

# Evaluation of the Wildlife Protection System Deployed on Highway 93 in Kootenay National Park During Autumn, 2003

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- ❖ Deer-tracking performance
- ❖ Effect on driving speeds
- ❖ Deer behavior
- ❖ Tracking of other species
- ❖ Maintenance issues
- ❖ Potential



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## Summary

A prototype of the Wildlife Protection System (WPS) was developed and first deployed in 2002. Its main components are an infrared (IR) camera that detects the body heat of animals entering the highway right-of-way, software that interprets this information, roadside warning signs with flashing lights that are triggered if wildlife is detected, and storage devices for the digital files. The WPS was again deployed in the summer and fall of 2003, using 1 km of the original test section in Kootenay National Park, British Columbia. This report summarizes measures of system performance, driver response and animal behavior, based on digital IR files collected between September 5 and October 14, 2003. Almost all animals recorded in the test section were deer (primarily white-tailed deer).

We measured system performance from 2 perspectives. *Absolute performance* measures were based upon precise estimates of the rates of tracking each deer and of falsely tracking non-animal heat sources ("falsing"), and were taken only from dusk to dawn. *Functional performance* measures represented the success of the system from the drivers' point of view, taking into account that (a) only 1 deer out of the total number present needed to be tracked in order for lights to flash; (b) falsing was irrelevant to system success if it occurred simultaneous to tracking of animals that were actually present; and (c) roadside lights continued to flash for 30 seconds beyond the end of any tracking event, whether real or false. Functional performance was measured for both day and night.

Absolute tracking success was affected very little if at all by temperature or time of night, with rates of close to 70% being typical. The main downward influence on tracking success was that deer remaining for extended periods were eventually lost in most cases. The rate of tracking of each deer at some point in its stay within the test section was much higher. In contrast to tracking, the rate of falsing was strongly influenced by weather, with falsing rates much higher on nights following warm days, and earlier in the night. Falsing rates as low as 7% and as high as 43% were observed, depending on temperature and time. Functional measures of performance were also influenced by temperature and day versus night. On cool nights, lights were flashing or not at appropriate times an average of 89% of the time, compared to 71% on warm nights, 72% on cool days and 25% warm days. Thus, on cool nights, the system was considerably more effective in providing appropriate guidance to drivers than the raw tracking and falsing rates would suggest.

Driving speeds were about 6 to 9 km/h lower within the test section than elsewhere in the park, even when the lights were not flashing. This was probably due to the presence of the equipment, signs and (for drivers with radar detectors) radar guns. Those values are probably conservative, as the comparison data comes from a portion of the park that should have lower driving speeds than within the general test section area. Even so, the driving speed appeared to drop further still when lights were flashing. Exact speed reductions could not be estimated because it was not clear how many of the radar-speed samples were from independent cars, but the data suggested reductions of a further 4 to 12 km/h. Thus, it appears that the total effect of the system, when lights were flashing, was a reduction of at least 10 to 21 km/h. Greater reductions may have been possible there been a more intensive effort to provide information about the system to park visitors this year. Anecdotal information suggested that drivers were more responsive to the presence of roadside deer when lights were flashing than when they were not flashing.

Deer behavior this year was correlated not only to time of night, but also temperature on the preceding day. Although roughly the same numbers of deer were present in the right-of-way regardless of the weather (almost exactly 1 deer at any given time, within the 1-km test section), they tended to be predominantly present early in the night when warm, and later in the night when cool. At any given time, the probability of a deer within the right-of-way being immediately adjacent to the road was about 33%, the great majority of which were stationary or traveling away from the road. The probability of a deer within the right-of-way being on the highway itself at any given time was about 5%, with a deer completing or aborting a crossing about once every 49 minutes on average. However, data was highly variable, with a range of 0 to 48 deer crossing or attempting to cross the highway per night within the test section. The type of behavior exhibited by deer when on the highway differed somewhat depending on weather and time of night. The probability of crossing in front of oncoming vehicles was higher earlier in the night (when more vehicles would have been present), and the probability of running when crossing was higher on cool nights. Results differed somewhat from those of 2002. This is probably because the sample was

taken several weeks later this year, since deer activity was related to temperature. However, like 2002, no wildlife-vehicle collisions were observed on IR footage. In situations where animal behavior is relatively predictable, knowledge of it could ultimately be used to guide the operation of the WPS.

Species other than deer that were identifiable on IR footage by human observers and that were tracked at least part of the time by the WPS included, elk, bears (apparently black bears), wolves and coyotes. Within the limitations of the very small dataset for these species, tracking success appeared to correlate to body size.

Maintenance issues related mainly to problems with the power supply and difficulties with computer malfunctions. Most, if not all, of these problems would likely be reduced or eliminated in locations where power could be accessed from power lines, rather than being generated on-site. Despite the need for ongoing improvements, there were many positive developments and indications during 2003. These included (a) the high initial tracking rates of deer; (b) the overall high functioning of the system on cool nights; (c) the potential for use in studying wildlife activity on, near and in crossing highways, including species other than deer; (d) the ability to track many animals beyond the 1-km limits that were formally tested; (e) the reduced driving speed in response to the signage and flashing lights; and (f) the potential for use as a portable tool to aid in preventing wildlife-vehicle collision, supplant or supplement existing crossing structures or fencing, and provide research opportunities.

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## 1. Introduction

In response to a need for an effective, low-impact method of reducing animal-vehicle collisions, InTransTech Corporation (ITT) and the Insurance Corporation of British Columbia (ICBC) developed a prototype Wildlife Protection System (WPS) in 2002. The concept is that an infrared (IR) camera detects the body heat of wildlife entering the highway right-of-way, software uses algorithms to interpret this information, roadside warning signs with flashing lights are triggered, and, if desired, digital files are stored for later analysis. The WPS was first deployed on a 2-km section of Highway 93 in Kootenay National Park (KNP) in southeastern British Columbia, Canada (Figure 1) in the summer and fall of 2002. Based on a review of IR files from that year, deer behaviors were analyzed in relation to collision hazard (Kinley et al. 2003).

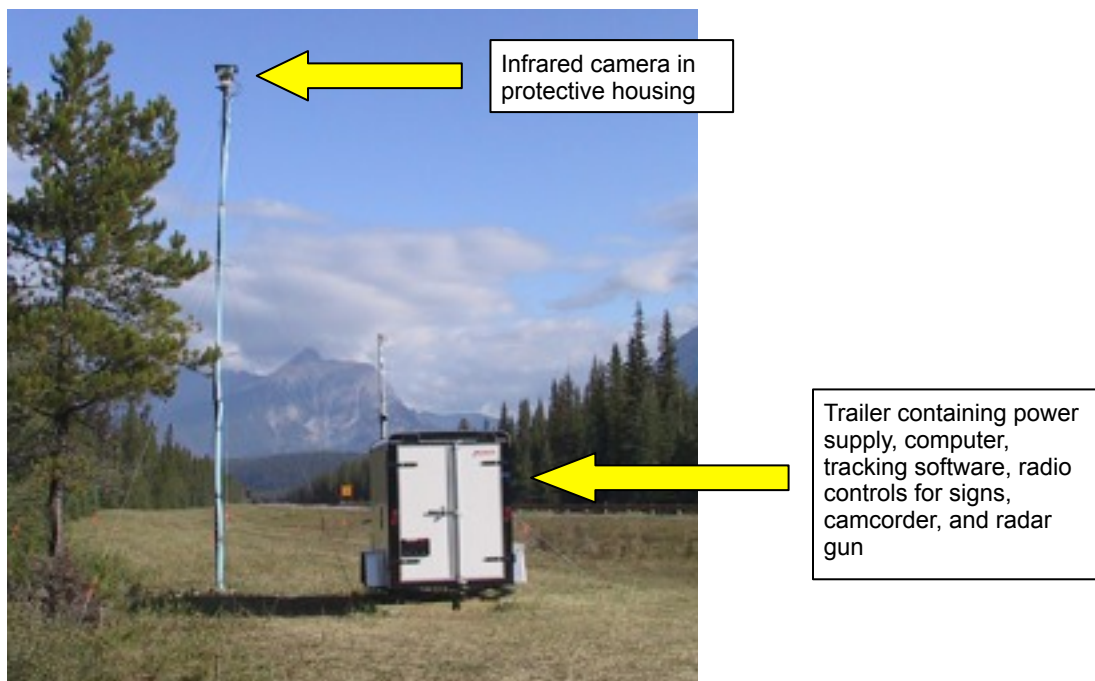
The WPS was again deployed in the summer and fall of 2003, using the southern half (1 km) of the original test section. The right-of-way was adjacent to a straight, level highway. Mowed, treeless ditches about 1 to 2 m below the road surface extended 18 m on each side of the pavement out to pine-spruce forest. The WPS (Figure 2) consisted of 2 trailers facing either end of the highway test section, with each trailer containing a power-supply system, a computer linked to an external IR camera mounted on a steel pole about 7 m high, a conventional digital camcorder, a radar gun, and a radio unit to communicate both with the other trailer and with switchable, solar-powered flashing lights located within the test section. One major change for 2003 was that the supercooled *QWIP* camera based on a Quantum Well Infrared Photodetector focal plane array (QWIP Technologies, Altadena, CA) used in 2002 was replaced with an uncooled *FLIR* camera (FLIR Systems, Portland, OR). The anticipated shorter range of this year's camera was responsible for the test section being shortened from 2 to 1 km. When the IR camera and software in the computer collectively detected an animal within the test section from either or both trailers, a tracking box appeared around it on the digital IR image, and the flashing roadside lights were switched on. If the animal moved out of the camera's field of view or was otherwise no longer being tracked, the lights remained flashing for an additional 30 seconds. An *Excel* data log in each computer recorded each "event", which would be the initiation or completion of a tracking session, or a change in speed detected by a continuously operating radar gun. The log recorded speeds in relation to whether the flashing lights were on or off. Files of infrared camera and camcorder footage were also stored on the computer. As in 2002, power for the IR camera and equipment in the trailer was generated on site because no power lines were present in the test section. More details of system operation have been reported elsewhere (Kinley et al. 2003; R. Soukoreff, XyTech Systems Inc., Fort Saskatchewan, Alberta, unpublished report).

Based on anecdotal observations and IR files, over 99% of animal-minutes of wildlife visible in the test section were produced by deer. These were almost entirely white-tailed deer, with a few mule deer also present. The 2 deer species could not be reliably differentiated from each other visually using IR footage, but deer species combined could generally be distinguished from other species. Traffic volumes in September 2003 averaged 2538 vehicles/day and in October were likely similar to the 2002 value of 1777 vehicles/day (M. Den Otter, Parks Canada, Radium Hot Springs, British Columbia, unpublished data).

During 2003, several large wildfires in the park resulted in the closure of Highway 93, so WPS testing was delayed until September. The following report summarizes the WPS's function from September 5 to October 14, 2003. The system was set to trigger lights only during a nominal dusk to dawn period, defined as 8:00 PM to 6:00 AM until September 17, then 7:30 PM to 7:00 AM until October 8, and 7:30 PM to 7:30 PM thereafter. A sign indicating that the system was functional from dusk to dawn only was placed at each end of the test section. This report summarizes animal-tracking performance (both from functional and absolute accuracy perspectives), the response of drivers to flashing lights, roadside deer behavior, other species recorded by the WPS, and maintenance issues for 2003. It also provides suggestions for refinement of the system. Partners in the WPS during 2003 included ITT, ICBC and Parks Canada.



**Figure 1.** Location of Wildlife Protection System test section along Highway 93 in Kootenay National Park, British Columbia, Canada.



**Figure 2.** Wildlife Protection System test equipment beside Highway 93, Kootenay National Park, viewing to north. In 2003, the test section began 200 m north of this trailer and extended for 1 km. Identical equipment was oriented into the test section 200 m beyond the opposite end.





## 2. Tracking Performance

Sections 2.1 and 2.2 summarize measures of WPS performance from 2 perspectives. **Absolute performance** refers to true measures of the system's rate of tracking each deer and errantly tracking non-animal heat sources. **Functional performance** refers to whether the correct signal (to flash or not) was transmitted to roadside lights, both (a) in relation to whether that signal was generated by tracking some deer, all deer, or non-animal heat sources, and (b) regardless of the source of the signal. Thus, for both performance approaches, we used 2 sources of information:

- Success in tracking deer present within the test section.
- Rate of falsely tracking other heat sources ("falsing"). A portion of the image of the test section visible from each camera was designated as an exclusion zone. This covered the highway and immediately adjacent portions of the ditch. Any hot objects appearing within the exclusion zone without having previously moved through the test zone (the remainder of the ditch), were interpreted by the software as vehicles. Occasionally, a large truck would travel near the edge of the highway. In doing so, and because of the exclusion zone's geometry in relation to the cameras' oblique orientation to the axis of the highway, the exhaust stacks sometimes appeared outside of the exclusion zone (in the test zone), and resulted in falsing. The other type of falsing occurred when unknown, ephemeral sources of heat, assumed to be warm air, warm ground, drifting exhaust or possibly small animals not visible to the human eye, occurred within the test zone and triggered a tracking event.

### 2.1 Absolute Measures of Performance

The system's rate of tracking each animal within the test zone and of falsing were determined instantaneously, from paused IR video footage, at the top of every minute from dusk to dawn. At each minute, records were made of the number of deer present, number of deer tracked, and whether falsing was occurring. Results were cross-referenced between files from the north and south trailers. If a deer was tracked by at least 1 camera, that animal was considered to have been successfully tracked, and if falsing occurred from either end it was recorded as a falsing event. This yielded a relatively precise estimate of the proportion of time the system was generating false tracking information and the proportion of time that each animal was tracked. Absolute tracking accuracy was measured only for the night because: (a) the great majority of deer were present then; (b) falsing was so high during the day that it was unlikely the system would be made functional during daylight hours in 2003; and (c) determining absolute performance was very labor-intensive.

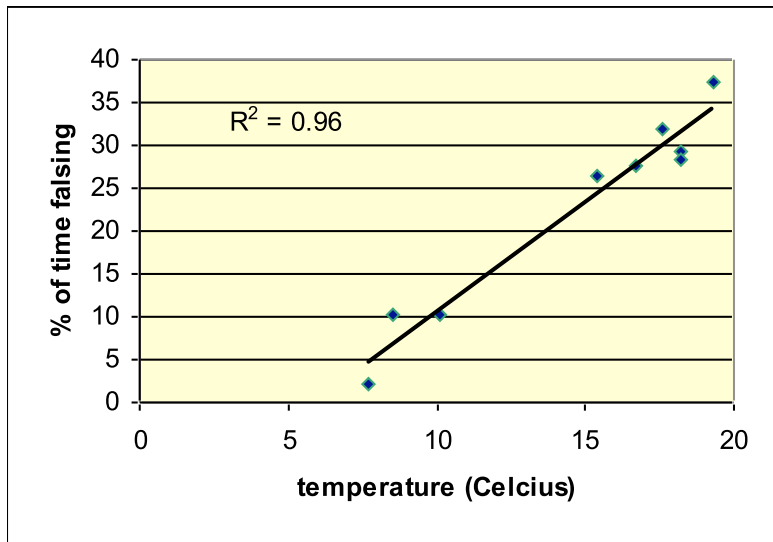
Relatively little data was available in 2003 due to WPS malfunctions (see section 6). Absolute performance was analyzed for 9 nights during which 3 or fewer hours of IR files were missing (8.5 to 11.5 hours of footage available per night). There were another 7 nights that fit this criterion, but the large (13 - 30Mb) IR files for those nights were overwritten before testing was completed because the additional firewire drives needed to store them were not yet available, and because at the time it was not anticipated how few nights of complete data would be available later in the test period. In any event, the 9 nights of data did provide a reasonably representative sample.

#### ***Falsing***

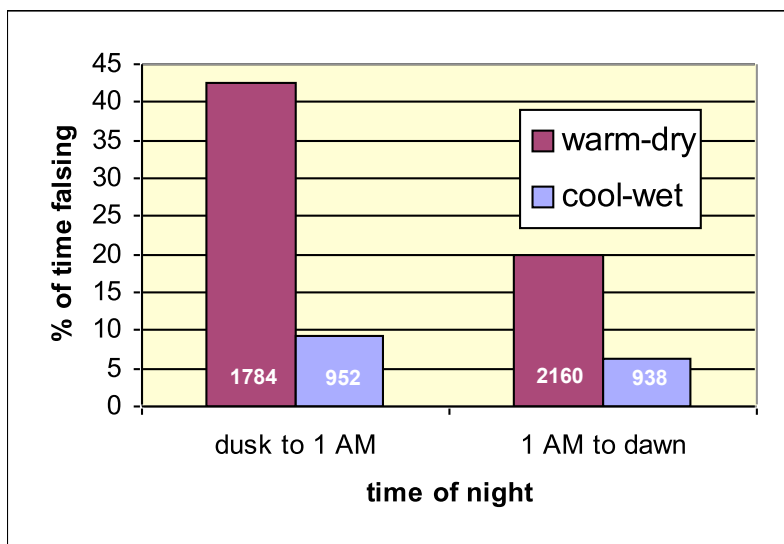
It was soon apparent that daytime temperature affected the level of falsing on the subsequent night, so the analysis was stratified on that basis. Data from the nearby Kootenay Crossing weather station was not available at the time of writing, so records were taken from an Environment Canada automated weather station at Field, in Yoho National Park. The Field station is about 75 m higher elevation, 60 km farther north, and in a cloudier area than the WPS test section, so it probably averages 1 to 2°C cooler and with slightly more precipitation than at the test section. Six nights were designated as "warm-dry" (maximums at Field of 15.4 to 19.3°C on the previous day, and no rain during the 24 hours in which the sampling period fell) and 3 nights as "cool-wet" (maximums of 7.7 to 10.1°C, with 0.6 to 4.2 mm of rain).

The rate of nighttime falsing was strongly correlated to the daytime temperature (Figure 3). Using average values between dusk and dawn, the probability of at least one camera falsing at any given instant ranged among nights from just over 2% to almost 38%. There were also strong differences within the night, with falsing being more prevalent between dusk and 1:00 AM than during the cooler 1:00 AM-to-dawn period (Figure 4). Presumably the increased level of falsing with higher temperatures was mainly related to the greater incidence of warm air pockets or warm patches of ground. Part of the lower falsing rate after 1:00 AM may have been due to reduced number of vehicles creating exhaust or having exhaust stacks pass through the IR cameras' test zones.

Falsing was about 13% more likely to occur on the north camera than on the south camera (738 versus 652 events, for periods when the camera that falsed was recorded). This could have been caused by differences in the sensitivities of the 2 cameras, their positions in relation to daytime heating surfaces, and/or by differing rates of truck exhaust stacks appearing outside of the exclusion zone, as this relates to the different shapes of exclusion zones drawn for the 2 cameras.



**Figure 3.** Rate of “falsing” (tracking of non-animal heat sources) from dusk through dawn in relation to maximum daily temperature. Values represent the probability of falsing by at least one camera at any moment. Temperatures are from a weather station with values about 1 - 2°C cooler than the test section.

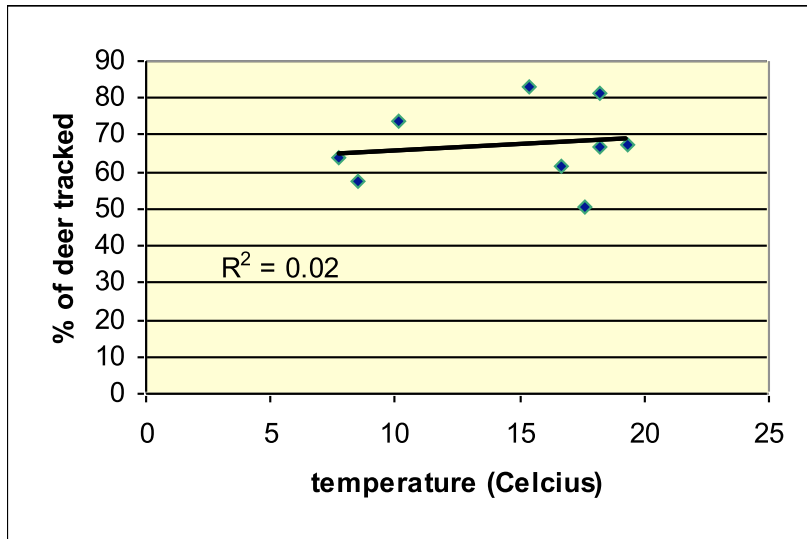


**Figure 4.** Rate of nighttime “falsing” in relation to time of night and weather. Values represent the probability of falsing by at least one camera at any moment. Number of samples at base of columns.

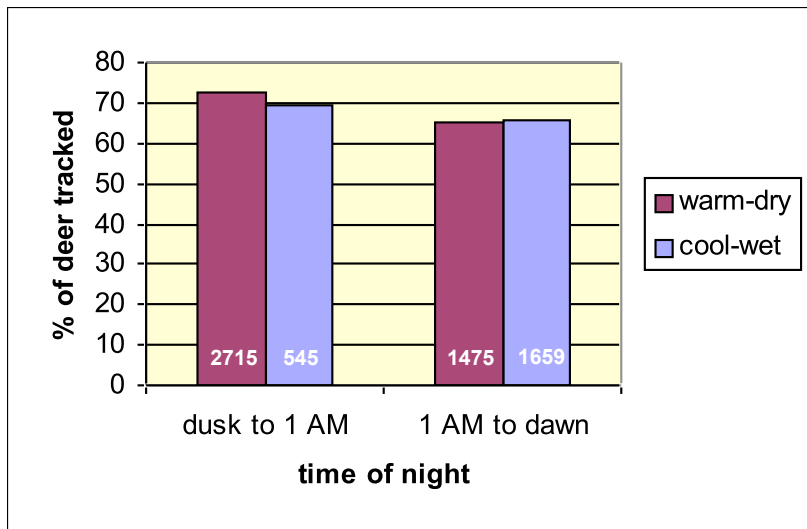


## Tracking

Based on total values between dusk and dawn, nightly proportions of deer (or more accurately, deer samples) within the test zone that were tracked varied from 51 to 82%. However, unlike the rate of falsing, the tracking rate did not appear to be appreciably affected by temperature, either as measured by the maximum temperature on the preceding day (Figure 5, Figure 6) or in relation to the time of night (Figure 6).



**Figure 5.** Rate of successful tracking of deer from dusk through dawn in relation to maximum daily temperature. Values represent the probability of any deer being tracked by at least one camera at any moment. Temperatures are from a weather station with values about 1 - 2°C cooler than the test section.



**Figure 6.** Rate of successful nighttime tracking of deer in relation to time of night and weather. Values represent the probability of any deer being tracked by at least one camera at any moment. Numbers at base of columns are number of samples with deer present.

Although we did not develop means of measuring other factors that might have affected the tracking success rate, it is clear that it was influenced by:

- Distance from camera. The images of deer close to a camera obviously covered more pixels on the IR image and were therefore more likely to be tracked than those farther away.

- Duration of stay. Deer that remained motionless or nearly so for extended periods (more than about 1 minute) were almost always lost from tracking. If deer were in the test zone (part of the ditch) when this happened, they were generally soon re-tracked and interpreted by the WPS as deer, with minimal implications for system performance or safety. However, deer were often in the exclusion zone (which included a large part of the roadside) when they were lost from tracking. In this case, the software interpreted them as vehicles if it began tracking them again. Deer could then remain for periods of several minutes to nearly an hour on the roadside or even road surface without triggering flashing lights. **This issue had the greatest impact on tracking success.** However, the loss of tracking was not universal as there were also examples of (a) deer being tracked continuously for periods of 15 to 30 minutes even when remaining essentially motionless, and (b) deer being lost even when moving.
- Direction of arrival. A few deer did move directly into the test zone without passing through the exclusion zone. This rare event was possible only when deer entered the test section by traveling longitudinally or diagonally down the highway from behind a camera's field of view to enter the extreme north or south ends of the test section. This situation happened more at the north end, due to the geometry of the exclusion zone there.
- Sudden movements. Animals that moved quickly, particularly when changing direction rapidly, were often lost temporarily, especially when distant from the cameras. However, they were generally soon re-tracked if they remained within the test zone.
- Moving behind road signs.

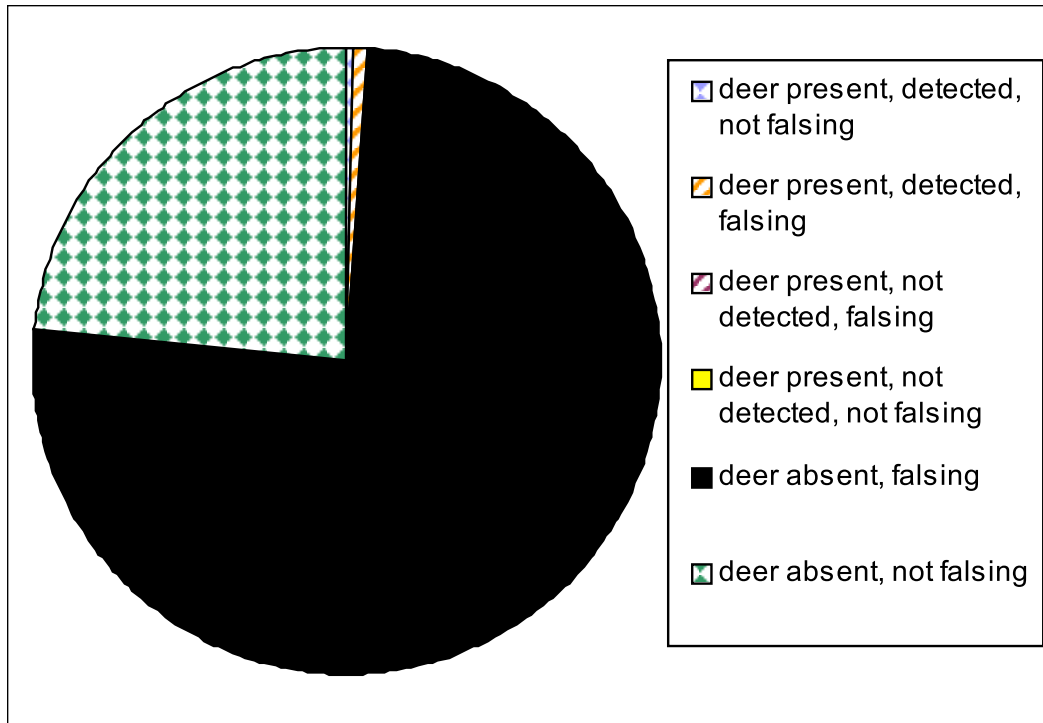
## 2.2 Functional Measures of Performance

Until September 20, this method was mainly used to provide daily feedback on system performance from the perspective of a driver. Therefore, in addition to quickly estimating levels of falsing and tracking, we determined whether the system gave the appropriate signal (lights flashing versus not flashing) regardless of how this came about. For example, if 2 deer were present but only 1 was detected, the system was still considered to be functionally correct because the lights were flashing. If neither deer was detected but the system was coincidentally falsing on another heat source, it was also considered to be functionally correct. Our time unit for measuring falsing or tracking was 30 seconds, because the WPS employed a delay of 30 seconds from the time it stopped tracking an object until the lights stopped flashing. Thus, an animal tracked only once per 30 seconds (or a false heat source generating a tracking signal) would still result in the lights flashing continuously. The first 30 seconds of data in each 15-minute block were reviewed to determine if at least 1 camera tracked at least 1 deer (if any were present) at any point in the 30-second sample, or whether at least 1 camera was falsing at any point in the 30-second sample (regardless of whether any deer were present). Data was evaluated for both day and night.

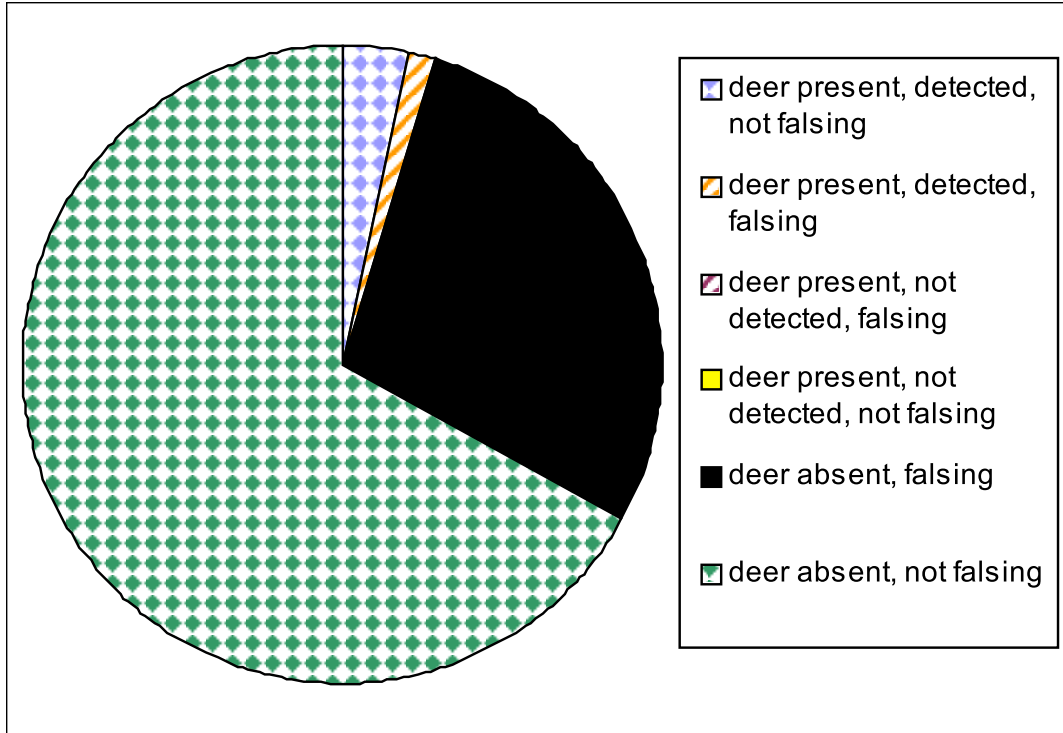
Because this approach was initially used to provide real-time feedback on system performance, some assessments were done immediately after files were recorded, for both day and night, and regardless of how many IR files were missing. As a result, the 7 nights of files that could not be used for absolute performance evaluation because they had been overwritten had already been included in the functional performance evaluation. However, functional-performance measures provided worthwhile information on how drivers in the WPS test section might view its success, so we continued it with data collected beyond September 20, after the initial evaluation period. Files collected after that date were assessed after system testing was completed, and were used only if 3 or fewer hours of files were missing from the monitoring period (day or night). Using the same weather criteria as for the absolute performance evaluation, 7 warm-dry days, 6 cool-wet or cool-dry days, 8 warm-dry nights, and 9 cool-wet or cool-dry nights were assessed for functional performance.

The proportion of time during which the WPS gave the correct message to motorists, with reference to lights flashing or not, varied with temperature and time of day (Figures 7 - 10). Differences in functional performance between day and night and between warm and cool were largely the result of much higher falsing rates during the day and with warmer conditions. This is consistent with the relationship between temperature and falsing rates, described above (Section 2.1). However, deer were often present when the system was falsing, so falsing often occurred simultaneous to or instead of tracking. As a result the

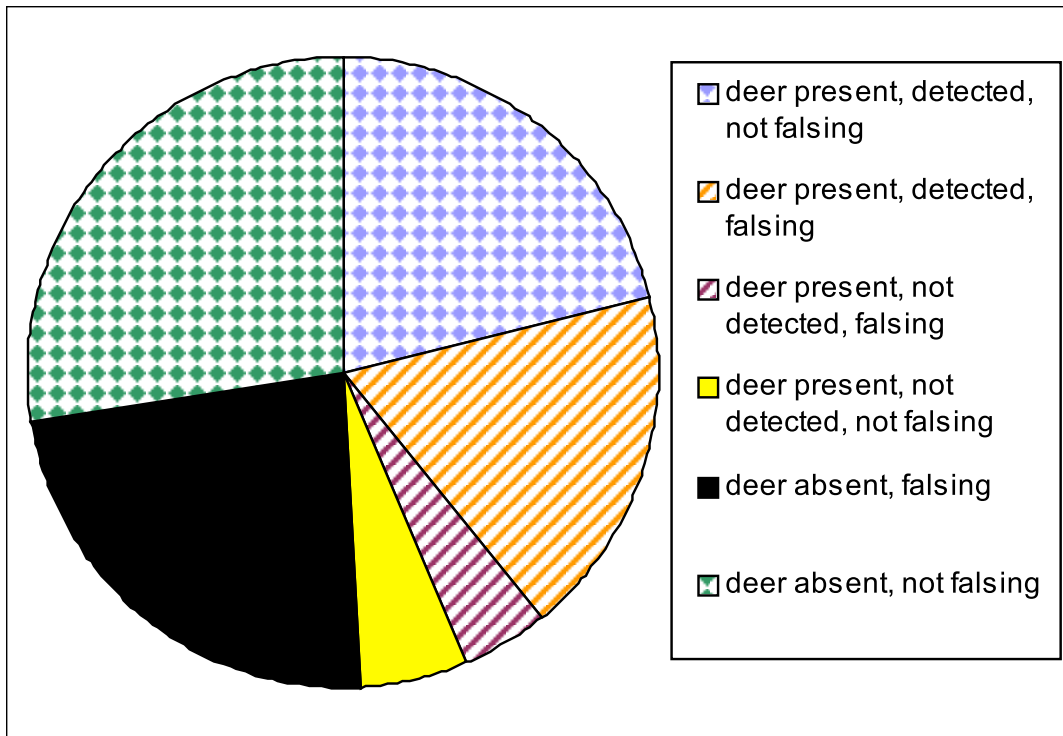
system was functionally correct during the night more often than indicated by absolute rates of falsing and tracking (Section 2.1), at least for nights following cool days. Thus, motorists traveling through the test section at night would have observed lights either flashing or not flashing at the appropriate times about 71 to 89% of the time when the system was activated, depending on temperature (Figures 9 and 10). Had the lights been activated during the daytime, a functionally correct signal would have been generated about 25 to 72% of the time (Figures 7 and 8). The daytime performance might have been considerably lower had there been more deer present; the near lack of deer during the daytime meant that any lack of performance was due almost solely to falsing.



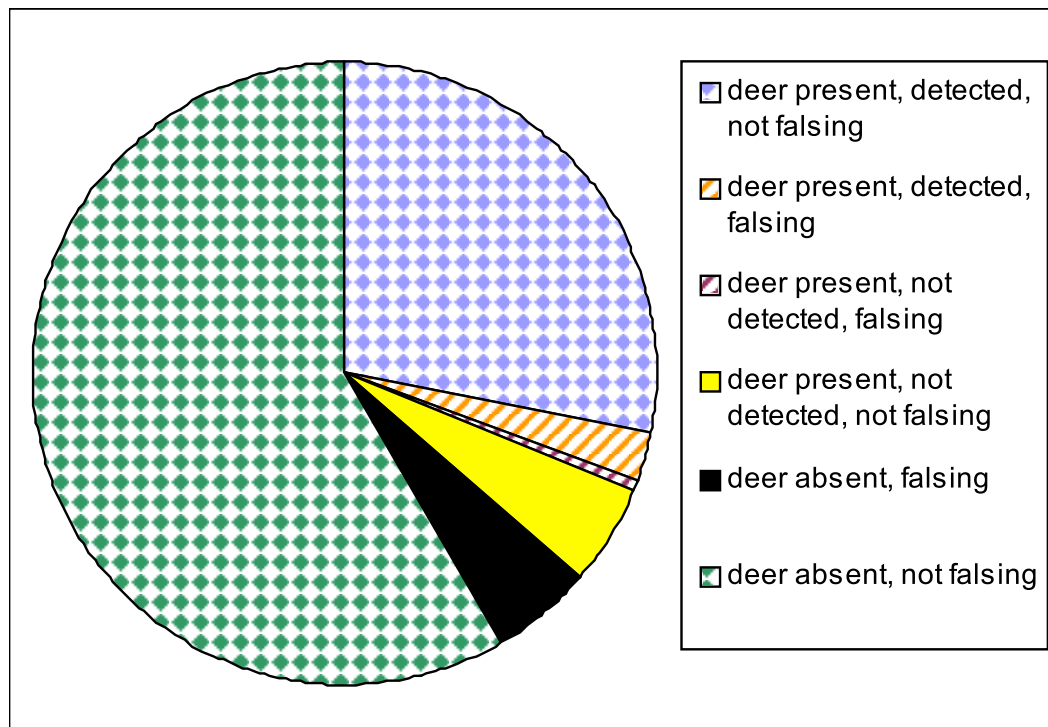
**Figure 7.** WPS functional performance during daytime on warm-dry days (n = 347 observations). System status was completely correct for checkered segments, functionally correct despite falsing for cross-hatched segments, and completely erroneous for solid segments. System performance tests for daytime periods were hypothetical only, as the flashing lights were not functional during between dawn and dusk.



**Figure 8.** WPS functional performance during daytime on cool days (n = 188 observations). System status was completely correct for checkered segments, functionally correct despite falsing for cross-hatched segments, and completely erroneous for solid segments. System performance tests for daytime periods were hypothetical only, as the flashing lights were not functional during between dawn and dusk.



**Figure 9.** WPS functional performance during nighttime following warm-dry days (n = 313 observations). System status was completely correct for checkered segments, functionally correct despite falsing for cross-hatched segments, and completely erroneous for solid segments.

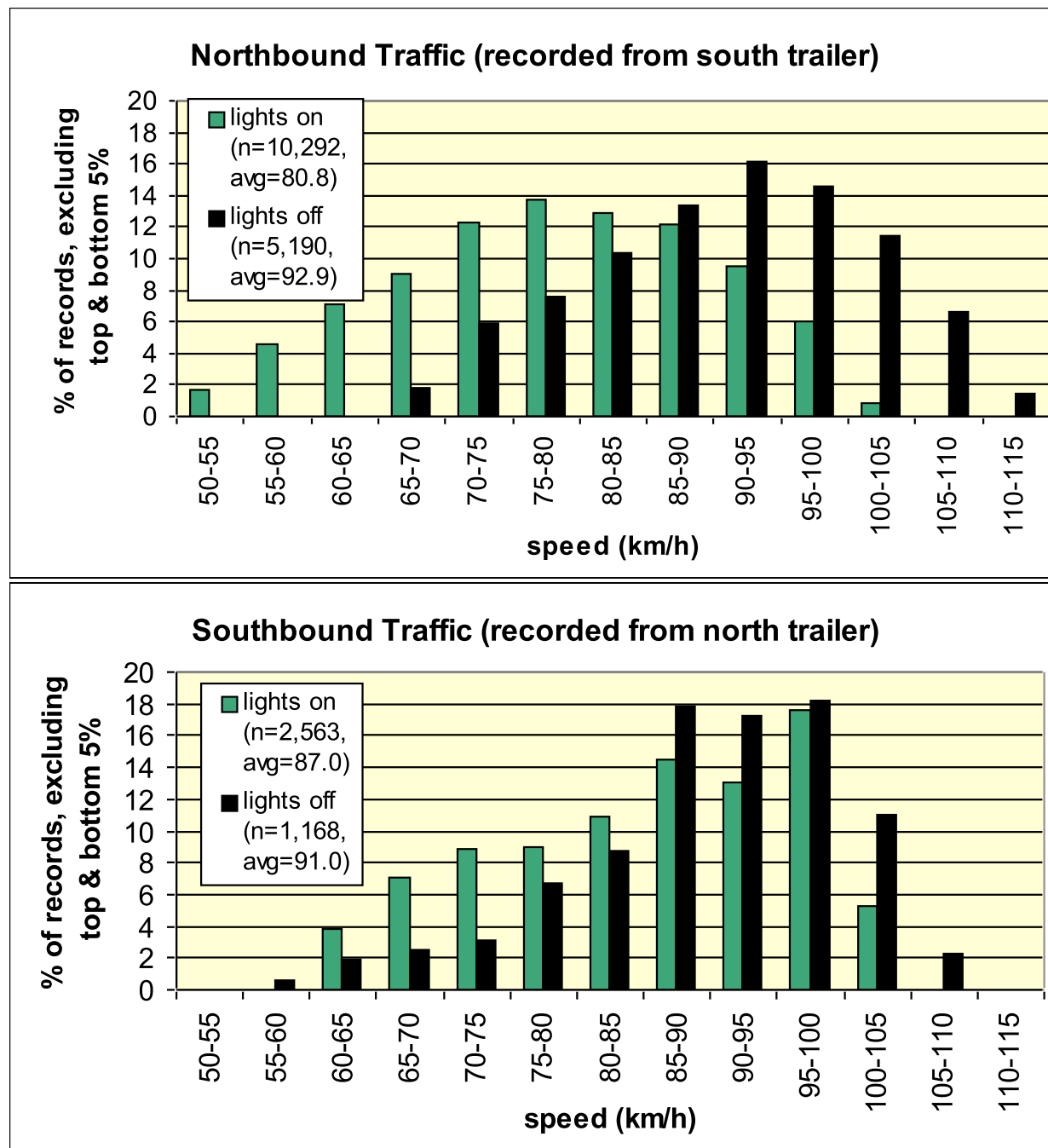


**Figure 10.** WPS functional performance during nighttime following cool days (n = 336 observations). System status was completely correct for checkered segments, functionally correct despite falsing for cross-hatched segments, and completely erroneous for solid segments.



### 3. Effect of Flashing Lights on Driving Speed

Radar guns aimed into the test section were deployed in each trailer. Driving-speed data was collected from dusk to dawn, when lights were potentially flashing. All changes in recorded speed were stored in an *Excel* event log at each trailer. Speeds were assessed on 17 nights. A software program developed by Russ Soukoreff of XyTech Systems Inc. allowed collation of speed data from each trailer into 5-km/h increments, both for periods when the flashing lights were on, and when they were off. Data is presented, less the fastest 5% and slowest 5%, in Figure 11.



**Figure 11.** Effect of lights flashing on nighttime speed index recorded at each trailer of the WPS on Highway 93, Kootenay National Park, September - October, 2003.

Figure 11 suggests that speeds recorded by the south trailer dropped by over 12 km/h, while those from the N trailer dropped 4 km/h. While it is apparent that speeds were reduced when lights were flashing, the results should be interpreted cautiously. It is not clear what length of highway each radar gun covered. There also appeared to be considerable differences between the setup of the 2 guns (possibly as a result of subtle differences in the orientations of the 2 trailers to the highway), because the north trailer consistently obtained far fewer speed records, especially when the lights were not flashing. In addition, there was no ability to determine whether a sequence of recorded speeds was the result of 1 car that varied its speed, or a series of cars traveling at different speeds. That relationship undoubtedly varied with traveling speed. Thus, speeds summaries reported above must be viewed as an index only, and not a true average.

It should be noted that, in 2003, there was no organized effort to make travelers entering KNP aware that the WPS test section was in place. Reductions in speed might well have been greater had motorists been aware in advance that they would be encountering a site with many roadside deer and an accident-reduction system in place.

An additional complication with interpreting this data is that "lights off" speeds were already considerably lower than they would have been had the test equipment not been present. This is based on 3 observations:

1. Even when lights were not flashing, drivers were exposed to a great deal of yellow signage for the test section, in addition to 2 trailers and camera towers and the 2 entrance signs for the Dolly Varden day-use area. The sudden appearance of this signage and equipment seemed to affect driving speed.
2. Drivers with radar detectors would have realized that radar guns were in use and would have lowered their speeds accordingly, regardless of whether lights were flashing.
3. More empirically, speed data collected for Parks Canada near the north end of KNP, an area that is more mountainous and has more curves, narrower, deeper ditches, and often poorer weather than the test section, showed higher averages than "lights-off" speeds in the test section. Data from the north end of the park shows mean speeds of 99 to 100 km/h during both days and nights in September 2003 and October 2002 (M. Den Otter, Parks Canada, Radium Hot Springs, British Columbia, unpublished data). The WPS test section "lights off" (baseline) mean speed values shown in Figure 11 were 6 to 9 km/h slower than that, despite driving conditions in the test section being considerably better.

Therefore, it appears that the presence of the test section reduced driving speeds even when lights were not flashing, so that the additional effect of the lights actually flashing was somewhat dampened.

One perspective on this situation is that the presence of test equipment and signage resulted in the flashing lights themselves having less impact. An alternative perspective is that the flashing lights plus the other signage and equipment collectively resulted in a major drop in speeds compared to what they would have been had the WPS test section not been there. In summary, driving speeds were measurably reduced when roadside lights were flashing, but the magnitude of this change is difficult to quantify.

In addition to general reductions in speed when lights were flashing, one key to decreasing the probability of animal-vehicle collisions would be to increase driver reaction to individual deer. The test section's signage likely increased driver alertness. While measures of driver behavior were not investigated except for changes in speed, informal observations were made opportunistically at the test section when deer were present. From these, it seemed that drivers were more likely to reduce their speed when approaching roadside deer if lights were flashing than if lights were not flashing. Thus, flashing lights may have not only reduced average speeds, they may have preconditioned drivers to be particularly responsive to deer they observed themselves.

## 4. Deer Behavior

Deer behaviors that were relevant to the risk of animal-vehicle collisions were recorded, based on an approach modified from that used by Kinley et al. (2003). The same sampling units and methods were used as for the absolute performance assessment. The following information was recorded from paused IR file footage at the top of every minute for dusk-to-dawn periods, with results cumulated and cross-referenced between trailers:

- number of deer on the paved road surface;
- number of deer on either roadside (slope between pavement and flat part of ditch); and
- number of deer in the remainder of the right-of-way, over to the treeline on either side of the road (hereafter "ditch").

For deer visible at the roadside on paused footage, files were played forward or backward until each deer could be classified as:

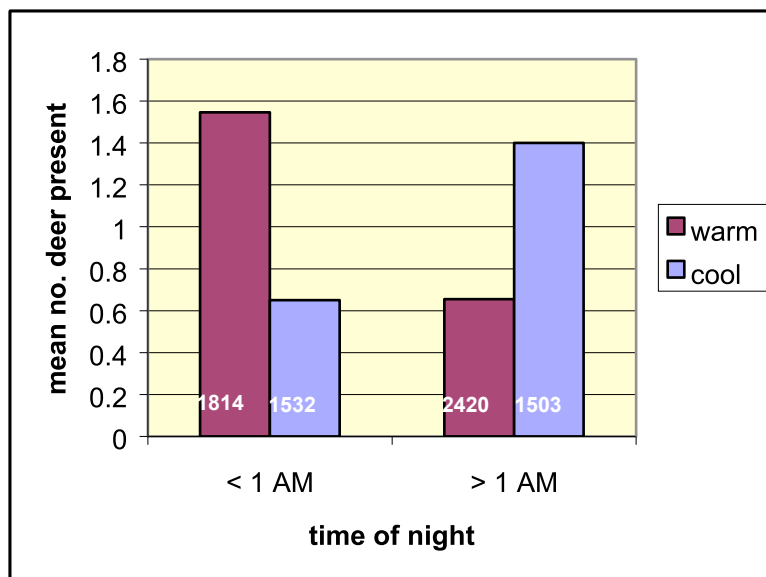
- approaching the pavement at a run (recorded if any portion of the approach was running);
- approaching the pavement at a walk; or
- not approaching the pavement (i.e. stationary or retreating).

For deer visible on the paved road surface from paused IR footage, files were played until each deer was classified as:

- walking versus running (considered running if any portion of the crossing was at a run);
- passing in front of an oncoming vehicle versus not doing so; and
- completely crossing the road versus (a) aborting the attempted crossing or (b) being hit by a vehicle.

Deer behavior is likely to be influenced by current weather conditions at least as much as by general weather trends from the preceding day. However, hour-by-hour weather data was not available, so the stratification by weather was limited to daily trends. We based behavioral assessments on the same files used for absolute performance analysis, but added 2 additional cool-wet nights and 1 warm-dry night, for a total of 7 warm-dry nights and 5 cool-wet nights.

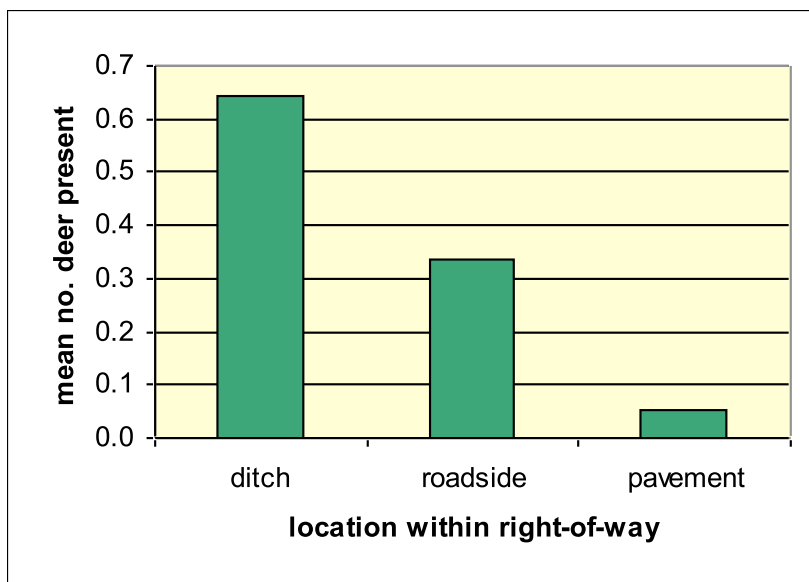
The average number of deer present within right-of-way of the test section at any point in time was almost identical on warm nights (mean = 1.04 deer over 4234 samples) and cool nights (1.02 deer, 3035 samples). However, the distribution of deer with respect to the time of night differed considerably with weather (Figure 12). Thus, drivers were over twice as likely to see deer before 1:00 AM on warm days, and over twice as likely to see them after 1:00 AM on cool days.



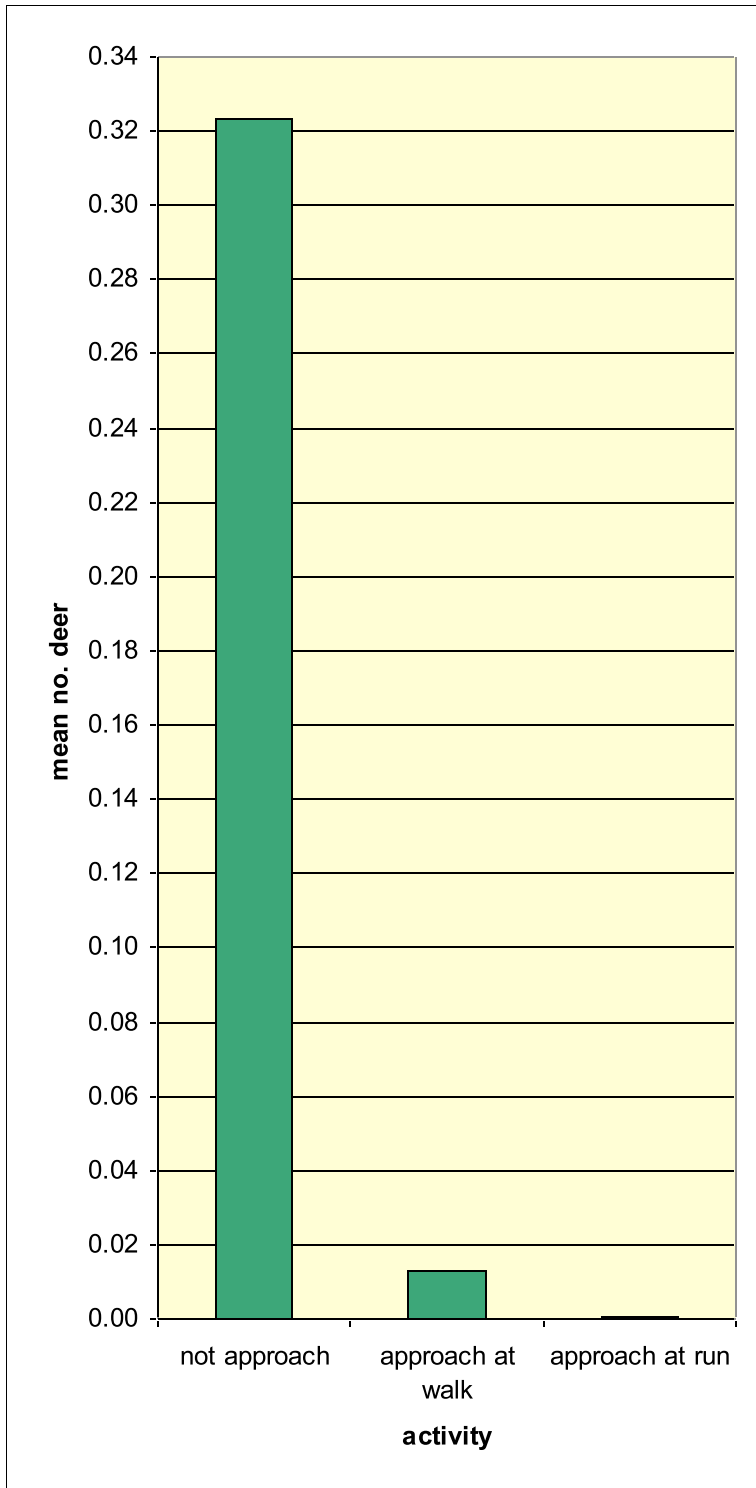
**Figure 12.** Mean number of deer present in right-of-way at any point in time within 1-km test section, in relation to weather and time of night (dusk to dawn). Numbers at base of columns are sample sizes.

Within the highway right-of-way, most deer were in the ditch, but roughly 1 in 3 was on the roadside and about 1 in 20 was on the paved road surface (Figure 13). Of those on the roadside, virtually all were either stationary or moving away from the road when observed (Figure 14), with deer walking toward the pavement on about 4% of the samples and running toward the pavement on only about 0.1% of the samples (2 deer). Using continuous footage (not paused samples), there were 148 observations of deer on the paved highway surface in just over 121 hours of nighttime footage, an average of 1.22 times per hour (once every 49 minutes). Numbers were similar for warm (1.29 per hour) and cool (1.13 per hour) nights. However, rates of deer crossings or attempted crossings were highly variable, ranging from 0.00 to 2.96 per hour on cool nights and 0.17 to 4.17 per hour on warm nights (nightly totals of 0 to 48 deer). No deer were struck by vehicles. Regardless of the time of night, the majority of deer on the highway were walking rather than running, and crossed completely rather than aborting the crossing attempt (Figure 15). The likelihood of being on the highway in front of an oncoming vehicle was greater before 1:00 AM (Figure 15), due at least in part to the much higher traffic volumes then. The proportion of deer crossing in front of oncoming traffic and the proportion successfully completing crossings did not differ between nights following warm days and nights following cool days (Figure 16). However, deer were more likely to be running when on the highway on cool nights than on warm nights (Figure 16). Reasons for this are unclear.

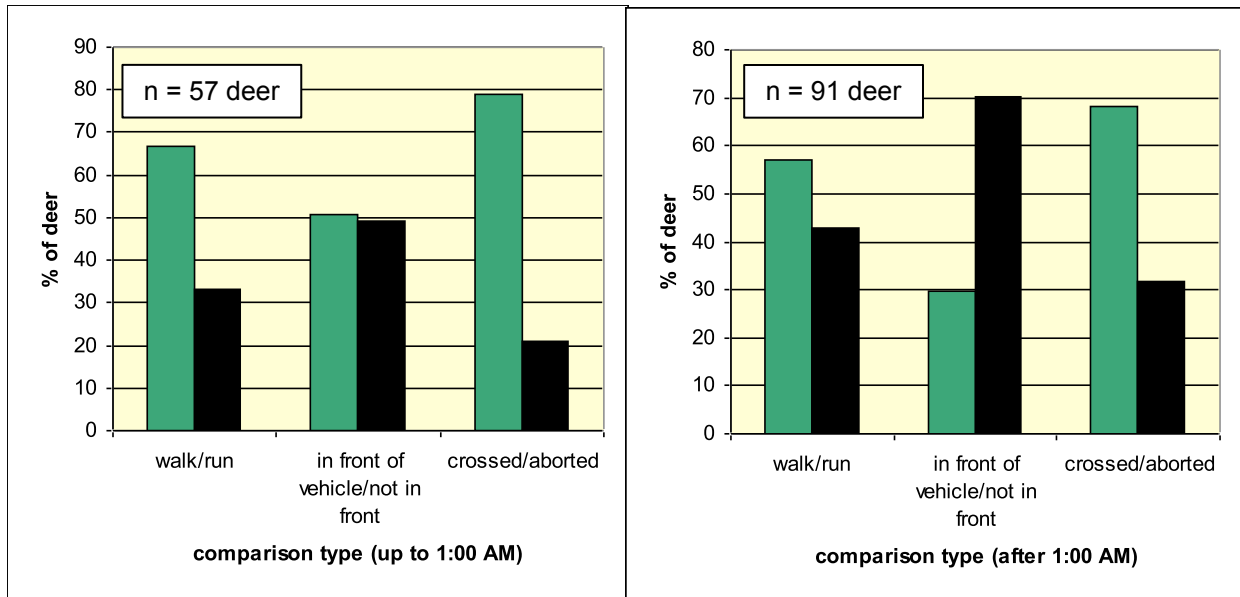
Samples within temperature and weather strata were highly variable and almost certainly included multiple observations of the same deer, so the results should be interpreted with caution. However, within that limitation, the per-driver risk of collision appeared to be highest after 1:00 AM following cool days. This was because such periods had a high number of deer on the highway (Figure 12) and there was a higher proportion of deer running on cool nights than on warm nights (Figure 16), and late in the night compared to early in the night (Figure 15). However, the chance of collisions at such times would have been mitigated by the lower instance of deer crossing in front of vehicles in the second half of the night, due to lower traffic volumes. Therefore the net risk of wildlife-vehicle collisions appeared to be roughly equivalent during all combinations of time-temperature strata. This contrasts somewhat with the results of the previous year in the same test section (Kinley et al. 2003), which indicated that all collision-risk behaviors were as high or higher per deer and per unit time for the midnight to 7:00 AM period than for 7:00 PM to midnight. This may have been related in part to differing sampling-period weather between the autumns of 2002 and 2003, as the 2003 results indicate that daytime temperature had a major effect on the timing and type of deer activity. This is consistent with the fact that the median date of samples used in 2003 (October 1) was over 3 weeks later than that of 2002 (September 7).



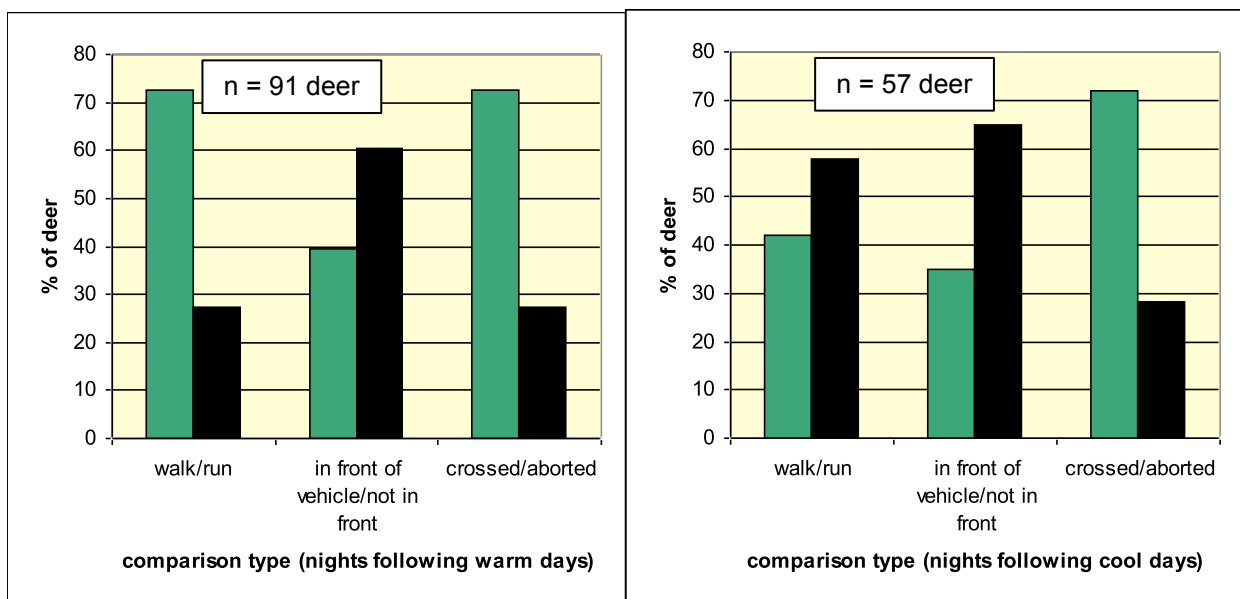
**Figure 13.** Location of deer within the highway right-of-way, based on 7,269 samples representing 7,489 deer observations. Values are for warm and cool nights combined.



**Figure 14.** Activity of deer on the roadside (sloped area between paved highway surface and lower, flat portion of ditch). Values are for warm and cool nights combined, and are based on 7,269 samples representing 2,448 deer observations



**Figure 15.** Characteristics of events in which deer were on paved highway surface, in relation to time of night. Each pair is based on the same sample, and each pair totals 100%.



**Figure 16.** Characteristics of 148 nighttime events in which deer were on paved highway surface, in relation to temperature on preceding day. Each pair is based on the same sample, and each pair totals 100%.

Ultimately, information on deer behavior could potentially lead to modifications to the WPS. For example, the algorithms used to control detection software could be adjusted to be less sensitive to heat sources (i.e. less likely to create false positives) during times when the probability of deer being present was low. Alternatively, if it was known that animals were likely to be present the great majority of the time at a certain time of day or under particular climatic conditions in some seasons, then the lights could be set to flash continuously in those periods as a precautionary measure. Any modifications would need to be tailored to the site and season in which the WPS was installed, and animal behavior would need to be relatively predictable and regular in order for modified operating rules to increase system reliability.

## 5. Other Species

Several species other than deer were visible on the digital IR footage. Because of the limited number of the image's pixels that animals occupied, especially when distant from either camera, it was often difficult to determine their identity with certainty. However, there are few species within the park that are large enough to be recorded, and classification was aided by relative body size (scaled from position within the image), general shape, and pattern of movement. In addition, when animals occurred close to the camera, their silhouettes and heat signatures made classification quite straightforward.

One or 2 coyotes remained in the ditch for periods of 9 to 69 minutes on 4 occasions, apparently hunting rodents or deer. Bears (likely black bears) appeared twice, once as a single bear and once as 2 bears. Each crossing occurred in less than 1 minute. Wolves were recorded in the test section once, for 8 minutes. A pair of wolf pups were chasing deer, followed by the arrival of an adult wolf. It was the adult wolf passing immediately in front of the camera that allowed positive identification. Four elk crossed the right-of-way in less than a minute on one occasion. These and other animals were undoubtedly present at other times, but only limited sections of the IR footage were used. In some cases, animals near the middle of the test section may have been mistakenly identified as deer because of their small size on both cameras' footage.

Observations about the WPS's ability to track elk, coyotes, wolves and bears relative to deer are highly susceptible to chance events (such as the location of animals in relation to the cameras), given the small sample sizes for those species and the fact that most samples were drawn from just a few occasions. Within that limitation, the tracking rates seem to be roughly proportional to body size. From largest to smallest, the tracking success rates from both cameras combined were:

- elk – 4 tracked out of 4 instantaneous samples (100%);
- bears – 3 of 4 samples tracked (75%);
- wolves – 21 of 24 samples tracked (88%); and
- coyotes – 46 of 139 samples tracked (33%).

These compare to an overall success rate of 69% for deer, which are roughly the same body size as the bears that passed through the test section.

In addition to body size, it is conceivable that body proportions or hair quality might affect tracking success. However, allowing for apparent body size in relation to distance from the camera (i.e. number of pixels occupied by an animal's image), no obvious differences between the ability to track these species versus deer was evident. That is, from our limited sample, there were no gross differences evident in the amount of heat produced per pixel occupied.

## 6. Summary of Maintenance Issues

There were 2 major maintenance issues with the WPS during the summer and fall of 2003, one of which was likely related to the other. Throughout the test period, (a) the power supply was unreliable, and (b) the tracking, data-logging and file-recording portions of the system collectively failed to operate for periods ranging from a few minutes to many hours. The south trailer was particularly problematic, but both trailers experienced problems. A technician visited the site on September 3 and 25 to make repairs to the power supply at each trailer. It should be noted that the KNP site was unusual in relation to most sites where the WPS might be deployed, because no power lines were present. Given that virtually all maintenance issues in 2003 were directly or indirectly the result of the self-contained power supply system in the trailers, it can be anticipated that few if any of the maintenance problems experienced this year would occur in locations where power could be accessed directly from the existing power grid. Specific issues identified in 2003 are summarized below.

- Both generators' control panels had lower ("turn on"), upper ("turn off") and mid-range settings. These settings drifted both up and down, sometimes little over the course of a day, but often by as much as 1 volt in a few hours. The result was that the settings needed constant adjustment to prevent overcharging or drawing down the batteries excessively, and even frequent adjustments did not prevent this entirely.

- The south trailer's batteries did not hold a charge properly. It is not clear whether this was related to being left outside during the winter of 2002/2003, overcharging or excessive drawdown, or lack of maintenance during the summer. When a technician looked at them on September 25, several were dry. In addition, it appeared that the batteries were in 2 circuits, 1 of which (the one that had not gone dry) was not charging as much as the other. There may therefore have been a system design problem.
- The generator periodically failed to shut off. This is a logical result of the control panel's upper setting drifting too high, and/or the batteries losing their ability to take a full charge. However, there were also times when it failed to shut off even when the battery voltage exceeded the upper setting. This did not happen after the first round of repairs by the technician on September 3.
- There were occasions when the generator failed to turn on to start charging the batteries, even when it was determined that the voltage was below the lower setting and there did not appear to be anything adjusted improperly. In at least one case a light on the control panel that normally indicates when the generator is actually running was activated, even though the generator was not running.
- The WPS sometimes failed to record IR files onto the computer, even though the system was functioning and an *Excel* log file of light switching and speeds was kept. This only happened on a few occasions, at the north trailer only. Another minor computer problem was that the monitor would regularly "freeze up" or fail to come on when switched on, in which case a hard restart was required (i.e. there was no shutdown of the program prior to restarting), this was an issue at the south trailer only.
- Much more seriously, the tracking and data-recording portion of the WPS frequently did not function at all from at least 1 trailer. On most nights there were periods of a few minutes to many hours when the software in at least 1 trailer (usually the south one) neither tracked animals nor transmitted messages to the signs, and no *Excel* log file was created. At such times, the affected trailer was neither able to detect deer and warn motorists, nor able to store data for us to analyze. Each time it malfunctioned, the system eventually began to function again spontaneously or when it was manually restarted. Our assumption is that this periodic glitch was a result of computers being subjected to power supply fluctuations, regular hard-shutdowns, or a previous winter in an unheated trailer. However, it is also possible that the hardware or software issues were independent of those factors.

These problems resulted in more maintenance and system checks being required, less data being collected, and fewer nights of the warning system functioning than expected. Extra site visits were needed to manually charge the batteries, refuel the generators and turn them off manually when they failed to shut off automatically, check the system status, adjust the turn-on and turn-off voltages on the control panel, enable or disable the flashing lights, and restart components of the system due to malfunctions of the computer equipment. The system was checked daily for most of the test period, but only 8 nights of uninterrupted IR footage were produced between September 5 and October 14. Had the system consistently functioned properly, site visits would have been necessary only once per 4 days to add fuel and change the firewire drives. Repairs to the generators, batteries and/or control panels on September 3 and 25 resulted in the power supply being somewhat more reliable but did not influence computer performance.

There were also several minor issues with the flashing lights, including a failure to turn on. These appeared to be wiring problems that could be readily repaired.



## 7. WPS Potential

Despite the maintenance issues itemized above, there were many positive developments and indications during 2003.

- Most day-to-day maintenance problems were ones that would likely be resolved if power lines were available.
- Although deer were generally no longer tracked after extended periods in either the test or exclusion zones, the WPS picked up a very high proportion of those first entering the test zone.
- Even with the eventual loss from tracking of many deer, the absolute tracking rate and the functional performance were relatively high, particularly in cooler weather.
- No data was analyzed for the portion of the IR image extending past the limit of the 1-km test section, but the WPS often tracked deer beyond that point.
- Drivers slowed down and appeared to be more alert to deer in response to flashing lights.
- All species that could be visually identified on the IR footage were tracked at least part of the time, including elk, deer, bears, wolves and coyotes. This included hunting by wolves of roadside deer, an unusual event that might otherwise have gone unnoticed. This suggests the utility of the system in studying highway crossings and activity by a range of species.
- The system provided an excellent tool for studying deer behavior and crossing rates.
- With further refinement, the WPS has good potential for efficiently warning drivers of the presence of wildlife. If so, the WPS would provide an important method of decreasing wildlife-vehicle collisions and potentially acting as a replacement for (or in conjunction with) fencing or wildlife overpasses or underpasses.
- The WPS as used was relatively portable, and with minor modifications would be highly portable. This would allow it to be moved seasonally or annually, or in response to new research projects or changes in land use.

## 8. Literature Cited

Kinley, T. A., H. N. Page, and N. J. Newhouse. 2003. Use of infrared camera video footage from a *Wildlife Protection System* to assess collision-risk behavior by deer in Kootenay National Park, British Columbia. Prepared for: Insurance Corporation of British Columbia, Kamloops, British Columbia.