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AN ANALYSIS OF NATURAL FACTORS OF TRAFFIC ACCIDENTS INVOLVING YEZO DEER (*CERVUS NIPPON YESOENSIS*)

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Summary

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In Hokkaido, Japan, the number of Yezo deer (*Cervus nippon yesoensis*) has recently increased drastically, causing a large number of deer-vehicle traffic accidents. This paper examines conditions related to deer-vehicle traffic accidents by analysing the following relationships: time of accident and lunar phase; time of accidents and time of sunrise/sunset; likelihood of accidents and rainfall patterns, temperature and season (particularly snow and hunting seasons). The results suggest that the potential for deer-vehicle traffic accidents increases during hunting and non-snow seasons when there is little or no rainfall, just before sunrise or just after sunset, or during a full, first quarter, or third quarter moon. A statistically significant relationship between temperature and deer-vehicle traffic accidents was not detected.

Key words: deer-vehicle traffic accidents, hunting season, lunar phase, rainfall, snow season, sunrise/sunset, temperature

INTRODUCTION

Recently, the number of Yezo or Hokkaido sika deer (*Cervus nippon yesoensis*) has increased drastically. Long term population size estimates for Yezo deer are not available; however, if we use cost of agricultural/forestry damage caused by deer as an index of population size, the total amount of damage in 1970, 1980, and 1990 equal 0.35, 2.1 and 24 million USD, respectively; the damage reached its peak in 1996 with a cost of 60 million USD. After 2000, the total cost of damage stabilized at around 36 million USD, which implies the deer population size is still large (Anonymous, 2002; 2008a).

As agricultural/forestry damage implies, the number of Yezo deer has increased, as has the number of deer-vehicle traffic accidents (in what follows, we concentrate on car accidents because of data limitations). In Hokkaido, they numbered 1,628 in 2008 (including 35 cases on expressways) and 1,838 in 2009 (including 31 cases on expressways) (Anonymous, 2010). Almost half the accidents in 2009 occurred in the eastern region of Hokkaido, and the number of accidents in this area has grown (Anonymous, 2010). The overall number of accidents increased from 293 in 1993 to 1,474 in 2007 (Anonymous, 2008b).

The situation has been the same or more severe in other countries (Putmam, 1997). For example, in the USA, there are roughly 4,100 accidents per day resulting in daily damage of over 2.7 million dollars (Gonser *et al.*, 2009), and it is estimated that 150 people are killed annually (Okwueze *et al.*, 2007). In addition, fatal accidents have more than doubled since 1990 (Sullivan, 2010).

Examining the possible reasons for the increased number of accidents will undoubtedly contribute to diminish such accidents. Thus, it is important to understand the conditions in which deer-vehicle traffic accidents occur with higher probability in order to prevent them. Existing researches examined several factors which might affect the frequency of accidents. Noro *et al.* (2007) state that the volume of traffic is heavier on national roads than on prefectural roads, which positively affects the frequency of accidents. Miyoshi (2006) states that the frequency of Yezo deer appearances on roads increases between October and April, between 16 and 20 o'clock, and that near-miss between cars and deer concentrate in the nighttime. Considering the results of existing researches, the number of accidents may grow around sunrise and sunset because, at these times, the activities of deer start to either increase or cease and deer may be moving within their home range just as humans are commuting to workplaces or schools. In addition, other factors, such as rainfall, temperature, and hunting and snow seasons, may also affect the size of deer's home ranges and the frequency of their movements, thus resulting in different frequencies of accidents.

In addition to the natural phenomena listed above, the lunar phase is also examined in this paper. Substantial former research compares lunar phase with conditions and events of wild animals or humans, and some studies identify a relationship. However, because conclusions are varied (negative and positive conclusions exist for each condition and event), a general scientific inference is not possible. In general, research tends to provide negative conclusions regarding the relationship between lunar phase and human suicide, crimes of battery, and madness (Maldonado & Kraus, 1991; Raison *et al.*, 1999; Foster & Roenneberg, 2008; Biermann *et al.,* 2009), but positive conclusions regarding the relationship between lunar phase and childbearing (Lieber, 1978; Shimokawa *et al.*, 1986; Ghiandoni *et al.,* 1998; Watanabe, 1998; Onaka *et al.*, 2001).

As far as we know, in cases of wild animals, research is mainly conducted in the area of reproduction. Watanabe (1998) suggested that the reproductive activity of primates increased during full moon and that reproductive activity and parturition was related to lunar phases for some species. In addition, some researches in Japan show that tidal shifts, which are influenced by lunar phase, influence the farrowing of domestic pigs. For example, Taura *et al.* (1990) state that farrowing tends to start around high tide and finish around low tide, although they could not detect statistically significant results. Usui *et al.* (2004) studied farrowing peaks at some pig farms over a six years period, and found that births occurred around full moons, although these results were not statistically verified.

As data pertaining to deer are not sufficient, the paper aims to examine the relationship between natural phenomena and deer-vehicle traffic accidents using publicly available data from the Hidaka subprefecture (Anonymous, 2007).

MATERIALS AND METHODS

This paper analyses three main relationships: between the time of deer-vehicle traffic accidents and the lunar phase (Analysis 1), between the time of accidents and sunrise and sunset (Analysis 2), and the number of accidents and different rainfall patterns, temperature and seasons (snow and hunting) (Analyses 3). Accident data officially provided (Anonymous, 2007) as its background materials, specifically examining 132 cases from 2005 and 134 from 2006 were used. Lunar phase data is provided by Koyomi no Page (http://koyomi.vis.ne.jp). Lunar phases vary continuously, and calculating the correct lunar phase poses substantial difficulty, therefore, in this paper, the lunar phase at noon on the day of an accident is used. Sunrise and sunset data is also provided by Koyomi no Page, as is the data for Hidaka subprefecture's Cape Erimo. Data for rainfall and temperature are taken from the Meteorological Agency of Japan (http://www.data.jma.go.jp/obd/stats/etrn/index.php). Data points for each 10 minute interval are used or in cases of insufficient available information, hourly data points.

In Analysis 1, the relationship between the lunar phase and number of accidents was expected to represent a multi–modal distribution, with peaks during full moons and other points and drops between peaks. In this paper, we occasionally use average values to define peaks and drops because the lunar phase is always derived from the conditions at noon, regardless of the actual times of accidents. We used statistical tests (mean equality test and mean test) to detect relationships between lunar phases and accidents.

In Analysis 2, we use a histogramme to depict the relationship between the time of accidents and sunrise or sunset. Needless to say, the time of sunrise and sunset differ daily and, in some seasons, sunset occurs during typical commuting times. Therefore, the number of accidents should be higher in these time zones, making Analysis 2 one of the most important parts of the study.

In Analysis 3, rainfall, temperature and season are examined. Data for rainfall is obtained from the website of the Meteorological Agency of Japan (average amounts of daily rainfall between 1979 and 2000 are provided). These values are converted into 10 minute intervals, which are compared with the amount of rainfall present at traffic accidents. Accidents are expected to be more concentrated in times when there is no or little rainfall, because, during rain, deer tend to remain in the forest to prevent rain exposure. The average daily temperature (between 1979–2000) is compared with the temperature at the time of an accident (between 2005 and 2006). Seasonal effects, specifically those related to snow and hunting seasons, are also examined. Snow season is of particular importance because, in general, as snow depth increases, the movement of wild animals decreases. Yezo deer tend to gather together and stay in their winter habitat (Koizumi, 1988; Yabe, 1995). However, data measuring daily snow depth is not available, so data for each year is divided according to snow season (from November 15th to next April 14th) and non–snow season (from April 15th to November 14th), and the average number of accidents in these two seasons are compared statistically. Additionally, hunting may affect the home ranges of Yezo deer. In 2006, hunting season in Hidaka subprefecture occurred between October 15th and February 13th; thus, these dates are used to define hunting season, while the remainder of the year is referred to as

non-hunting season. The average number of accidents in these two seasons is compared statistically.

For the majority of the analyses, data from 265 accident cases are used, but, in Analysis 2 and in the rainfall measurements in Analysis 3, we used 266 and 247 cases, respectively. Statistical analyses were conducted using Eviews 6.

RESULTS

Relationship between accidents and lunar phase

The total number of accidents according to the lunar phase is presented on Fig. 1. The average number of accidents per lunar phase (over a two year period) is 8.83. Because the number of accidents fluctuates widely, a moving average of three lunar phases (hereafter simply referred to as moving average) is also shown. The moving average peaks at lunar phases 7, 15 and 25. Interestingly, the first two peaks nearly coincide with the first quarter and full moon, respectively. The low points between these peaks occur at 4, 11, 18–19, and 29.

The data for the moving average are divided into three groups: peaks (lunar phases at 7, 15, and 25), drops (4, 11, 18–19, and 29), and others as well as average values of these groups (11.78, 6.47, and

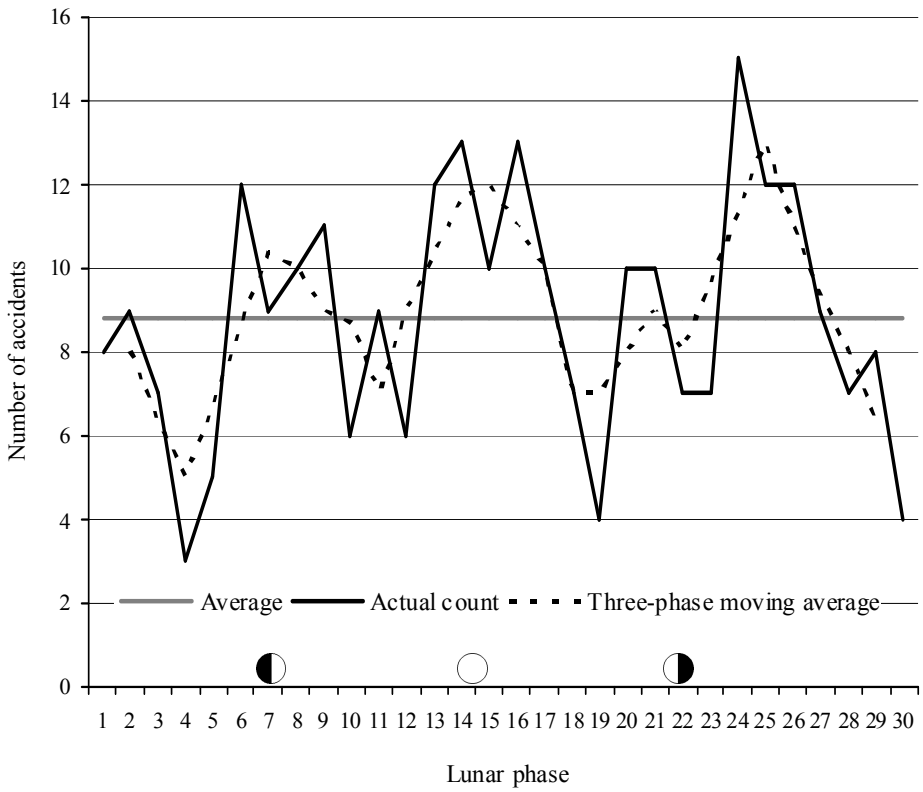

Fig. 1. Relationship between the number of deer-vehicle accidents and lunar phase (2005–2006).

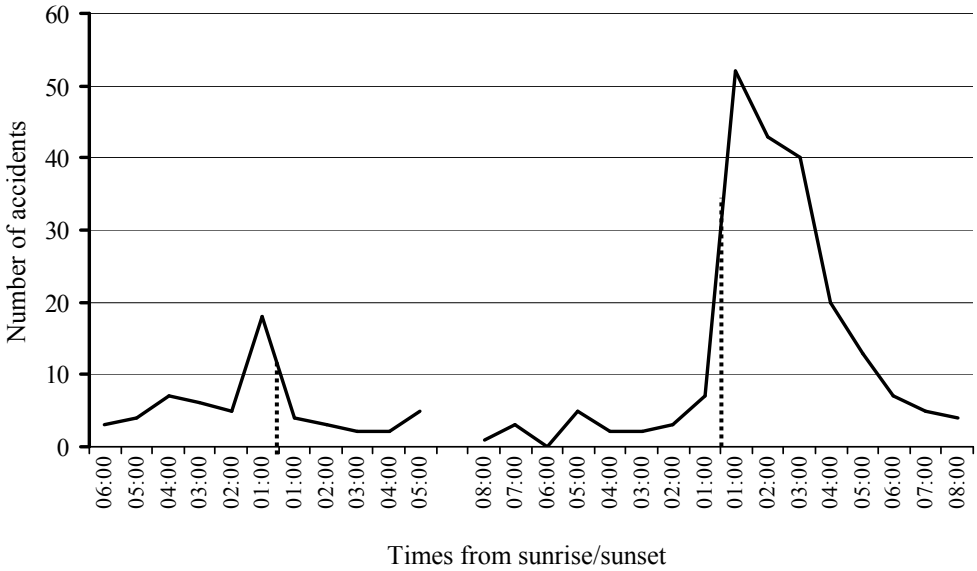

Fig. 2. Relationship between the number of deer-vehicle accidents and sunrise/sunset.

9.18). If "the average values of peaks, bottoms and others are the same" is a null hypothesis and a mean equality test is applied, the null hypothesis will be rejected at a 1% significance level (n = 265, statistically significantly different at $P<0.001$). It could then be inferred that accidents were related to lunar phase.

Relationship between time of accidents and time of sunrise/sunset

The relationship between the number of accidents and the time of sunrise and sunset is depicted on Fig. 2. Apparently, accidents tend to be most concentrated in the few hours surrounding sunrise and sunset. Within three hours after sunset, 135 accidents took place, which accounted for 51% of the 266 total cases. The times of sunrise and sunset change daily; according to data used in this paper, sunrise occurs between 3:50 and 6:54 and sunset between 15:56 and 19:07.

Influence of rainfall, temperature and season towards frequency of accidents

Fig. 3 shows the average rainfall of the day (the average rainfall between 1979 and 2000 as per the website of the Meteorological Agency, divided into 10-minute intervals) and rainfall at the time of each accident (sum of 10 minutes). Average rainfall of the whole year (the average of "the average rainfall of the day", on a ten minutes basis) was 0.023 mm. Of 247 accidents, only five occurred during rain fall, one with 2 mm of rain and four with 0.5 mm. Accidents were more heavily concentrated on days without rainfall.

The differences between temperature at the time of an accident and average daily temperature (hereafter referred to as difference in temperature) are plotted on Fig. 4. The average of the difference in temperature is 0.43 ^{o}C. If "difference in temperature is zero" is a null hypothesis and a mean test is applied, the null hypothesis will be rejected at a 10% signifi-

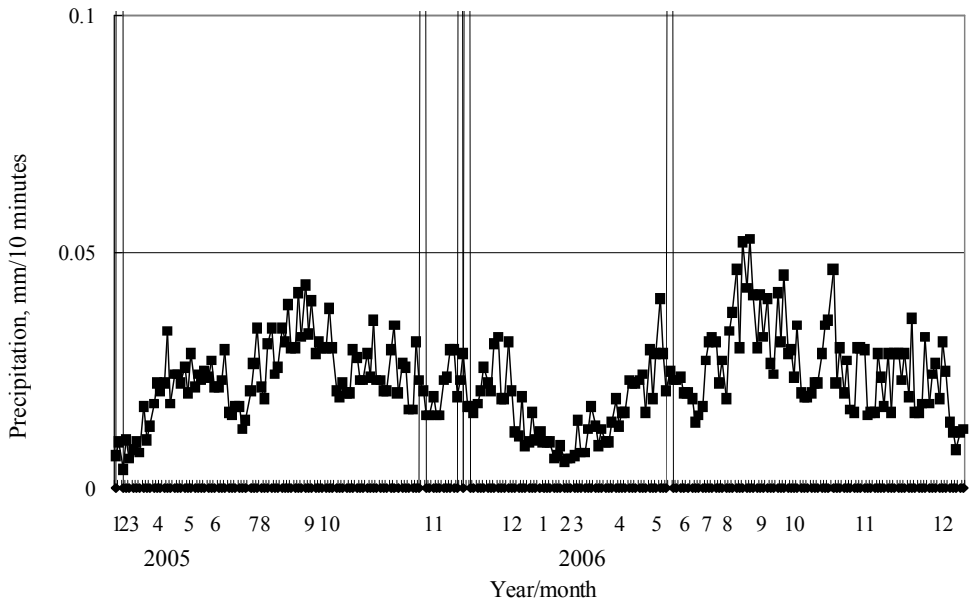

Fig. 3. Relationship between the number of deer-vehicle accidents and rainfall.

cance level (mean test; n=265, P=0.051). However, in our case, this result seems meaningless. The difference between maximum and minimum temperatures within a single day is 8.0 °C on average, and, as seen from Fig. 4, the difference in temperature is scattered almost randomly with no specific tendency. It follows that temperature at times of accidents has little or nothing to do with the maximum or minimum temperature. While not shown, the difference in temperature often has small or negative values in the case of morning accidents.

Finally, we examined the relationship between seasons and accidents (Tables 1 and 2). First, accidents during snow season (November 15th until next April 14th) and non-snow season (April 15th until November 14th) were 0.29 cases/day and 0.41 cases/day, respectively. If "the number of accidents during snow season and non-snow season are the same" is a null hypothesis and a mean equality test is applied, the null hypothesis will be rejected at a 1% significance level (mean equality test; n=730, P=0.0095). Second, accidents during hunting (October 15th until February 13th) and non-hunting season (February 14th until October 14th) were 0.48 cases/day and 0.30 cases/day, respectively. If "the number of accidents during hunting season and non-hunting season are the same" is a null hypothesis and a mean equality test is applied, the null hypothesis will also be rejected at a 1% significance level (n=730, P=0.0011).

DISCUSSION

The analysis of data showed that the number of accidents tended to increase during the first quarter moon, full moon, and the third quarter moon and to decrease in periods in between (Fig. 1). It is often said that wild animals are more active during

full moons (Freund, 1988). Much scientific research, including work by Lieber (1978), has detected a positive or negative relationship between animal/human activity and the moon phases. It would seem that, during full moons with no rain, drivers should have less trouble seeing deer and we could expect a lower number of accidents. However, as this paper shows, accidents occur more often during full moons. This paper also suggests a relationship between lunar phases and aggression of wild animals and, consequently, a relationship between the number of accidents and lunar phases.

Accidents are most concentrated during the few hours before sunrise and after sunset. Sunrise occurs between 3:50 and

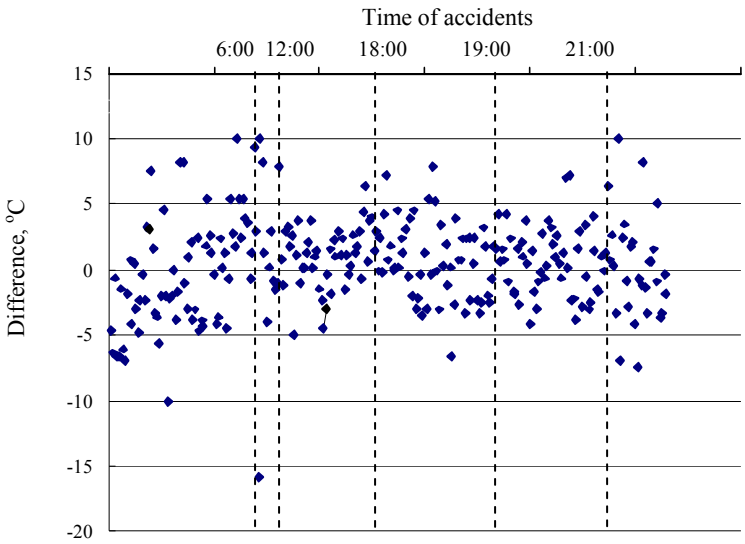

Fig. 4. Difference between temperature at the time of accidents and average daily temperature.

Table 1. Number of traffic accidents in snow and non-snow seasons

	Number of days	Number of accidents	Number of accidents per day
Snow season (November 15th until next April 14th)	152 days/year	95 cases/2 years	0.29 cases/day
Non-snow season (April 15th until November 14th)	213 days/year	170 cases/2 years	0.41 cases/day

Table 2. Number of traffic accidents in hunting and non-hunting seasons

	Number of days	Number of accidents	Number of accidents per day
Hunting season (October 15th until next February 13th)	122 days/year	125 cases/2 years	0.48 cases/day
Non-hunting season (February 14th until October 14th)	243 days/year	140 cases/2 years	0.30 cases/day

6:54, slightly before the primary commuting time in Japan. Sunset occurs between 15:56 and 19:07, which overlaps with the main evening commuting time. This concentration of accidents could be explained by a number of factors. First, these are times during which roads are most heavily-travelled. Second, sunrise and sunset can make vision difficult for drivers. Third, deer begin to become active around the times of sunrise and start to cease their activities around sunset, which means deer may be travelling within their home range during these peak times.

Discussing rainfall patterns, it should be said that it was raining in only four out of 247 cases, which accounts for only 2% of the total accidents. Visibility should decrease during rainfall, but accidents remain more concentrated in times without rain. This may be because deer decrease their activity during rainfall and remain in forests. When accidents occur, temperature tends to be higher than average, and the difference is statistically significant. This may reflect the fact that accidents rarely occur around midnight, while they occur more often when humans are active. In addition, the average temperatures included in this paper are derived from data from the years 1979 to 2000, whereas all accidents occurred between 2005 and 2006; this may have some influence on results. No other relationship between temperature and accidents existed.

Based on research, which conducted radio-tracking of 62 Yezo deer in eastern Hokkaido between 1997 and 2000, Yezo deer appear to have summer and winter home ranges and move from one to the other between October and January (from their summer to winter home range) and March and April (from their winter to summer home range). The areas of summer and winter home range measure 5,734 km^2 and 821 km^2, respectively (Igota *et al.,* 2004). It is therefore expected that in summer, the number of accidents may increase because home ranges are larger. In winter, the number may increase when deer move from one home range to the other.

Snow season (November 15th to April 14th) overlaps with the movement of deer between home ranges. Accidents increased statistically significantly from 0.29 cases/day during snow season to 0.41 cases/day during non-snow season. Although some factors (e.g. less rainfall and movement between home ranges) would seemingly lead to more accidents during snow season, our results suggest higher numbers of accidents during non-snow season. This result is consistent with former research, which has concluded Yezo deer gather in their winter habitat during snow season (Yabe, 1995).

Hunting season lasts from October 15th to February 13th. There was also a statistically significant difference between the number of accidents during hunting and non-hunting seasons (0.48 and 0.30 cases/day, respectively). Former research has reported that, during hunting season, the home ranges of some ungulates become wider, and deer and wild boar escape into protected areas to avoid hunting (Maillard & Fournier, 1995; Takatsuki, 2001; Anonymous, 2003). That way, accidents increase both directly and indirectly because of hunting.

Some periods of the snow and hunting seasons overlap, but the number of accidents during snow season remains lower than during non-snow season, whereas the number of accidents during hunting season remains higher than during non-hunting season. The possible reason for this reversal may be that many accidents

occur between October 15th and November 14th, during the first month of the hunting season and before snow fall begins; 58 accidents have occurred during this period over the past two years, which account for 22% of all accidents.

It can be concluded that the potential for deer-vehicle traffic accidents increases during hunting and non-snow seasons when there is little or no rainfall, just before sunrise or just after sunset, or during a full, first quarter, or third quarter moon. A statistically significant relationship between temperature and deer-vehicle traffic accidents was not detected.

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