Title: Analysis of Deer Ecology and Landscape Features as Factors Contributing to Deer-Vehicle Collisions in Hokkaido

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ABSTRACT

Collisions between vehicles and wildlife, particularly large ungulates are a serious problem in many countries around the world. The damage from such collisions, including injuries and fatalities of humans and animals, tends to be serious. The number of sika deer on Hokkaido, the northernmost island of Japan, is steadily increasing, as are deer-vehicle collisions (DVCs) there. To develop measures to prevent such collisions, this study investigated the details of DVCs on the seven national highways in the Tokachi area in east Hokkaido. For the investigation, a database that includes the number of DVCs for the 12 years from 1995, each DVC location, the route name and deer carcass pickup date was used. First, the relationship between DVC frequency and deer seasonal behavior was investigated. Next, a Poisson regression model was used to understand the effect of explanatory valuables on the number of DVCs. These explanatory valuables included DVC site topography features and average daily traffic volume (ADT). A topographic dataset including the spatial distribution of avg. elevation and of avg. annual max. snow depth, and landscape features within 1,000-m-radius zones around each kilopost on each sample route was created by using GIS software. Those analyses results identified the specific conditions of DVC-prone sites: collisions tended to be more common in the spring migratory season and the autumn breeding season, and on road sections through woodland or those in a border area between woodland and farmland. These results provide clues for identifying what DVC prevention measures should be implemented and where they should be implemented.
INTRODUCTION

Wildlife-vehicle collisions are a serious problem in many countries around the world. The most problematic of such collisions are ungulate-vehicle collisions, because the damage from such collisions, including injuries and fatalities of humans and animals, is serious. In Europe, more than 500,000 ungulate-vehicle collisions are reported a year, with about 300 human fatalities, 30,000 human injuries and property damages of about 10 billion euro\(^1\). Ungulate-vehicle collisions in the U.S.A. are estimated to number more than 1 million a year\(^2\). In Canada, in the state of British Colombia alone, annually about 5,000 wildlife mortalities and 300 human injuries are reported\(^3\). The cumulative number of wildlife-vehicle collisions in Japan is estimated to range from 110,000 to 370,000 in 1998\(^4\). The number of wildlife-vehicle collisions on all the expressways in Japan totals 33,791 in 2001\(^5\).

The population of sika deer (\textit{Cervus nippon yesoensis}) in Hokkaido, the northernmost island of Japan, sharply decreased early in the 20\(^{th}\) century from overhunting and heavy snowfall. Since then, the population has rebounded because of deer protection policies and increases in the area of grassland suitable as deer habitats\(^6\). About 300,000 deer are estimated to live in Hokkaido’s 83,450 km\(^2\) (32,200 sq mi)\(^7\). Increases in deer population have resulted in increases in deer-vehicle collisions (DVCs) throughout Hokkaido. DVCs on national highways there numbered 421 in FY 1996. Seven years later, in 2003, that annual figure had more than doubled to 1,030\(^8\).

There have been a number of studies about DVCs in Europe and North America, and they have reported on seasonal factors\(^1\(^3\)^9\(^\text{10}\)^11\(^\text{12}\) and landscape features\(^10\)^11\(^\text{12}\). In Japan, few studies have addressed DVC seasonal or locational factors in detail. DVC prevention facilities, including deer-proof fences and underpasses, have been installed on sections of national highways in Hokkaido\(^13\). These facilities are effective, but they are costly to install. Toward developing cost effective, efficient DVC prevention measures, we surveyed DVCs and landscape features along all seven highways (including at DVC sites) in the Tokachi area, one of the most DVC-prone area in Hokkaido, and we analyzed the relationship between the seasonal behavior of deer and the landscape of the DVC sites.

METHOD

DVCs in the Tokachi Area

To determine the number, location and occurrence time of DVCs on the seven national highways in the Tokachi area (Figure 1), we used records of road kills for the 12 years from April 1995 to March 2007 that were compiled by the road administrator (The Hokkaido Regional Development Bureau, Ministry of Land, Infrastructure, Transport and Tourism). The records include the name and location on the national highway where each deer carcass is picked up, the type of animal and the pickup date. Each deer road kill is counted as one DVC in this study. The location is specified by the distance from the nearest kilometerpost (kilopost), with a precision of 100 m. In this study, the location is expressed in units of km. The number of deer road kills was aggregated for each kilopost of the seven national highways in the Tokachi area. Each DVC was indicted by the nearest kilopost. Because the total length of the seven highways is 703 km, the kiloposts number 703. To facilitate analysis, these were renumbered such that KP0 indicates the first kilopost from the boundary of Tokachi area.
FIGURE 1 National highways in the Tokachi area.

Deer Seasonal Behavior

In the spring migratory season, sika deer move from their winter habitat to their spring-summer habitat to give birth to fawns from late May to June and to raise them there by early fall. Fall is the breeding season, and that season peaks in late October. During the breeding season, male deer tend to be aggressive and less wary of danger. Dominant male deer have a harem that may consist of more than ten female deer. After the breeding season, they start migrating to their less snowy winter habitat, which can be more than 100 km away. In Hokkaido, the start of this migration varies from early October to late January, depending on the summer habitat location, so that their arrival in the winter habitat varies from early November to early February. They leave the winter habitat from early March to late April, arriving at the summer habitat from early April to mid May.

The seasonal behavioral patterns of sika deer are broadly divided into five ecological seasons: spring migration (April–May), fawn bearing/raising (June–September), breeding (October), fall migration (November–January) and wintering (February–March).

Database of the Landscape Features along the Seven Routes

In addition to the database of DVC numbers and locations in Tokachi, to identify the DVC site characteristics, an environment database was created for the seven national highways. The environment factors collected and stored in the database include: avg. annual max. snow depth, avg. elevation and landscape (woodland, grassland, farmland, urban area, open water area, other), the distance from the nearest river and the avg. daily traffic volume (ADT). For woodland landscape, the vegetation was specified as evergreen coniferous trees, broadleaf trees or larch (Table 1). To obtain topographic data that would adequately show the spatial distribution of avg. elevation, avg. annual max. snow depth and landscape features that fall within 1,000-m-radius zones around each kilopost along the route, the Natural Environment Geographic Information System (GIS) database of the Ministry of the Environment (FY 1979-1998) was used.

To visualize and analyze the data from the Natural Environment GIS, we used ArcGIS Arc View9.2. For avg. annual max. snow depth at each collision site, 1-km-mesh weather data from the Japan Meteorological Agency (1971-2000) were used; for the site elevation, 50-m DEM maps
(50-m-mesh topographic maps) of the Geographical Survey Institute, Japan (2001) were used. To determine the distance from the nearest river to each kilopost on the surveyed routes, Geographical Survey Institute Map #25000 (2003) was used. The data of ADT were obtained from the 2005 traffic census data of the Hokkaido Regional Development Bureau.

**DVCs BY SEASON**

The number of DVCs by season for 12 years and the average accident rate per km of road section for a seasonally DVC prone section for 12 years are shown in Figure 2. The fall breeding season has the highest number of DVCs (260), followed by the spring migration season (162) and the summer/early autumn fawn bearing/raising season (109.5). The summer/early autumn fawn bearing/raising season has the highest average accident rate (2.3 per km), following by the spring migration season (2.2 per km). The fall breeding season has the relatively lower average accident rate (1.7 per km) compare to those of spring-summer seasons.

**TABLE 1  Explanatory Variables Obtained from DVC Site Characteristics**

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Unit</th>
<th>Content</th>
<th>Year (FY)</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Avg. of the max. snow depth</td>
<td>cm</td>
<td>Avg. of the max. snow depth within the surveyed zone</td>
<td>1971~2000</td>
<td>Mesh Kikochi 2000 (Weather data)</td>
</tr>
<tr>
<td>2 Avg. elevation</td>
<td>m</td>
<td>Avg. elevation of the area within the surveyed zone</td>
<td>2001</td>
<td>50-m DEM (50-m-mesh map)</td>
</tr>
<tr>
<td>3 Evergreen coniferous woodland area</td>
<td>m²</td>
<td>Avg. area proportion within the surveyed zone</td>
<td>1979~1998</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>4 Broadleaf tree woodland area</td>
<td>m²</td>
<td>&quot;</td>
<td>1979~1999</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>5 Larch woodland area</td>
<td>m²</td>
<td>&quot;</td>
<td>1979~2000</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>6 Grassland</td>
<td>m²</td>
<td>&quot;</td>
<td>1979~2001</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>7 Farmland</td>
<td>m²</td>
<td>&quot;</td>
<td>1979~2002</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>8 Urban area</td>
<td>m²</td>
<td>&quot;</td>
<td>1979~2003</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>9 Open water</td>
<td>m²</td>
<td>&quot;</td>
<td>1979~2004</td>
<td>Natural Environment Information GIS</td>
</tr>
<tr>
<td>10 Distance from nearest river</td>
<td>m</td>
<td>Distance from each kilopost to the nearest river</td>
<td>2003</td>
<td>25000 map of G.S.I.</td>
</tr>
<tr>
<td>11 Avg. daily traffic volume</td>
<td>No. of cars</td>
<td>Avg. 24-hr. weekday traffic volume for the determined census unit road section that includes the kilopost</td>
<td>2005</td>
<td>Traffic Volume Census 2005</td>
</tr>
</tbody>
</table>
The graphs in Figure 3 show seasonal changes in the number of DVCs on Routes 236 and 273 as examples. They indicate that DVCs tend to occur at the same locations in every season and that the accident frequencies are high in the spring migration and fall breeding seasons, and low the fall migration season and wintering season. Almost the same tendencies are observed on other sample routes.

FIGURE 3  DVCs on route 236 and route 273 by season.

RELATIONSHIP BETWEEN TOPOGRAPHY AND DVCs

Poisson Regression Analysis of DVC Factors

The Poisson regression model is used in this study to understand the effect of explanatory variables on the
number of deer accidents. The overdispersion estimated for the model is 3.03. The model assumes that \( Y_i \),
the dependant valuable for \( i \) (with \( i = 1, 2, \ldots, n \)), has a Poisson distribution with a mean of \( \mu_i \).

\[
P(Y_i = y_i) = \frac{\mu_i^{y_i} e^{-\mu_i}}{y_i!} \quad (1)
\]

where \( y_i \), which is the element of \( Y_i \), is the number of accidents observed on road section \( i \) in a given period,
and \( \mu_i \) is the mean number of accidents on road section \( i \).

The link function used is that of the Poisson regression, and that function is shown in Equation (2):

\[
\mu_i = E(Y_i) = e^{X_i' \beta} = e^{\sum_{j=1}^{k} x_{ij} \beta_j} \quad (2)
\]

where \( \beta_j \) is a vector representing the set of parameters to be estimated, \( X_i \) is a vector representing the
explanatory variables, \( j=1, \cdots, k \) is the number of explanatory variables, and \( i \) is the number of road sections.

The regression parameters \( \beta = (\beta_1, \beta_2, \cdots, \beta_k) \) of this model can be estimated by using the Maximum
Likelihood Method. An unknown parameter is determined such that the likelihood of the dependent
variable becomes maximum. The explanatory variables are normalized. The parameter estimates are
obtained by JMP6.0. As a result, the explanatory variables and the number of DVC accidents are found
to be significantly related (Likelihood Ratio: \( x^2 = 456.19, p<0.0001 \)).

The data fit the Poisson regression model well. The parameter estimates for the respective
explanatory variables are listed in Table 2. The parameter estimates of values with positive signs
indicate that the factors that contribute to the number of DVCs include avg. annual max. snow depth,
avg. area of woodland (evergreen coniferous trees, broadleaf trees, larch), grassland, farmland and open
water. The parameter estimates for the variables such as avg. elevation, distance from the nearest river
and average day traffic volume (ADT) have negative signs. (Table 2)

TABLE 2 Parameter Estimates Obtained by Poisson Regression Model
for the Respective Explanatory Variables

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Parameter estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. of the max. snow depth</td>
<td>0.2066 ***</td>
</tr>
<tr>
<td>Avg. elevation</td>
<td>-0.0137</td>
</tr>
<tr>
<td>Evergreen coniferous woodland area</td>
<td>1.1832 ***</td>
</tr>
<tr>
<td>Broadleaf tree woodland area</td>
<td>0.8848 ***</td>
</tr>
<tr>
<td>Larch woodland area</td>
<td>0.4960 ***</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.4754 ***</td>
</tr>
<tr>
<td>Farmland</td>
<td>0.9187 *</td>
</tr>
<tr>
<td>Urban area</td>
<td>0.0718</td>
</tr>
<tr>
<td>Open water area</td>
<td>0.3666 **</td>
</tr>
<tr>
<td>Distance from nearest river</td>
<td>-0.1604 **</td>
</tr>
<tr>
<td>Avg. daily traffic volume</td>
<td>-0.1514</td>
</tr>
<tr>
<td>Log likelihood function</td>
<td>423.528</td>
</tr>
<tr>
<td>Restricted log likelihood</td>
<td>651.623</td>
</tr>
<tr>
<td>( \hat{\rho}^2 )</td>
<td>0.350</td>
</tr>
</tbody>
</table>

\[ \hat{\rho}^2 = 1 - \frac{\log \text{likelihood function}}{\text{restricted log likelihood function}} \]

Level of significance: *** 0.1%, ** 1%, * 5%
Observed Number of DVCs versus the Number of DVCs Estimated by the Poisson Regression Model

The graphs in Figure 4 compare the numbers of DVCs, shown by solid lines (number of DVCs here refers to the cumulative number of DVCs at a section for 12 years; the number of DVCs per kilometer is obtained by dividing the total by the section length) and the numbers of DVCs estimated by the Poisson regression model, shown by the grey lines. The numbers on the horizontal line are kiloposts. To facilitate analysis, these are renumbered such that KP0 indicates the first kilopost from the boundary of Tokachi area. The two sequential line graphs show that the observed numbers of DVCs roughly agree with the estimated numbers of DVCs. However, there exist some sections where the disparity of the observed DVC numbers and the estimated numbers is great compared with the disparity for other sections.

In Figure 4, the sections boxed in by solid lines (H-1, H-2, H-3) are road sections with high DVC frequencies, and those boxed in by broken lines (L-1, L-2, L-3) are road sections with low DVC frequencies. The sections where DVCs occurred 2 times or more/km were defined as high-frequency sections, and those where DVCs occurred less than 2 times/km were defined as low-frequency sections. Figure 4 indicates that there are high-frequency and low-frequency sections on all the sample routes. Part of those sections include sub-sections where the disparity of the observed DVC numbers and the estimated numbers is great. In the sections including H-1 on Route 336, H-2 and L-2 on Route 38, H-1 on Route 273 and H-1 on Route 274, there are sub-sections where observed DVCs are much more numerous than estimated DVCs. Conversely, in the section H-1 on Route 241, observed DVCs numbers are much fewer than estimated DVCs.

Relationship between Landscape Composition around the Seven Routes and DVC Frequency

Figure 4 visualizes the landscape composition along the sample routes. As in Figure 4, the numbers on the horizontal line are kiloposts that are renumbered such that KP0 indicates the first kilopost from the boundary of Tokachi area. The definitions of the sections boxed in by solid lines (H-1, H-2, H-3) and those boxed in by broken lines (L-1, L-2, L-3) also are road sections with very high DVC frequencies, and road sections with low DVC frequencies, respectively.

The relationship between landscape composition around the sample national highways and the numbers of DVCs (here, this refers to the cumulative number of DVCs at a section for 12 years; the number of DVCs per kilometer is obtained by dividing the total by the section length) was analyzed for each route (Table 3). For the analysis, the land classification in 1000-m-radius zones set around every kilopost of the sample roads was identified by using GIS software to demonstrate the characteristics of DVC-prone sites. In this analysis, tree types in the vegetation around the road were investigated, because deer prefer some sorts of trees for food and shelter.

Route 38 (Figure 4-1)
As Figure 4-1 shows, sections H-1 and H-2 of Route 38 are characterized by a high proportion of woodlands. Around L-1 and L-2, farmland accounts for a high proportion of the area within the zones. Around the DVC-free section between H-1 and L-1, as well as that between L-2 and H-2, urban areas exist.

Route 236 (Figure 4-2)
On Route 236, L-1 and L-2 are characterized by a high proportion of farmlands, followed in predominance by larch and broadleaf woodland. H-1 tends to have almost the same proportion of landscape classifications as L-1 and L-2. Along H-2, the proportion of broadleaf woods is high and the proportion of farmland decreases moderately as one moves toward the end of the route.
Route 241 (Figure 4-3)

H-1 and H-2 of Route 241 are characterized by evergreen coniferous woodland, and by broadleaf tree
and larch woodland, respectively. For L-1 and L-2, almost 50% of the surrounding landscape is
broadleaf and larch woodland, and farmland also predominates. In the DVC-free section between L-1
and L-2, urban area exists. For H-3, broadleaf woodland and grassland predominate.

Route 242 (Figure 4-4)

On Route 242, H-1 is characterized by a predominance of larch and broadleaf woodland. L-1 is
characterized by a high proportion of wooded area in which broadleaf and evergreen coniferous
predominate. Although the DVC frequencies differ between H-2 and L-2, these two sections share
similar landscape, with a moderate proportion of broadleaf and larch woodlands and high proportion of
farmland area. In the landscape around L-3, farmland predominates.

Route 273 (Figure 4-5)

The most landscape of H-1, a highly DVC-prone section of Route 273, evergreen coniferous woodland
predominates, although some broadleaf tree woodland, grasslands and open water areas of lakes are
found. In the landscape of L-1, however, the proportion of farmland is high, followed by the proportion
of larch woodland.

Route 274 (Figure 4-6)

On Route 274, H-1 is characterized by a high proportion of broadleaf woodland and by moderate
proportions of evergreen coniferous woodland and grasslands. In the landscape around H-2, evergreen
coniferous woodland predominates. L-1 is characterized by high proportions of farmlands and some
broadleaf woodlands.

Route 336 (Figure 4-7)

Along H-1 of Route 336 except the first short section, farmland is dominant though some broadleaf tree
and larch woodland appear. Around H-2, the proportion of farmland is high in the first half of the
section and the proportion of broadleaf woodland is high in the second half of the section, which also
has with some farmland. L-1 has a high proportion of broadleaf tree woodland and open water areas.
L-2 has a high proportion of farmland, and there are some areas of broadleaf and larch woodland. At L-3,
farmland predominates.

Table 3 The number of DVCs and the number of DVCs per km for high DVC sections (H) and
low DVC sections (L) on each route.

<table>
<thead>
<tr>
<th>Route</th>
<th>H-1</th>
<th>H-2</th>
<th>H-3</th>
<th>L-1</th>
<th>L-2</th>
<th>L-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 38</td>
<td>66</td>
<td>66</td>
<td>-</td>
<td>7</td>
<td>31</td>
<td>-</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>2.9</td>
<td>3.9</td>
<td>-</td>
<td>0.8</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>Route 236</td>
<td>8</td>
<td>117</td>
<td>-</td>
<td>10</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>2.7</td>
<td>4.7</td>
<td>-</td>
<td>1.7</td>
<td>1.4</td>
<td>-</td>
</tr>
<tr>
<td>Route 241</td>
<td>33</td>
<td>55</td>
<td>21</td>
<td>20</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>4.1</td>
<td>3.1</td>
<td>3.5</td>
<td>1.4</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>Route 242</td>
<td>20</td>
<td>33</td>
<td>-</td>
<td>15</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>2</td>
<td>2.1</td>
<td>-</td>
<td>1.7</td>
<td>1.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Route 273</td>
<td>458</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>10.2</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Route 274</td>
<td>49</td>
<td>33</td>
<td>-</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>2.6</td>
<td>3.7</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Route 336</td>
<td>75</td>
<td>77</td>
<td>-</td>
<td>9</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>No. of DVCs</td>
<td>6.8</td>
<td>2.1</td>
<td>-</td>
<td>1.1</td>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>
FIGURE 4  Landscape composition around the sample routes, and DVC frequencies/number of DVCs and estimated number of DVCs for 12 years by kilopost and route

H: high-DVC section   L: low-DVC section

[Diagram showing landscape composition and DVC frequencies for different routes with various labels and symbols indicating different areas such as Farmland, Evergreen coniferous woodland area, Broadleaf tree woodland area, Larch woodland area, Grassland, Open water area, Urban area, and Other. The diagrams are labeled with route numbers and sections (H-1, L-1, L-2, H-2, L-3) and show the distribution of DVCs along the routes.]
In-Depth Analysis of the Relationship between Landscape Composition/Configuration and DVC Frequency

Here, the relationship between landscape around roads and DVC frequency is investigated by examining maps that show landscape around sections of the seven routes (Figure 5). Sections of Route 236 that are less prone to DVCs (L-1 and L-2) are in farmland areas, and a DVC-prone section (H-1) is in a farmland area adjacent to expansive woodlands (Figure 5-1). Road sections that pass along farmlands that are adjacent to woodlands tend to be prone to DVCs.

Road alignment may also affect DVC frequency. For example, L-1 on Route 38 is a road section with low DVC frequency (Figure 5-2); however, the 1-km road section encircled by the broken line experiences much more frequent DVCs (7 accidents /12 years) than other places on section L-1. The high frequency of DVCs on this section may result from the road alignment that is designed as the roadway goes through woodland, separating what would otherwise be continuous woodland. Because deer are likely to use such woodlands as corridors of travel, even if it is cut into separate parts by a roadway, they tend to traverse the roadway in the corridor they used for travel before the road construction, which may result in frequent DVCs.

Figure 6 shows the landscape of the DVC-prone section (H-1) on Route 336. More DVCs occurred than there were predicted by the model created by Poisson regression. A possible reason for the discrepancy between the estimated DVCs and the actual DVCs is the landscape configuration specific to this road section. Although the share of woodland and farmland in the landscape for this section is almost the same, the woodland intersperses farmland, which is different from other road sections with similar landscape. To realize more precise DVC estimation for such a road section,
including more detailed data concerning landscape configuration in the analysis seems to be necessary. DVCs in this road section shows another DVC characteristic which may be resulted from deer ecology. It is also different from other road sections. Each pie chart in Figure 6 indicates each ecological season’s share of DVCs at every kilopost in section H-1 on Route 336. The size of each pie chart represents the number of DVCs recorded for the kilopost at that location. Pie chart A, encircled by the broken white line, indicates that the spring and fall migration seasons account for a large share of the DVCs there. The pie charts in B, encircled by the broken black line, indicate that the breeding season accounts for a large share of the DVCs there. To determine why the DVC occurrence tendencies for these areas differ from those on other sections, we need to analyze more detailed data on site landscape conditions and deer behavior.

![Figure 6: A DVC-prone section on Route 336 and the DVC ratio by deer ecological season.](Sources: The 2nd–5th Green Census, Ministry of the Environment)

**Relationship between DVC Frequency and Sika Deer Population along the Roadway**

On DVC-prone section H-1 on Route 273, there are multiple 1-km sections where DVCs have occurred frequently. Figure 7 shows the deer population along the road section, the number of DVCs and the number of DVCs estimated by Poisson regression. The deer population was counted by spotlight survey. A spotlight survey is a method of sampling the population of deer in the given area by shining a spotlight along the roadside from a slowly moving car in order to count the deer population based on observations of the reflection from a pair of illuminated eyes. The deer spotlight surveys for this study were conducted along Route 273 twice a month from May to November in 2002. The sections marked gray in Figure 7 have the most frequent DVCs. These DVC-prone frequent sections coincide with...
sections that are more densely populated with deer. The DVC-prone sections tend to have open spaces such as open roadside slopes or grasslands, and deer can easily reach the roadside where edible grasses are abundant. In the spring and fall deer migratory seasons, the deer population is recognized to be higher than other seasons at the DVC-prone sections. The roadside environment that facilitates deer feeding and deer seasonal migration may work synergistically to promote DVCs in the specific sections.

FIGURE 7 Deer population along Route 273 and DVC frequency.

DISCUSSION and CONCLUSION

To find effective prevention measures for DVCs, this study identified the state of DVCs in detail on the seven national highways in Tokachi, Hokkaido, on the basis of records from a database that included the number of DVCs for the 12 years from 1995, each DVC location, the route name and the deer carcass pickup date. Data on DVC site landscape features such as avg. annual max. snow depth, avg. elevation, vegetation type, land use, distance from the nearest river and ADT were also surveyed to investigate their effects on DVC frequency. The analysis results are summarized as follows.

- DVC frequency differs by season, because of seasonal differences in deer behavior. DVCs tend to be the most frequent in the spring migration season (April–May) and the fall breeding season (October).
- DVC-prone road sections are almost the same throughout the year.
- The Poisson regression model that was used to understand the effect of explanatory variables that consist of DVC site landscape factors fits the data well. Avg. annual max. snow depth, woodland, grassland, farmland, open water area and proximity to a river were found to relate to DVC frequency. Like a case of the H-1section on Route 336, when there is discrepancy between the estimated no. of DVCs and the actual no. of DVCs, more detailed analyses of data including landscape configuration will be necessary to realize more precise DVC estimation by the model.
- The analysis of the relationship between landscape around the roads and DVC frequency found that road sections with a high proportion of woodland tend to be prone to DVCs. Conversely, road sections where farmland predominates tend to have low numbers of DVCs.
- As for the relationship between landscape and DVC frequency, road sections that pass through woodland or along farmland that is adjacent to woodlands tend to have frequent DVCs. Road sections on the boundaries between farmland and woodland also are prone to DVCs.
- A road section whose road alignment is designed as the roadway goes through woodland, separating what would otherwise be continuous woodland, tends to have frequent DVCs.
- For some road sections where the numbers of DVCs were greater than the value estimated by the model, those greater values may be attributable to the high populations of deer along the road sections.
The analysis results generally suggest that DVCs tend to occur the most frequently on road sections in woodlands or at woodland-farmland boundaries. Different DVC prevention measures could be implemented for these two types of DVC sites, which differ in landscape. For DVCs in woodland, the installation of deer-proof fences and underpasses, restriction on vehicle speeds and some sort of deer warning whistles including electric ones\(^{17}\) may be effective. On roadside slopes that deer can use for foraging or resting, plants that deer dislike could be planted.

On the DVC-prone sites at woodland-farmland boundaries, deer-proof fences cannot be used because at such locations farming roads connect different parts of the farmlands through woodlands. Installing deer passages such as underpasses at such sites after identifying where deer tend to cross the roadway will be useful. Because throughout the year, DCVs tend to occur at almost the same road sections and in the same seasons, reminding road users, especially non-locals, to be alert to DVCs on DVC-prone road sections and in DVC-prone seasons will be effective. Road patrols need to be intensified in the DVC-prone season on the specific sections where DVCs have repeatedly occurred.

DVC prevention efforts tailored to the DVC prone site or season will enable the cost-effective and efficient decrease in DVCs.

The database used for this study lacked detailed DVC data including those of the DVC occurrence time, specifics of drivers who experienced DVCs and how each DVC occurred. Identifying DVC factors for a DVC-prone section whose accident frequency cannot be explained by typical DVC factors will require more detailed DVC data, and careful surveys of the surroundings at DVC-prone sections and of deer behavior around such sites will be required.

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**REFERENCES**


