 August to 7 October, 2002. Values from 5-minute samples taken at the beginning of each half-hour, with data from approximately 1-km segments of the test section. Night = 0:00 – 6:59, midday = 7:00 – 18:59, and evening = 19:00 – 23:59.

Measure	Night	Midday	Evening
Mean number of deer in ROW per 5-minute sample	1.08	0.25	0.60
Mean duration of stay (min) per deer in ROW per 5-min sample	3.92	1.40	2.81
Mean deer-minutes in ROW, extrapolated to hourly rates	51.3	3.5	20.7

Vehicle numbers followed a pattern inverse to that of deer activity (Figure 4), with greatest numbers in midday (mean = 263/hour), followed by evening (mean = 194/hour) and night (mean = 57/hour). Measures of deer behavior were also variable between periods of the day. The incidence of each risk behavior measured was highest per unit time at night, with the exception of running approaches to the highway, which was highest in midday (Table 3). However, the incidence of each risk behavior per deer was highest during midday (Table 3). No deer-vehicle collisions were observed. An IR video clip (*WPS deer crossing video.WMV*) from the test section is attached to the electronic version of this report. It shows a group of deer in the ditch, from which 1 makes a running crossing in front of an oncoming car and transport truck while the remaining 2 deer return to the forest edge.

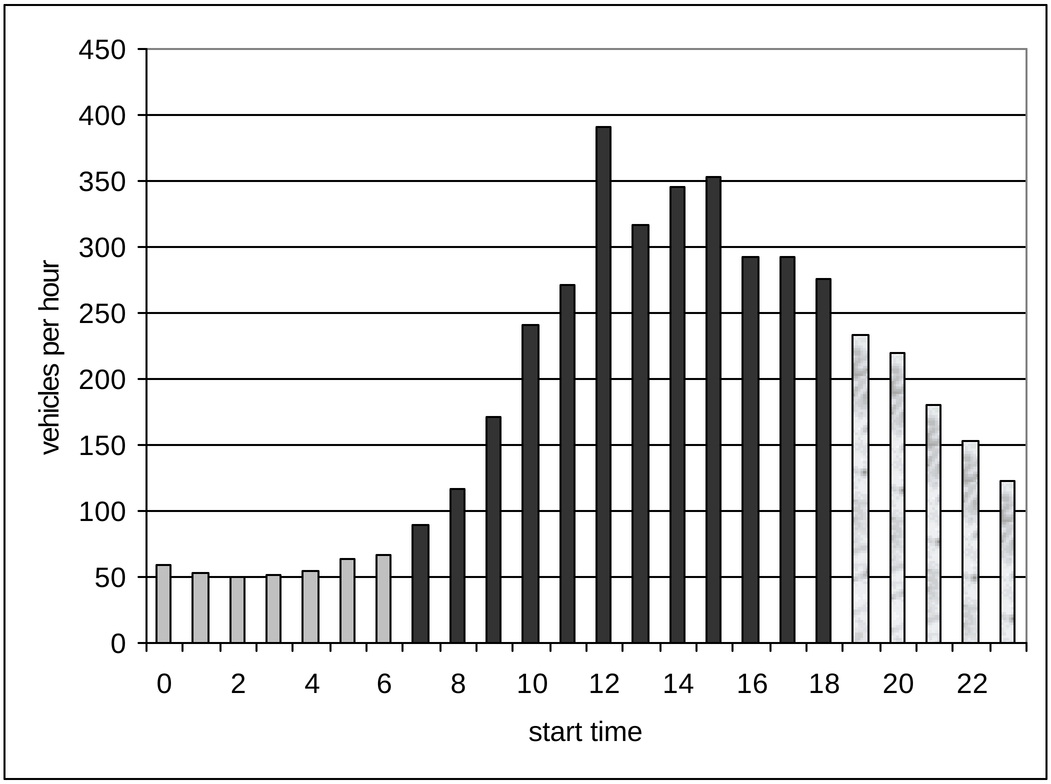

Figure 4. Vehicle numbers (2-way) per hour on Highway 93, Kootenay National Park, British Columbia on 16 days from 29 August to 7 October, 2003. Values extrapolated from 5-minute samples taken at the beginning of each half-hour, with data from approximately 1-km segments of the test section. Data stratified into night (0:00 – 6:59), midday (7:00 – 18:59), and evening (19:00 – 23:59) periods.

Table 3. Measures of deer behavior along Highway 93, Kootenay National Park, British Columbia on 16 days from 29 August to 7 October, 2002. Values measured within or extrapolated from 5-minute samples taken at the beginning of each half-hour, with data from approximately 1-km segments of the test section. Night = 0:00 – 6:59, midday = 7:00 – 18:59, and evening = 19:00 – 23:59. Shaded numbers are the highest values for each category.

Measure	Mean Occurrence per 5-Minute Sample Period			Mean Occurrence per Deer Observed		
	Night	Midday	Evening	Night	Midday	Evening
Present in ditch (total)	0.90	0.25	0.61	*0.83	1.00	*0.94
Present at roadside (total)	0.61	0.16	0.36	0.56	0.62	0.55
Approaches to highway (run/walk)	0.47	0.18	0.39	0.43	0.70	0.60
Running approaches to highway	0.04	0.11	0.06	0.03	0.42	0.09
Present on highway (total)	0.11	0.04	0.07	0.10	0.14	0.10
Attempted highway crossing	0.09	0.03	0.05	0.08	0.12	0.08
Highway crossing running	0.02	0.01	0.00	0.02	0.04	0.00
Highway cross. in front of vehicle	0.03	0.01	0.00	0.02	0.05	0.00
Highway crossing aborted	0.02	0.01	0.00	0.01	0.04	0.00
Wildlife-vehicle collision	0.00	0.00	0.00	0.00	0.00	0.00

* all deer must have occurred in the ditch at some point in order to enter the ROW (i.e. occurrence in reality is 1.00/deer), but some were observed only on highway or roadside during some 5-minute samples for evening and night, so occurrence values for the ditch are < 1.00/deer during those periods

Discussion

Successes from this preliminary trial include confirming the ability of the *WPS* to track wildlife within a 1 km range and collect both conventional and infrared video data, providing a unique opportunity to study wildlife behavior on and near road systems.

Deer activity was greatest at night (midnight to 7 AM), with the number of deer-minutes per hour over 2x higher at night than evening (7 PM to midnight), and over 15x higher at night than midday (7 AM to 7 PM). Similarly, the hourly rates of most collision-risk behaviors were greatest at night. This corresponds to patterns from Pennsylvania, where white-tailed deer were present near roads only from 5 PM to 8 AM (Peek and Bellis 1969) or were much more abundant from 5 PM to 6 AM (Carbaugh et al. 1975). However, when viewed as the rate per deer rather than per hour, risk behaviors in our study were all greatest during midday. These high per-deer rates correlated with informal observations from viewing the deer and video footage that deer were much more "skittish" and less sedentary during daylight hours than at night (i.e. frequently looking up, moving, re-entering the forest, etc.). It is not clear whether this difference in behavior was driven by daylight, traffic volumes, or some other factor correlated to time of day. Determining this relationship was not possible because peak traffic volumes corresponded to the daylight hours, so patterns could be attributed to either one of these variables. Isolating effects of the two variables would require either closing the highway to traffic for an extended period of time during the day, or having data from enough days to reliably compare high traffic-volume days to low traffic-volume days within the same general season.

Regardless of the causes of differences within the day, our data led to at least three important conclusions:

1. Within this study area in the autumn, deer presence on and near the highway appears to peak at night, rather than the "dusk and dawn" periods often assumed to be associated with maximum deer activity.

2. In spite of higher hourly rates of risk behaviors during the night, those deer that are located in the ROW during midday probably present a much greater risk per individual deer. This is because they are more likely to be on or approaching the highway, to be running while doing so, to cross in front of vehicles and to turn back part way through attempted crossings, in comparison to other times of the day. This risk is partly related to traffic volume (i.e. deer in midday presumably do not intentionally cross in front of vehicles; it is more likely the case that crossing are more often in the path of an oncoming vehicle then, simply due to higher traffic volumes). Deer collision-risk behavior may in fact be even greater than indicated by the measures we took, because increased deer movements may also be associated with decreased cognizance of vehicle presence. Furthermore, daylight would make these animals far more visible than those present in the evening or at night, but the much higher traffic volumes in midday presumably reduce lines of sight and increase the probability of multi-vehicle accidents caused by drivers swerving or braking to avoid deer. Thus, the net collision risk during midday, at least in our test section during autumn, is higher than the raw deer numbers would initially suggest, and may even be as high or higher during midday than at evening or night. Unfortunately, no reliable data is available indicating the time of day for wildlife collisions and other wildlife-related accidents in our test section. In a nearby study area within the Rocky Mountains, wildlife-vehicle collisions peaked at night and were lowest during midday (Clevenger et al. 2002). Similar patterns of collision rates peaking from late afternoon or evening through early morning have been found for white-tailed deer in Michigan (Allen and McCullough 1976), mule deer in Colorado (Reed 1981), and moose in Alaska (Garrett and Conway 1999) and Newfoundland (Joyce and Mahoney 2001). Collectively, those reports suggest that elevated risk behaviors during midday by individual white-tailed deer or other ungulates may not be adequate to compensate for the lower numbers of animals present, and therefore may not cause disproportionately high accident rates. However, it is not known whether animal movement, species-specific behaviors and traffic

patterns are consistent enough between study areas and between seasons to draw this conclusion. For example, Gordon (2001) noted dramatic differences between months in the proportion of Wyoming mule deer activity that occurred during the daytime, suggesting that daytime risk may be considerably higher in some months. Furthermore, it has been reported that over one-third of animal collisions in the southern interior of BC occurred from 7 AM to 7 PM (Province of British Columbia 2001, p. 67). In fact, "swerved-to-miss" types of accidents, which are potentially more common when traffic volumes increase, were not included in any of the studies cited above and are not typically recorded as being wildlife-caused, making any assessment of timing of wildlife-related accidents problematic. Preliminary data suggest that claims for such accidents cost ICBC roughly an additional 50% beyond losses for direct wildlife collisions (G. Gilfillan, ICBC, personal communication), so are a serious issue for economic and safety reasons. It should be stressed that our results are specific to the location and season in which the study was done. Deer activity patterns may differ considerably elsewhere in North America or at other times of the year. Factors such as predator activity and hunting may also have local effects on deer activity patterns.

3. At a minimum, it can be concluded that animal-vehicle collision risk can be a significant concern during midday, not just in the evening or at night. Thus, systems designed to be effective only at night, such as reflectors, are not appropriate in situations similar to those we observed. In addition, systems that are capable of working at any time of the day but which are switched off during the daylight to avoid causing driver complacency (such as flashing lights that are not tied to animal detections) would also be unsuitable. Systems such as the *WPS*, that work in all light conditions and create warnings only when animals are detected, provide more complete warnings of the hazards presented by deer on or near the highway.

Acknowledgements

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