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

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Wildlife vehicle collisions in Japan

- The cumulative number of wildlife-vehicle collisions in Japan is estimated to range from 110,000 to 370,000 in 1998. (Saeki et al., 2004)

- The number of wildlife-vehicle collisions on all the expressways in Japan totals 35,933 in 2002. (Shinoda et al., 2003)

- Our research target has been sika deer-vehicle collisions (DVCs) in Hokkaido, Japan.
Hokkaido
Northern most island of Japan
Area: 83,450 km² (32,200 sq. mi.)
Population: About 5 million
Climatic features:
Four seasons and cold, snowy winter.
Changes in sika deer population in Hokkaido

About 300,000 or more sika deer are estimated to live in Hokkaido. The population is still increasing.

Factors of the deer population increase: deer protection policies, increases in grassland area, extinction of wolves and a decrease in the no. of hunters.
Deer population in Hokkaido

The land area of Montana is almost the same as that of Japan (377,929.99 km²)

<table>
<thead>
<tr>
<th></th>
<th>Area(km²)</th>
<th>Population (human)</th>
<th>Population density</th>
<th>Estimated deer population</th>
<th>Deer population density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montana</td>
<td>381,156</td>
<td>944,632 (in 2006)</td>
<td>2.48</td>
<td>530,161*</td>
<td>1.39</td>
</tr>
<tr>
<td>Hokkaido</td>
<td>83,450</td>
<td>5,571,770 (in 2008)</td>
<td>66.77</td>
<td>about 300,000**</td>
<td>3.59</td>
</tr>
</tbody>
</table>

*: Mule deer and White tailed deer in Montana in 2007,
Source: Montana Fish Wildlife and Park (http://fwp.mt.gov/default.html)
**: Sika deer in 2006 (Source: Article of Asahi Shinbun)
Increases in DVCs in Hokkaido

Increases in deer population have resulted in increases in deer-vehicle collisions (DVCs) throughout Hokkaido.

DVCs on national highways:

- 421 in 1996
- 1,030 in 2003

Seven years later

Noro et al. 2005
Research background:

Few detailed studies on DVC seasonal or locational factors

Research Objective:

Development of cost effective, efficient DVC prevention measures through the analyses of the relationship between the seasonal behavior of deer and the landscape of the DVC sites.

Study Area: Tokachi in Hokkaido, Japan

Sample Routes: All the seven national highways in Tokachi (Routes: 38, 236, 241, 242, 273, 274, 336)
Seven national highway routes in Tokachi
Research Methods

Records used for the research:

- Records of road kills for the 12 years from 1995 to 2007
  - Route name and the location on the national highway where each deer carcass is picked up, the type of animal and the pickup date
  - Each DVC was indicated by the nearest kilopost.
- The total length of the seven highways: 703 km
- The total number of such kiloposts: 703.
# Database of Landscape Features along the Seven Routes

<table>
<thead>
<tr>
<th>Explanatory variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Avg. of the max. snow depth</td>
</tr>
<tr>
<td>2 Avg. elevation</td>
</tr>
<tr>
<td>3 Evergreen coniferous woodland area</td>
</tr>
<tr>
<td>4 Broadleaf tree woodland area</td>
</tr>
<tr>
<td>5 Larch woodland area</td>
</tr>
<tr>
<td>6 Grassland</td>
</tr>
<tr>
<td>7 Farmland</td>
</tr>
<tr>
<td>8 Urban area</td>
</tr>
<tr>
<td>9 Open water</td>
</tr>
<tr>
<td>10 Distance from nearest river</td>
</tr>
<tr>
<td>11 Avg. daily traffic volume (ADT)</td>
</tr>
</tbody>
</table>
Seasonal behavioral patterns of sika deer

Wintering

Fawn bearing/raising

Breeding

Migration

Spring migration
(April - May)

Fawn bearing/raising
(June - September)

Breeding
(October)

Fall migration
(November - January)

Wintering
(February - March)
DVCs by season

Number of DVCs by season, and number of DVCs per km for DVC-prone road sections on all the target routes.

![Bar chart showing DVCs by season](chart)

- Spring migration: 162.0 DVCs
- Fawn bearing/raising: 109.5 DVCs
- Breeding: 260.0 DVCs
- Fall migration: 73.3 DVCs
- Wintering: 19.0 DVCs

<table>
<thead>
<tr>
<th>Season</th>
<th>No. of DVCs</th>
<th>DVC rate/km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>162.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Fawn bearing/raising</td>
<td>109.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Breeding</td>
<td>260.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Fall migration</td>
<td>73.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Wintering</td>
<td>19.0</td>
<td>1.2</td>
</tr>
</tbody>
</table>
DVCs on Route 236 and Route 273 by season

- DVCs tend to occur at the same locations in every season.
- High rate of accidents: spring migration and fall breeding seasons
- Low rate of accidents: the fall migration season and wintering season.
Poisson Regression Analysis of DVC Factors

The Poisson regression model: (overdispersion parameter = 3.03)

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

(1)

\( Y_i \): the dependant valuable for \( i \) (with \( i = 1, 2, \ldots, n \))

\( Y_i \) has a Poisson distribution with a mean of \( \mu_i \).

\( y_i \): the element of \( Y_i = \)the number of accidents observed on road section \( i \) in a given period

\( \mu_i \): the mean number of accidents on road section \( i \).

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

(2)

\( \beta_j \): a vector representing the set of parameters to be estimated,

\( X_j \): a vector representing the explanatory variables

\( j = 1, \ldots, k \): the number of explanatory variables

\( i \): the number of road sections
## Poisson Regression Analysis of DVC Factors

Parameter Estimates Obtained by Poisson Regression Model for the Respective Explanatory Variables (likelihood ratio: \( x^2 = 456.19, p < 0.0001 \)).

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Parameter estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avg. of the max. snow depth</strong></td>
<td>0.2066 ***</td>
</tr>
<tr>
<td>Avg. elevation</td>
<td>-0.0137</td>
</tr>
<tr>
<td><strong>Evergreen coniferous woodland area</strong></td>
<td>1.1832 ***</td>
</tr>
<tr>
<td><strong>Broadleaf tree woodland area</strong></td>
<td>0.8848 ***</td>
</tr>
<tr>
<td><strong>Larch woodland area</strong></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><strong>Open water area</strong></td>
<td>0.3666 **</td>
</tr>
<tr>
<td><strong>Distance from nearest river</strong></td>
<td>-0.1604 **</td>
</tr>
<tr>
<td>Avg. daily traffic volume (ADT)</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>( \rho^2 )</td>
<td>0.350</td>
</tr>
</tbody>
</table>

Level of significance: *** 0.1%, ** 1%, * 5%

\[
\rho^2 = 1 - \frac{\text{log likelihood function}}{\text{restricted log likelihood function}}
\]
The no. of DVCs and estimated number of DVCs on Route 38 and Route 236

The observed numbers of DVCs roughly agree with the estimated numbers of DVCs.
Landscape composition around Route 38, and the no. of DVCs and estimated number of DVCs.

H: high-DVC section
(2 DVC or more/km)
low-DVC section
(less than 2 DVC/km)

Route 38
H-1
L-1
L-2
H-2

Farmland
Evergreen coniferous woodland area
Broadleaf tree woodland area
Larch woodland area
Grassland
Open water area
Urban area
Other

Estimated No. of DVCs  No. of DVCs
In-Depth Analysis of the Relationship between Landscape Composition/Configuration and DVC Frequency

Route 38

H-1 and H-2 of Route 38: a high proportion of woodlands.
Route 236

L-1 and L-2: Farmland areas

H-1: Farmland area adjacent to expansive woodlands

Road sections that pass along farmlands that are adjacent to woodlands tend to be prone to DVCs.
Road alignment and DVC frequency (Route 38 : L-2)

Road alignment may also affect DVC frequency.
Road sections where more DVCs occurred than there were predicted by the Poisson Regression model.
Route 336

This road section on Route 336 shows DVC characteristics which may be resulted from deer ecology which may be also different from other road sections.
Relationship between DVC Frequency and Sika Deer Population along the Roadway

Deer population along Route 273 and DVC frequency.
CONCLUSION

*DVC frequency differs by season, because of seasonal differences in deer behavior.
*DVC-prone road sections are almost the same throughout the year.
*The Poisson regression model fits the data well.
  Factor found to relate to DVC frequency:
    Avg. annual max. snow depth, woodland, grassland, farmland, open water area and proximity to a river.

*To realize more precise DVC estimation by the model more detailed analyses of data including landscape configuration will be necessary.
*A high proportion of woodland tend to be prone to DVCs.
Road sections where farmland predominates tend to have low numbers of DVCs.
*Road sections prone to DVCs:

- That pass through woodland,
- Along farmland that is adjacent to woodlands,
- On the boundaries between farmland and woodland
- Road alignment is designed as the roadway goes through woodland
- With the high populations of deer along the road sections.
DVC Prevention Measures Differentiated by Road Environment

- 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

**Woodland:** deer-proof fences and underpasses, restriction on vehicle speeds, deer warning whistles

**Woodland-farmland boundaries:** non-locals, to be alert to DVCs on DVC-prone road sections and in DVC-prone seasons
DVC Prevention Facilities in Hokkaido

Deer-proof fence

underpass
Issues toward the future:

Collection of more detailed DVC data to realize effective DVC prevention measures:
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
Thank you for your attention.

Visit Hokkaido to observe sika deer!

**Acknowledgements**: I am grateful for Hokkaido Regional Development Bureau that has offered me the materials necessary for animal-vehicle collision analyses.

Sika deer in Shiretoko Peninsula designated as a World Heritage Site