The relationship between deer-train collisions and daily activity of the sika deer, *Cervus nippon*

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**Abstract.** The relationship between deer-train collisions and daily activity of sika deer *Cervus nippon* was investigated between Mashu and Biruwa railway stations on the Senmou Line in eastern Hokkaido from April 1995 to March 1997. Deer-train collisions were concentrated near Mt. Biruwa, in the period from January to March (72% of the total), and in the evening (69%). Few collisions occurred in April when the first train passed through after sunrise. Deer crossing concentrated around sunset or sunrise during January to April. Monthly deer-train collisions were positively correlated with the number of deer crossing the railway tracks. Furthermore a constant directionality in railway crossing was detected in most months. This directionality resulted from deer moving between a feeding site in the evening and a resting site in the morning. Deer-train collisions occurred in relation to the daily activity pattern of deer in the vicinity of the railway tracks.

**Key words:** daily activity, deer-train collisions, railway crossing, sika deer, videotape recorder.

The sika deer occurs throughout most areas of Hokkaido and populations have increased rapidly since 1970, especially in eastern Hokkaido (Kaji et al. 2000). As a result of the increasing deer population, crop or forestry damage by deer and deer-vehicle and -train collisions have become serious social problems especially in eastern Hokkaido (Uno et al. 1995; Hokkaido Institute of Environmental Sciences 1997; Ohtaishi et al. 1998). For example, the number of deer-vehicle collisions nearly doubled in Nemuro city, eastern Hokkaido, from 1990 to 1993 (Tamada and Matsuda 1994). Deer-train collisions occurred 696 times on a 331 km-long section of the Senmou and Nemuro lines in eastern Hokkaido from 1987 to 1995 (Onoyama et al. 1997). There have also been reports indicating an increasing trend of deer-vehicle collisions overseas (Chapman 1993; Romin and Bissonette 1996). To prevent deer-vehicle and -train collisions various measures have been employed including: fencing, underpass or overpass construction, Swareflex reflectors® (reflective mirrors set alongside railways or roads to deter deer from entering), deer crossing signboards, and repellents. However, no significant reductions in traffic accidents have been achieved (Groot Bruinderink and Hazebroek 1996; Romin and Bissonette 1996; Ohtaishi et al. 1998).

Although there have been many studies of deer-vehicle or -train collisions (Allen and McCullough 1976; Tamada and Matsuda 1994; Groot Bruinderink and Hazebroek 1996; Romin and Bissonette 1996; Onoyama et al. 1997), studies of the ecological factors affecting collisions have been few. Romin and Bissonette (1996) suggested that deer behaviour and habitat use should be examined in areas with frequent collisions before applying mitigating methods. Deer-vehicle or -train collisions obviously occur when deer cross railways or roads. But why do deer cross railways or roads? Most collisions occur in the evening or at night (Allen and McCullough 1976; Onoyama et al. 1997). Allen and McCullough (1976) suggested that transition from evening to night corresponded with the start of the deer feeding period. Sika deer, mule deer *Odocoileus hemionus crooki* and white-tailed deer *O. virginianus* are all most active in the morning and evening (Fukunaga 1976; Ando and Kakizawa 1977; Beier and McCullough 1990; Hayes and Krausman 1993), suggesting that deer crossing is related to the daily activity and habitat use patterns of deer.

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In the case of deer-train collisions, it is possible to collect all records of collisions because it is mandatory for motormen to submit records of all collisions to their railway company. As trains travel on a timetable, deer-train collision data are more accurate than those of deer-vehicle collisions. To understand the cause of deer-train collisions, it is important to analyse collisions in relation to deer ecology based on field surveys. Biruwa, in Teshikaga district, is one of the areas where deer collide with trains most frequently in eastern Hokkaido (Ohtaishi et al. 1998). The objectives of the present study were therefore to clarify the following:

1. Seasonal and hourly variation in the numbers of deer crossing and deer-train collisions.
2. The relationship between the daily activity patterns of deer and railway crossings.

**Study area**

The survey was conducted in the Biruwa area (Teshikaga district) near Biruwa railway station on the Senmou Line in eastern Hokkaido, Japan (Fig. 1). The distance along the track between Mashu and Biruwa stations was 7.16 km. Trains passed one to three times per hour between 06:00 and 20:00 on this section. Highway 391 runs parallel to the Senmou Line, separated from it by 50–400 m (Fig. 2). To the east of the railway line, lies Mt. Biruwa, a forested mountain, connected to Mt. Mashu further to the east. In this area the representative vegetation consists of Sakhalin Fir *Abies sachalinensis* plantations with oak *Quercus crispula* growing alongside the railway. To the west, there are natural grassland areas alongside the railway line, and the source of the

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**Fig. 1.** Map of the study area. The distance between Mashu and Biruwa stations along the tracks is 7.16 km. The Senmou Line and Highway 391 run side by side through the study area.
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Biruwa River, which does not freeze even in winter. Along the river (between the railway and Highway 391), Japanese alder *Alnus japonica* and ash *Fraxinus mandshurica* var. *japonica* predominate, with an understory of dwarf bamboo *Sasa senanensis*. To the west of Highway 391, there are cultivated meadows. The average temperatures range from –5.0°C in February to 18.0°C in August. Maximum snow depth throughout winter was approximately 45 cm in 1995 and 1996.

**Methods and study periods**


Data on deer-train collisions between Mashu and Biruwa stations were collected by the Engineering Section of the Kushiro Branch of the Hokkaido Railway Company. When a motorman stopped a train as a result of a collision or a close encounter with a deer, the incident was counted as one deer-train collision under the mandatory system. The data recorded included the date, time and place of deer-train collisions from April 1987 to March 1997, making it possible to analyse the yearly, monthly and hourly variation in the number of deer-train collisions. To compare this data with the number of deer crossing, I used collision data from 1995 to 1997 for monthly change and from 1987 to 1997 for hourly change because of the small data sets. The fiscal year, from April one year until March the next, was followed for convenience’ sake.

**Field study**

Deer crossing the railway tracks were recorded using a videotape recorder set overlooking the railway line (Fig. 2). The maximum distance at which deer were detectable by video camera was approximately 700 m. Video recording was used for analyzing seasonal and hourly changes in deer crossing behaviour. To obtain data on seasonal variation in deer crossing, the recorder was set to run for two hours after sunrise and again for two hours before sunset, three days per month from April 1995 to March 1997. To collect information on hourly variation in deer crossing, a video camera was used during daytime and a spotlight at night. The video camera was set to run from sunrise to sunset on one day per month from August 1996 to July 1997. Nocturnal activity was observed for five minutes every hour from sunset to sunrise using a spotlight.

Data on the time of appearance and disappearance, number, sex, age, group size, place and crossing direction of all deer that crossed the railway tracks were recorded by video camera. Railway crossing was defined as a deer approaching the railway line from one side and passed completely across to the other side. Individual were classified as either fawns or adults and adults were sexed based on the presence or absence of antlers. Some deer could not be aged because of distance or darkness. If a subsequent deer appeared following the same direction within one minute of the disappearance of a previous one, they were counted as belonging to the same group. Solitary deer were also considered as being a group to facilitate group size calculations. When the same individual crossed the tracks again within a short period, it was not recounted so as not to affect the calculation of group size.

**Statistical analysis**

The Chi-square test was used to test the significance of differences in the monthly and hourly number of deer collisions. When examining monthly change I took special notice of differences between data from January to March and from other months because frequent collisions occurred from January to March. Data were pooled for every three hour period between...
Fig. 3. Annual variation in the number of deer-train collisions between Mashu and Biruwa stations (7.16 km) on the Senmou line in eastern Hokkaido. Fiscal year run from April to the following March. Oblique lines indicate the number of collisions during January, February and March.

Fig. 4. Daily variation in deer-train collisions between Mashu and Biruwa stations from April 1987 to March 1997. Trains pass one to three times per hour between 06:00 and 20:00, with none at other times. Numbers indicate the number of trains each hour.

Fig. 5. Monthly variation in the number of deer crossing and deer-train collisions between Mashu and Biruwa stations from April 1995 to March 1997.
06:00 and 21:00 to be able to examine hourly change in collisions because of the small data set. Significance of directionality of deer crossing was also tested using the Chi-square test. However, it was impossible to analyse directionality between May and August, October and November because data were too few. I used the t-test to examine the differences in the average number of deer crossing between years and the monthly group size. The Pearson’s Correlation test was used for analysing monthly change of deer crossing between 1995 and 1996, and the relationship between the numbers of collisions and deer crossing. Data with 95% probability or more were accepted as significant.

Results


A total of 72 collisions occurred from April 1987 to March 1997 between Mashu and Biruwa stations (Fig. 3). 97% of all collisions occurred along an approximately 2 km section of the trail at the foot of Mt. Biruwa, which I used for field work. The number of collisions increased from 1987 to 1996, with 33% of the total occurring in the last two years.

Frequent collisions (72% of total) occurred during January, February and March, and the number then was significantly higher than during other months (Fig. 3) ($\chi^2 = 85.63$, df = 1, $P < 0.01$).

Collisions were most frequent after 17:00 (69% of the total; Fig. 4). The hourly number of collisions varied significantly ($\chi^2 = 40.39$, df = 4, $P < 0.01$).

Relationship between numbers of deer crossing and deer-train collisions

I recorded a total of 1,178 deer crossing the railway tracks from April 1995 to March 1997. The average number of deer crossing (the total number of deer crossing divided by the total recording time) was 4.4±1.6 deer/hour in 1995 and 4.7±2.7 deer/hour in 1996, with no significant differences between the years (t-test, $df = 11$, $P = 0.86$). In both the first and second fiscal years however, the monthly numbers of deer crossing differed significantly (1995: $\chi^2 = 895.02$, df = 11, $P < 0.01$; 1996: $\chi^2 = 1545.40$, df = 11, $P < 0.01$). Monthly variation in the number of deer crossing in the first fiscal year was correlated with the number in the second fiscal year ($r = 0.76$, df = 11, $P < 0.01$).

Most deer crossing (81%) occurred from January to April, and most collisions (83%) occurred from January to March (Fig. 5). The monthly variation in the number of deer crossing was positively correlated with the number of collisions ($r = 0.68$, df = 23, $P < 0.01$). In April many deer crossed the railway tracks, however, no collisions occurred. From May onwards, until December, both deer crossing and collisions were very much fewer.

The timing of deer crossing and deer collisions varied depending on the season. From January to March both crossings and collisions were concentrated around sunset. The number of hourly changes (between 06:00 and 20:00) of deer crossing was positively correlated with collisions during January, February and March ($r = 0.67$, df = 14, $P < 0.01$). In April, the hourly peak of deer crossing coincided with sunrise or sunset, however, few collisions happened. From May to December a small numbers of collisions and few deer crossings occurred during the morning and evening (Fig. 6).

The deer tended to move across the railway tracks in a particular direction at certain times of day, thus in the evening the deer crossed from the side of Mt. Biruwa (East) to the Biruwa River (West), then in the morning they returned to the Mt. Biruwa side from the river (Fig. 7). The direction of crossing followed the same trend throughout the year. The direction differed significantly between morning and evening and showed the same pattern in almost all months ($\chi^2$-test, all $P < 0.01$ for January to April, September and December).

Group size and deer crossing

A total of 478 groups were recorded from April 1995 to March 1997. A total of 246 deer were solitary, and comprised 51% of the total number of groups. The average group size was 2.5 with a maximum of 3.7 in April and a minimum of 1.3 in July (Fig. 8). The largest group recorded was of 28 in April. The mean group size did not differ significantly from month to month (t-test, df = 11, $P = 0.72$), nor was there a correlation between monthly variation in mean group size and deer crossing or the number of deer-train collisions ($r = 0.19$, df = 11, $P = 0.56$).

Discussion

Most collisions between sika deer and trains occurred in winter (January to March) in the Biruwa area of eastern Hokkaido. It is known that deer migrate between summer and winter ranges in Hokkaido (Uno and Kaji 2000), and that they concentrate in their winter range because of the availability of food and cover there,
resulting in high density (Kaji 1981). The rapid increase in the number of crossings recorded in January in this study, and the seasonal change in the number of collisions seem likely to have resulted from seasonal migration by the deer. Because frequent crossing continued until April, it appears that the area may be within a winter range. Thus the increase in the number of deer in winter, resulting from seasonal migration, was a direct cause of the increase in deer-train collisions in Biruwa.

In the Biruwa area, deer-train collisions were most frequent between 17:00 and 19:00, a period coinciding with the peak period for collisions (16:00 and 23:00) previously reported by Onoyama et al. (1997). Allen and McCullough (1976) also indicated that deer-vehicle
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Collisions involving white-tailed deer happened during the evening and at night in southern Michigan. On roads, the increased volume of traffic in the evening was considered to contribute to the more frequent collisions (Ohtaishi et al. 1998), as was poor visibility (Waring et al. 1991). With regards to deer-train collisions, however, the number of trains per hour is constant and the visibility for the motorman is different from that of a vehicle driver. Therefore, some factor other than visibility or traffic volume seems to affect deer-train collisions, and this may be related to the daily activity pattern of the deer. The peaks of deer crossing overlapped with sunrise and sunset in this study and this characteristic was clear especially in April. Although deer frequently passed across the railway at sunrise in April, no collisions happened because the time of crossing peak was earlier than the first train. It is well known that deer are most active in the morning and evening (Fukunaga 1976; Ando and Kakizawa 1977; Beier and McCullough 1990; Hayes and Krausman 1993), thus when sunrise or sunset fall within the train operating schedule, more deer-train collisions are likely to occur.

The direction of crossing was found to be constant in all seasons, with deer crossing the railway from the Mt. Bijuwa side to the Bijuwa River in the evening, and returning in the morning. Miura (1976) described sika deer moving regularly between their feeding habitat, resting sites and sleeping sites. Deer in several parts of

Fig. 7. The direction of deer railway crossings in the morning and evening. Mt. Bijuwa lies to the eastern and the Bijuwa river flows to the west of the tracks. Videotape recording was conducted for two hours after sunrise in the morning and for two hours before sunset in the evening. Numbers indicate the total number of deer crossing from April 1995 to March 1997.
the world are also known to spend the daytime within woodland, to avoid human disturbance, and move out into open fields at night (Montgomery 1963; Beier and McCullough 1990; Sakuragi et al. 2002). Montgomery (1963), for example, observed that white-tailed deer in Pennsylvania moved out of forest in the evening to spend the night feeding in fields, and then returned the next morning to the forest. The same situation was expected in the Biruwa area. Coniferous forest on Mt. Biruwa, to the east of the railway tracks was suspected as being a resting site, however, ground cover in the coniferous forest was poor and this area lacked a source of water, thus making the area unsuitable as a winter feeding area. Across the tracks, the Biruwa River provides a permanent source of water. Furthermore, alongside the river the snow was less deep, and dwarf bamboo, S. senanensis was exposed. Many authors have reported that various dwarf bamboo species are very important food for deer in winter (Maruyama 1981; Kaji 1988; Takatsuki 1992; Yabe 1995). Therefore, the area of the Biruwa River, lying to the west of the railway tracks, provides both water and food for deer in winter, but does not provide suitable resting areas in winter because the vegetation there consists of temperate deciduous forest and cultivated meadows. In the Biruwa study area, the railway tracks separate the deer feeding site from the resting site thereby forcing the deer to cross the railway line as part of their normal daily activity pattern in winter.

In conclusion, deer-train collisions in the Biruwa area were correlated with an increase in deer crossing in winter and with the daily movements of deer. Deer in this area are forced to cross the railway line on a daily basis, especially in the morning and evening, in order to access both feeding and resting areas. Deer-train collisions showed clear patterns at fine spatial and temporal (daily and monthly) levels. In order to reduce deer-train collisions, it is important to slow trains down along the section where most collisions have been recorded. Furthermore, as deer-train collisions relate to the size of the deer population, both habitat and deer population manipulation should be considered as part of any future management policy for sika deer in the area.

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Fig. 8. Monthly variation in the mean group size of deer crossing the railway from April 1995 to March 1997. Vertical lines show standard deviations and numbers indicate the total number of deer groups.
References


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