Title

Evaluating the effectiveness of wildlife accident mitigation installations with the wildlife accident reporting system (WARS) in British Columbia

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EVALUATING THE EFFECTIVENESS OF WILDLIFE ACCIDENT MITIGATION INSTALLATIONS WITH THE WILDLIFE ACCIDENT REPORTING SYSTEM (WARS) IN BRITISH COLUMBIA

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Abstract: The British Columbia Ministry of Transportation (BC MoT) administers the Wildlife Accident Reporting System (WARS), a database designed to collect and analyze information on wildlife killed on provincial highways. Over 70,000 wild animal accidents have been recorded in the WARS database since 1978. More than 90 percent of the accidents involve large ungulates, primarily deer, moose and elk. Since the mid-1980's, BC MoT has invested heavily in wildlife exclusion fencing and wildlife warning reflectors in an effort to reduce the number of ungulate-related motor vehicle accidents on provincial highways. To better focus its resources and stem the rising societal cost of human fatalities and injuries, motor vehicle damage, highway clean-up, and lost wildlife value, BC MoT is using the WARS database to identify problem wildlife accident locations and investigate the effectiveness of existing wildlife accident mitigation installations. As part of the effectiveness investigation, the performance of Swarflex and Strieter-Lite wildlife warning reflectors is being assessed. Research findings on the fundamental spectrometric and photometric characteristics of the reflectors raise questions regarding how wildlife warning reflectors may influence ungulate roadside behavior, and which reflector designs and installation configurations may be best suited for highway applications.

Introduction

The British Columbia Ministry of Transportation and Highways (BC MoT) administers the Wildlife Accident Reporting System (WARS), a database designed to collect and analyze information on wildlife killed on provincial highways. Over 70,000 wild animal accidents have been recorded in the WARS database since 1978. More than 90 percent of the accidents involve large ungulates, primarily deer, moose and elk. Between 1995 and 2000, 13 people were reported killed in wildlife-related motor vehicle accidents in British Columbia.

In 2000, over 4,700 wildlife-related accidents were reported in British Columbia. After weather, wildlife rates as the next highest environmental contributing factor for police-attended accidents. In 2000, it is estimated wildlife accidents cost British Columbia over $12US million in motor vehicle accident claims and $400,000US in highway accident clean-up costs. It is estimated these accidents also cost British Columbia $200,000US in lost provincial hunting license revenues; and $20US million in lost value to residents and non-residents who view or hunt wildlife (Reid 2001). Between 1997 and 2000, the Insurance Corporation of British Columbia (ICBC), the Provincial Crown corporation insuring all motor vehicle in British Columbia, spent over $45US million on wildlife-related motor vehicle accident claims (Gilfillan 2001).

As part of its commitment to protect the safety of the motoring public; stem the rising societal cost of human fatalities and injuries, motor vehicle damage, and highway maintenance; and reduce the loss of wildlife on provincial highways, MoT uses the WARS system to:

1. Identify wildlife accident-prone locations and wildlife accident trends
2. Direct wildlife accident mitigation efforts
3. Evaluate the effectiveness of wildlife accident mitigation techniques
4. Provide wildlife data for highway planning purposes
5. Model and forecast wildlife accidents
6. Establish policies and strategies for wildlife accident issues

Since the mid-1980's, BC MoT has used WARS data to direct its investments in wildlife exclusion fencing and wildlife warning reflectors. BC MoT is currently using WARS data to assess the performance of Swarflex and Strieter-Lite wildlife warning reflectors. Research findings on the fundamental spectrometric and photometric characteristics of the reflectors raise questions regarding how effective wildlife warning reflectors are at influencing ungulate roadside behavior and reducing ungulate-related motor vehicle accidents; and, if effective, which reflector designs and installation configurations may be best suited for highway applications.

Wildlife Accident Reporting System (WARS) Overview

Software and Hardware

The WARS system operates using Microsoft Access running on an IBM compatible PC platform. The WARS system has a user interface which allows data to be entered directly into the database and information to be extracted using a range of database query functions. WARS is a flexible system designed to meet a broad range of requirements, from producing site specific reports over a few kilometres of highway to creating detailed reports of various aspects of wildlife-vehicle accidents for the entire province.

Data Collection

Wildlife accidents are recorded by the Ministry's Road and Bridge Maintenance Contractors located throughout British Columbia. Data regarding wildlife-vehicle accidents, such as species and location, are recorded on WARS forms as they occur. The forms are sent to BC MoT District Offices where they are screened, and then forwarded to BC MoT Headquarters for entry into the WARS database. WARS forms are not completed for highways maintained by the Federal Government or the Yukon Government under agreements with the British Columbia Government.

Assumptions and Constraints

BC MoT estimates the number of wild animals recorded by the WARS system represents only about 25-35 percent of the actual number of wild animals killed. The low number of reports can be attributed to a number of factors. In high traffic areas, the remains of small species of wildlife, like badgers and raccoons, often become unrecognizable after being run over by a number of vehicles. Other animals, primarily deer and moose, are often removed from the roadside by passing motorists before they are recorded by MoT Contractors. Data is also lost or compromised due to the following:

1. Animals die outside the highway right-of-way and are not found.
2. Animal remains are removed by natural predators or scavengers.
3. Animal remains are obscured by snow, ice, vegetation, or roadside debris.
4. Animal species or accident locations are incorrectly identified.
5. Random and systematic errors and omissions in reporting and data processing.

Data Quality

The quality of the data contained in the WARS system is very dependent on the reporting diligence of the Ministry's Maintenance Contractors. Since wildlife accidents often occur at very untimely hours, under less than ideal weather conditions, comprehensive reporting at the accident scene is difficult at times.

Accurate reporting of wildlife accident locations is critical for effectively identifying and evaluating accident patterns. Given the limited amount of training provided for reporting wildlife accidents, accurate differentiation between various species of bears, deer, and sheep has been sporadic. Correct species identification is completely dependent on those completing the WARS accident forms. Consequently, some species are misreported, based on species and normal range. Historically, not all WARS report forms have been completed with diligence. In particular, the accuracy of accident locations has varied considerably. In 2000, of the 4,768 reports received, 20 percent lacked valid segment numbers, and 31 percent lacked valid kilometre references. These reports did not contain enough information to determine the valid segment numbers and km references.

This was a significant improvement over 1995, when 28 percent lacked valid segment numbers and 44 percent lacked valid km references. In 1999, new WARS forms were developed, in conjunction with the Ministry's Maintenance Contractors, to address the issue of data completeness and accuracy. To date, the data provided on the new forms is increasingly more complete and accurate.

Wildlife Accident Location Reporting

Some confusion exists between the use of the Road Features Inventory (RFI) and the Landmark Kilometre Inventory (LKI) systems for identifying wildlife accident locations. Ministry Contractors use the RFI system for locating highway features and structures such as bridges, signs, etc. The WARS system uses the LKI system for locating wildlife accidents. Wildlife accidents reported with RFI references are often converted to LKI references by Ministry Maintenance Contractors staff or Ministry staff. Errors can occur during data conversion.

Wildlife Species Accident Summaries

Accident Rates by Ungulate Species

In 2000, approximately 80 percent of the wildlife-vehicle accidents recorded on British Columbia numbered highways involved deer. Of the remaining reported accidents; moose were involved in over 6 percent, elk were involved in over 3 percent, bears were involved in 2 percent, coyotes were involved in over 2 percent, and all other wild animals, ranging from badgers to wolves, made up the remaining 7 percent (table 1). These accident trends appear to have remained relatively consistent over the last decade. When the accident patterns for ungulates, specifically deer, moose, elk, and sheep are examined, it is apparent the monthly accident distributions vary by species (table 2).

When deer accidents are evaluated by season and sex, female deer are involved in most accidents, occurring between March and May, and occurring between October and November. The majority of bucks are killed between May and July and in November. The fall peak for both does and bucks is most likely related to the rutting season. When deer accidents are evaluated by age, adult deer are involved in most accidents. Young deer are mostly killed between May and November. This may be related to natural reproduction and cohort survival rates, and the fact adult deer vastly outnumber young deer at all times.

The majority of moose are killed between October and March. This coincides with times of high snowfall when moose are often found alongside highways actively cleared of snow. An accident peak is also observed in June, this may be due to pregnant cows moving to calving grounds in the early summer or licking salt on or along the highway.

Lesser numbers of elk are reported. The pattern for elk-related motor vehicle accidents is less established, however a small peak occurs between October and March. Elk appear to be influenced by the same snow conditions that affect moose. Sheep accidents exhibit peaks in February, June and September, with the largest peak occurring in February. In late winter, as snow levels at higher elevations increase, sheep migrate to valley bottoms where highways are typically located. In early summer, sheep begin moving out of the valleys, feeding near highways, on their way to higher elevations for lambing. In late summer, they begin moving back in preparation for the rutting season, which usually occurs in October or November.

Table 1
Total Annual Number of Ungulates Killed (1991 to 2000)

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Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Totals
all species	3,305	3,174	4,798	5,335	4,764	3,853	3,650	4,559	4,845	4,707	42,990
all ungulates	2,998	2,860	4,353	4,922	4,396	3,549	3,352	4,163	4,443	4,344	39,380
Specific Ungulates											
caribou	6	8	0	0	9	4	2	3	0	3	35
deer	2,745	2,585	3,992	4,375	3,917	3,148	3,017	3,683	3,896	3,836	35,194
elk	59	63	75	120	93	104	77	103	127	167	988
moose	183	196	271	405	367	283	250	361	411	323	3,050
sheep	5	8	14	22	10	10	6	13	9	15	112

Table 2
Total Monthly Distribution of Ungulate Accidents (1991 to 2000)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
all ungulates	3,183	2,826	3,138	3,097	3,447	3,138	3,404	3,020	2,788	3,739	4,242	3,362	39,384
Specific Ungulates													
caribou	5	1	1	0	5	2	1	1	4	6	11	5	42
deer	2,451	2,454	2,926	2,961	3,244	2,804	3,101	2,752	2,576	3,494	3,822	2,661	35,246
elk	150	83	79	0	75	76	55	53	41	65	104	144	925
moose	563	272	122	129	121	247	241	207	158	169	293	537	3,059
sheep	14	16	10	7	2	9	6	7	9	5	12	15	112

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Evaluating Wildlife Vehicle Accident Mitigation Methods

Overview

Methods utilized by BC MoT to reduce wildlife vehicle accidents are pursued with multi-faceted objectives. The Ministry strives to reduce, and ultimately eliminate human and wildlife deaths and injuries, and motor vehicle and property damage; as well as increase public awareness and ensure mitigation techniques are cost effective. The mitigation methods employed by MoT include the installation of wildlife warning reflectors.

Wildlife Warning Reflectors

BC MoT has been installing wildlife warning reflectors since the late 1980s as the largest component of its continued effort to reduce wildlife-related accidents. The reflectors are prisms mounted on posts and installed along the sides of the highway as a means of deterring animals from entering the highway when vehicles are present (figure 1).

Fig. 1. Swarflex reflectors installed on a highway shoulder

At night, as the headlights of an approaching vehicle strike the reflectors they reflect beams of light at ninety-degree angles to the roadway. The reflected light apparently catches the attention of animals and distracts them long enough to delay their movement onto the road until the vehicle has passed (figure 2).

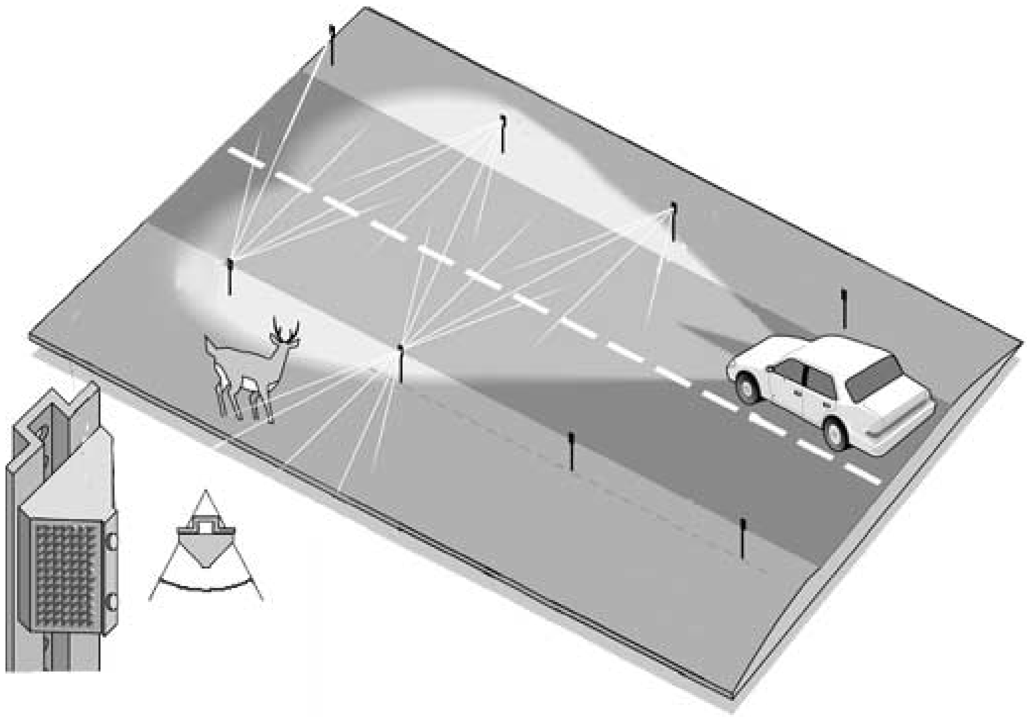

Fig. 2. Light reflection concept of wildlife warning reflectors
[Source: Brian Shellito, The Detroit News (copyright) (Adapted) (used with permission)]

To date, reflectors have been installed at over 95 locations throughout British Columbia. Reflectors cost approximately $7000US/km to install along both sides of a highway. The reflectors have been installed on either one side or both sides on over 100 miles of highway. Reflectors have been used along highways prone to high numbers of deer-related accidents.

The success of wildlife warning reflectors for reducing wildlife accidents has been the object of much discussion and speculation. Research by BC MoT and other transportation agencies appears to provide inconsistent evaluations of the devices.

Most installations are less than 2 kilometres long, with 17 percent being 0.5 kilometres or less in length. Given the relatively short distances of the majority of the reflector installations, the relatively low number of wildlife accidents recorded before and after the reflectors were installed, and the lack of measurable controls, determining if the reflectors produce statistically significant reductions in the numbers of deer-related motor vehicle accidents is very difficult.

Short installations make evaluation difficult because it is easier for animals to travel to the end of the reflectors and cross the highway. Short installations also make the accuracy of reporting accident locations difficult because the remains of animals may be found outside the reflectorized areas, thereby undermining any measurement of reflector effectiveness.

The "before and after" method typically used to evaluate reflectors does not give a true picture of effectiveness because there is no control of those factors which can change during the course of the evaluation period, such as weather, traffic flow, and deer population densities (Damas and Smith, 1983). However, even if accidents are reduced following the implementation of a safety project, it does not necessarily follow that the decrease was caused by the project (Griffin, 1997).

Case Studies

Highway 3, located near the Canada/US border in British Columbia, north of the U.S. states of Washington, Idaho, and Montana, has one of the worst records for ungulate related motor vehicle accidents in British Columbia (Sielecki 2000). In an attempt to reduce the number of deer related motor vehicle accidents, BC MoT installed wildlife warning reflectors on a 9.37 km section of Highway 3 (LKI Segment 1325), east of Grand Forks, and on a 7.45 km section of Highway 3 (LKI Segment 1375), east of Creston. The installation were completed in March 1995. These are the longest continuous reflector installations in British Columbia.

Highway 3 (Segment 1325)

When comparing the deer accident rate for the 9.37 km reflectorized section of the highway with the deer accident rate for immediately adjacent 9.37 km non-reflectorized sections of the highway, it appears the installation of reflectors did not alter the overall local accident trends (figure 3).

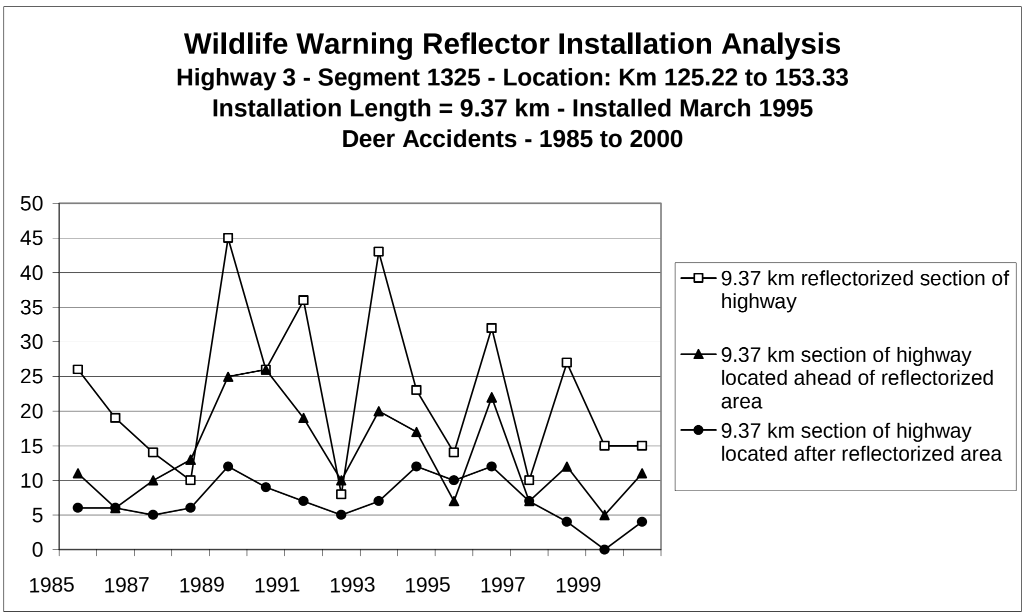

Fig. 3. Wildlife Warning Reflector Installation Analysis (Highway 3, Segment 1325)

Highway 3 (Segment 1375)

When comparing the deer accident rate for the 7.45 km reflectorized section of the highway with the deer accident rate for immediately adjacent 7.45 km non-reflectorized sections of the highway, it appears the installation of reflectors did not alter the overall local accident trends (figure 4).

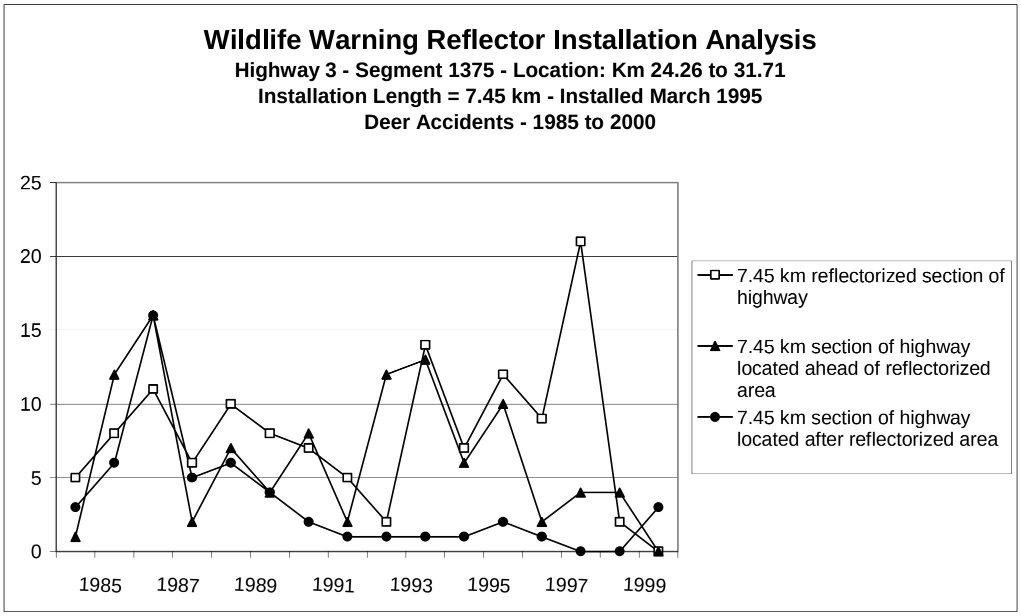

Fig. 4. Wildlife Warning Reflector Installation Analysis (Highway 3, Segment 1375)

Although these trends were not observed as part of a controlled scientific experiment, they raise questions about the effectiveness of wildlife warning reflectors. When comparing the deer accident rates before and after a reflector installation, there appears to be no consistent accident rate drop after the reflector installation that can be specifically attributed to the reflectors.

There are many reasons why dramatic fluctuations in the number of accidents occur, including climate, traffic speed and volume, and wildlife movement. ICBC has found approximately 45 percent of the animal collisions which occur in the Southern Interior of British Columbia occur between 7:00 p.m. and 12:00 p.m. (Gilfillan 2001). In 1999, BC MoT and ICBC initiated a controlled study to determine the effectiveness of wildlife warning reflectors on a 3.4 km stretch of Highway 5 between Clearwater and Vavenby, in central British Columbia. It is anticipated data will be collected for at least 5 to 10 years before any conclusive results can be expected.

Spectrometric Analysis of Wildlife Warning Reflectors

In addition to field tests, BC MoT is examining how wildlife warning reflectors may influence the roadside behavior of deer. BC MoT has traditionally used red coloured Swarflex ("old" style, level terrain and slope terrain models) and Strieter-Lite reflectors ("new" style models) (figures 5 and 6) because the manufacturer indicated deer responded to the colour red. "In a long series of experiments conducted by scientists in the field of behaviourism it was established that red light exerts a warning effect on deer." (Swarovski AG 2001) As a first step toward understanding how wildlife warning reflectors operate, BC MoT conducted tests on different coloured Swarflex and Strieter-Lite reflectors to determine their fundamental spectrometric and photometric properties (Sivic and Sielecki 2001) (figure 7). The tests were designed to measure the reflected light spectrum, luminous intensity and light distribution in a horizontal and vertical plane. Several spectrometric and photometric characteristics were found.


Fig. 5. Swarflex wildlife warning reflectors ("old" style) (Models 7172 and 7182)

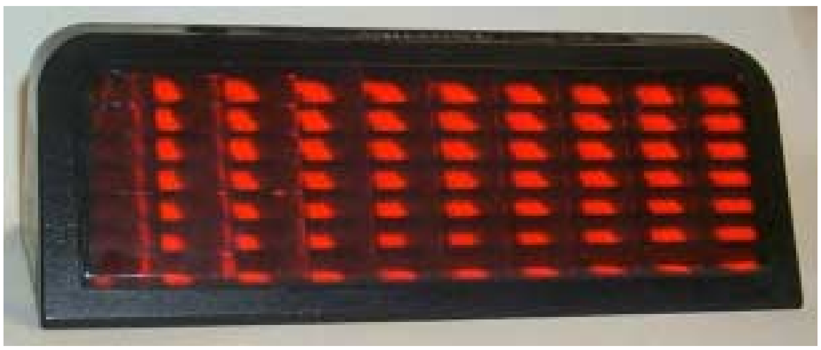
Fig. 6. Strieter-Lite wildlife warning reflector ("new" style) (Model 7176)


Fig. 7. Strieter-Lite wildlife warning reflectors (Model 7176)

The Swarflex "old" style models appear to have five to ten times higher light reflection intensity compared to the Strieter-Lite new style models (figures 8 and 9). The functional design of the Swarflex "old" style level terrain model (Model 7172) appears better suited for reflecting light from motor vehicle headlights on a horizontal plane than the Strieter-Lite "new" style reflector (Model 7176).

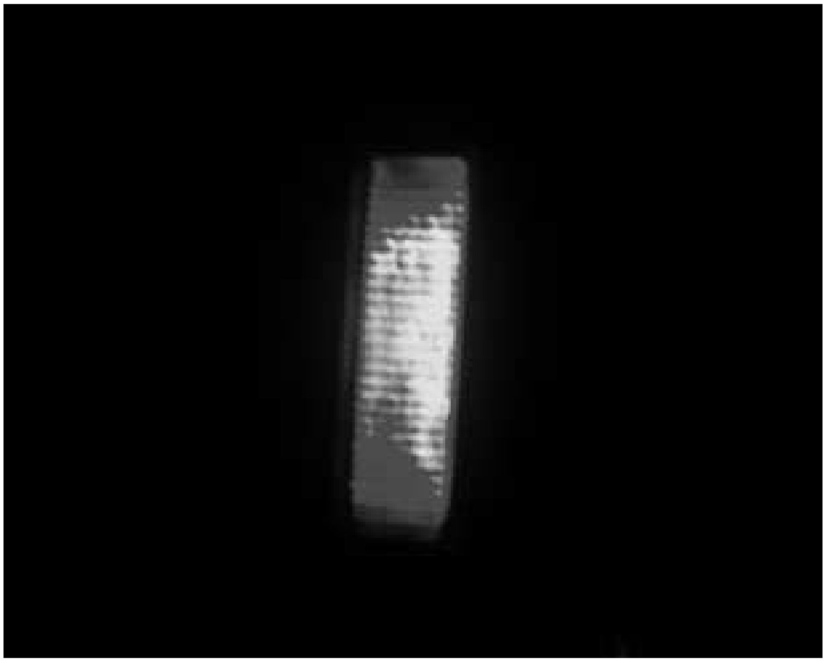

Fig. 8. Swarflex wildlife warning reflector ("old" style) (Model 7172) illuminated

Fig. 9. Strieter-Lite wildlife warning reflector ("new" style) (Model 7176) illuminated

The function design of the Swarflex “old” style slope terrain model (Model 7182) appears better suited for reflecting light from motor vehicle headlights at an angle than the Strieter-Lite “new” style reflector (Model 7176). Generally the coloured reflected light intensity readings are very low. The reason for this appears to be the small size of the reflector. The reflector reflects only a small portion of the incoming light from the car headlight. The readings at the distance of two meters from the reflectors are below 0.1 lux, which indicates the intensity at greater distances will be negligible (figure 10).

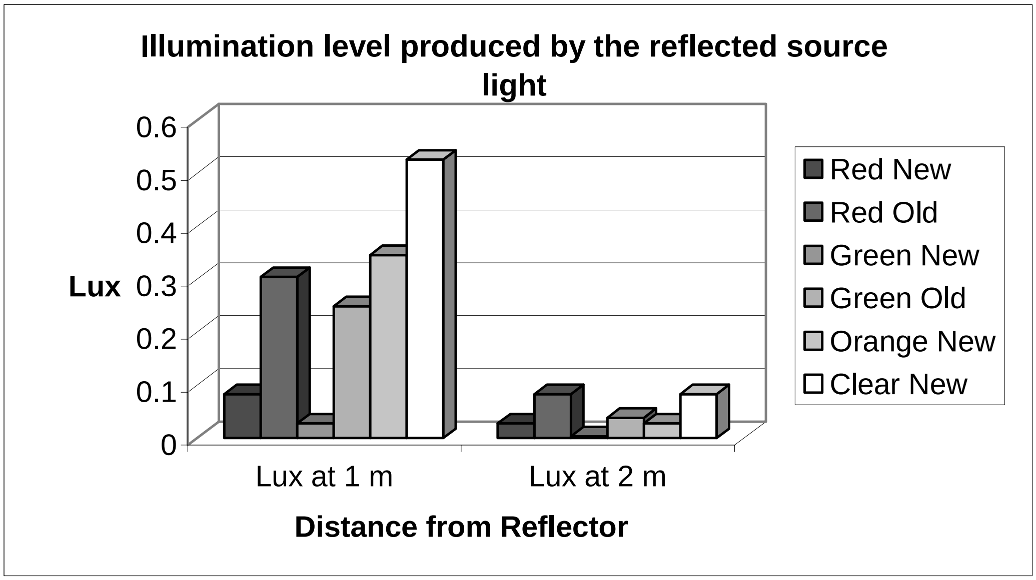

Fig. 10. Illumination levels produced by the reflected source light

One feature of the reflectors not previously reported in the literature was the white first surface reflection produced by the external lens surface of both the Swareflex and Strieter-Lite reflectors (figure 11). The highest intensity white reflections were produced by the new style reflectors produced the white first surface reflections with the highest intensity. This reflection was seen as a strong white flash in a very narrow beam. The intensity of this reflection was much higher then the intensity of the internal lens reflections. The luminance of the white reflection was measured and found to be from several times to several hundred times higher than that of coloured light from the coloured lenses.

Fig. 11. White first surface reflection (Strieter-Lite reflector) (Model 7176)

On a clear night, full Moon illumination level is 0.1 lux. Depending on the intensity of ambient light, the drop in reflected light intensity may influence the effectiveness of the reflectors "Nighttime observations have shown that the reflectors are only visible at short distances from the roadway and only at certain angles." (Woodham 1991). Consequently, in the transitional period between day and night when the illumination levels from the Sun or Moon range from several lux to several tenths of a lux, the effectiveness of the reflector should be further diminished. At distances greater than several meters from the reflector only the white first surface reflection would be noticeable.

The Strieter Corporation has indicated the brightness or reflective illuminance should not be the main factor in selecting the reflector because wild animals have acute night vision (Strieter 2001). However, these factors have operational implications. In a roadside application, it is impossible to ensure reflector surfaces are kept clean at all times (figure 12). In winter, deer related motor vehicle accidents appear to be closely correlated with snow falls, a time when maintaining wildlife reflectors is very difficult (figure 13).

Fig. 12. Wildlife warning reflectors operating under winter roadside conditions

Given the low amount of light reflected by these reflectors, any dust or other material generated by traffic or nature deposited on a reflector has the potential to significantly reduce the reflector's effectiveness for reflecting light. Reflectors with higher light reflection intensities may be more effective. Of the reflectors tested, the clear Strieter-Lite "new" style reflectors (Model 7176) had the highest intensity of the reflected light. This suggests that if wildlife reflectors are effective for modifying the behavior of wildlife, reflector light reflection intensity should be examined to determine how it may contribute to the performance of the reflectors. Low light intensity was considered a factor in the reduction in effectiveness of WEGU wildlife warning reflectors by Ujvari et al. (1998).

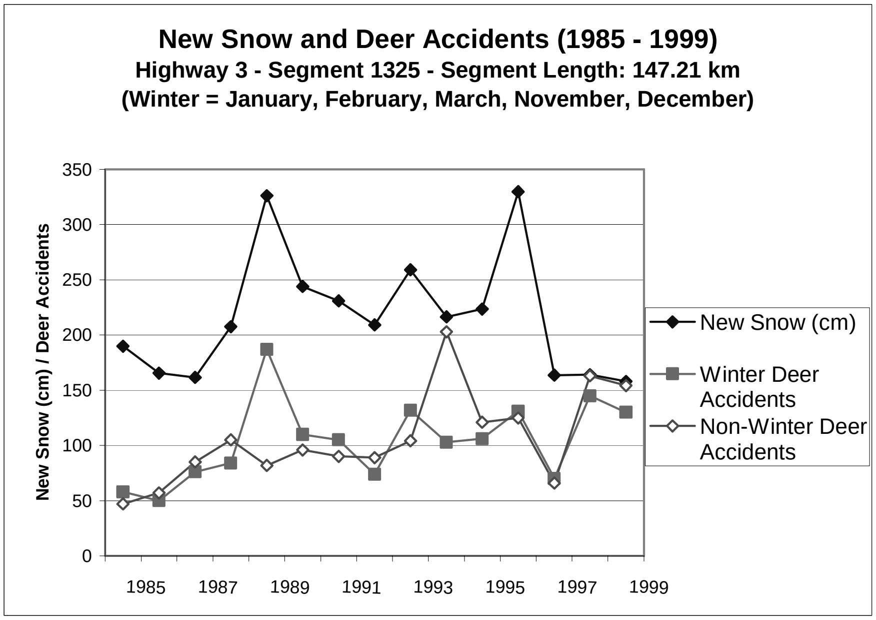

Fig. 13. New snow and deer accidents

Since the Swarflex "old" style level terrain model (Model 7172) has greater light reflection intensity than the Strieter-Lite "new" style reflector (Model 7176), a comparison should be made to determine which reflector, either the Swarflex "old" style level terrain model (Model 7172), or the Strieter-Lite "new" style reflector (Model 7176), is more effective for deer accident reduction applications where reflectors are installed facing the road.

Deer Vision

To fully understand how reflectors may influence the behavior of ungulates, the effects of white first surface reflection should be investigated. The white first surface reflection may be a more significant feature of the reflectors than the internal reflections from a coloured or uncoloured lens. However, deer vision research conducted by Jacob et al. (1994), raises serious questions about what colour of reflectors may be best suited for highway purposes. Apparently, deer do not see well in the red end of the light spectrum (figure 14).

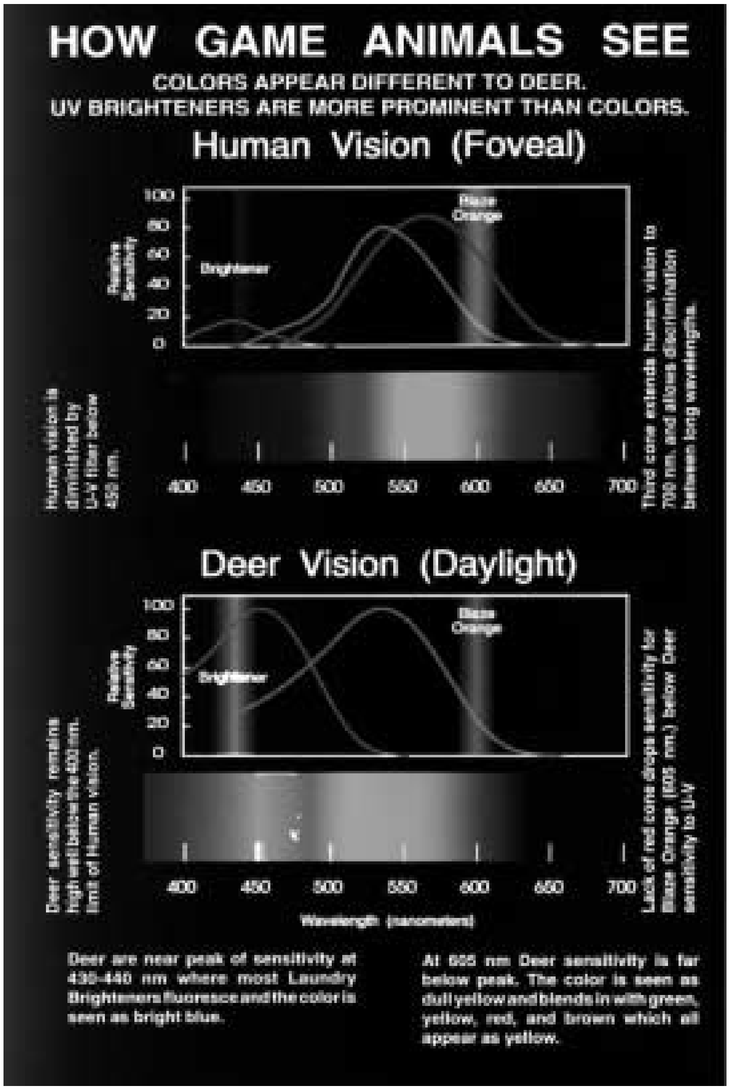

Fig. 14. Comparison of human and deer colour vision

[Source: Brian P. Murphy, Karl Miller, and R. Larry Marchinton, University of Georgia; Jess Deegan II, University of California; Jay Neitz, Medical College of Wisconsin; Gerald H. Jacobs, University of California. (used with permission)]

If one applies the concept of deer having limited red colour vision to the examination of the effectiveness of wildlife warning reflectors, it appears red coloured reflectors may not be the most suitable for highway applications to reduce deer related motor vehicle accidents. Given the properties of ungulate vision, the effectiveness of colour on should also be determined (Jacob et al. 1994; Zacks 1986).


Fig. 15. Wildlife reflectors (visible light spectrum)

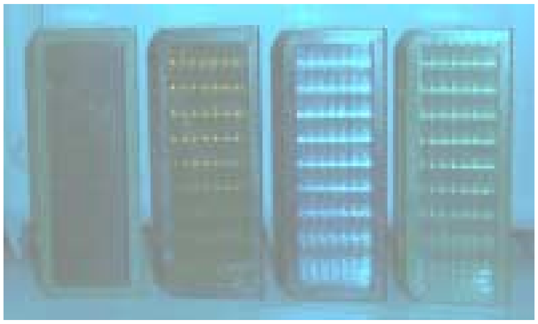

Fig. 16. Wildlife reflectors (visible light spectrum with a minus red filter)

Conclusions

Given the number of unknowns regarding the behavior of ungulates, primarily deer, to the patterns, intensities and colours of light reflected by wildlife warning reflectors in a highway environment, more basic research is required. Use of the wildlife warning reflectors without consideration of the impact of these factors may compromise any tests of their effectiveness.

Biographical Sketch: Leonard Sielecki is the environmental issues analyst for the British Columbia Ministry of Transportation. He is a professional biologist and a professional land use planner. Since 1995, Leonard has provided the Ministry with direction and support for highway-related wildlife accident mitigation programs. He manages the Ministry's Wildlife Accident Reporting System (WARS) database and publishes the WARS annual report. Leonard acts as a Ministry liaison with federal and provincial departments and ministries, the Insurance Corporation of British Columbia, and wildlife consultants on wildlife accident reduction initiatives. He has over 16 years experience in land use and transportation planning and policy development with Agriculture Canada, Fisheries and Oceans Canada, Indian and Northern Affairs Canada, Alberta Municipal Affairs, and Alberta Transportation and Utilities. Leonard's academic background includes a B.S. in biology (animal physiology) and geography (cartography and resource management), an M.S. in geography (satellite image analysis), and doctoral studies in GIS and digital image processing. Currently, he is developing GIS applications to use the WARS database for modeling the spatial and temporal characteristics of wildlife accidents and evaluating the effectiveness of wildlife accident reduction measures.

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