An assessment of traffic volume impacts on brown bear movements near roads in Shiretoko National Park, Hokkaido, Japan

Takahiro Murakami1, Masami Yamanaka2, Hideaki Okada3, and Noriyuki Ohtaishi1

1Laboratory of Wildlife Biology, Division of Veterinary Science, Graduate school of Veterinary Medicine, Hokkaido University, N18 W9 Kita-ku, Sapporo, Hokkaido 060-0818 Japan

2Division of Environmental Conservation, Shari Town Office, Honcho 12, Shiretoko, Hokkaido 099-4192 Japan

3Shiretoko National Park Nature Center, Iwaobetsu 531, Sharicho, Hokkaido 099-4356 Japan

Abstract Detectable movement rates and road crossing rates of seven radio-collared brown bears Ursus arctos yesoensis were compared with traffic volume indices (TVI) in Shiretoko National Park during 1994, 1995 and 1996 in order to evaluate the impacts of vehicle traffic on bear road crossings. All bears in our study moved most often during daytime, although they showed some individual variation. Road crossing rates of bears were highest in the morning, daytime and evening periods. Brown bears crossed roads during the daytime, when TVI was the highest, as well as during the morning and evening when TVI was low. Furthermore, when vehicle traffic volumes peaked, the mean pooled TVI values during the time periods when road crossings were detected did not differ from the values when no road crossings were detected. Road crossings by brown bears were not inhibited by vehicle traffic in Shiretoko National Park.

Key words: brown bear, movements, radiotelemetry, road crossing, traffic volume, Shiretoko National Park

INTRODUCTION

Because of their large home ranges, brown bears Ursus arctos often encounter roads. Shoen (1990) reviewed studies of bear habitat management and recommended that those delineating bear habitat should recognize the significance of both natural landscape features and human activities. If vehicle traffic volume inhibits bear movements, it may restrict bear habitat utilization. Several studies have assessed the influence of traffic volume on the movements of brown and American black bears Ursus americanus. Archibald et al. (1987) showed that logging track noise limited habitat utilization by two grizzly bears in British Columbia, Canada. Brody and Pelton (1989) and Beringer et al. (1990) observed lower crossing rates by black bears along roads with high traffic volume compared to roads with less traffic. However, differences in habitat quality might have affected the results of these studies. If foods were scarce near a particular road, then bears would avoid that area and the road. As assessments of the impacts of road traffic should be robust in relation to habitat heterogeneity, we developed a new method for use when analyzing the impacts of roads on bears.

Until the present study, there had been no assessment of the impact of vehicle traffic on bears in Japan. It has been suggested that, in general, road and railway traffic limit brown bear movements (Hokkaido Institute of Environmental Sciences 1996), and more specifically that increasing visitation rates and traffic volume in Shiretoko National Park (NP) may affect brown bear behavior (Yamanaka and Aoi 1988). The current study was designed to test these assumptions. Quantitative studies of the impacts of human activity are important for brown bear conservation and for the improvement of the management of national parks in Japan. In this study, the impacts of road traffic volume on brown bear movements near roads were assessed by comparing

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detectable movement rates, road crossing rates, and traffic volume indices among diel periods.

STUDY AREA

This study was conducted in the northwestern part of the 386 km² Shiretoko NP in eastern Hokkaido, Japan (Fig. 1, 44°N, 145°E). The annual mean temperature in Utoro, adjacent to study area, is 6.1°C and monthly mean temperatures range from −7.1°C in January to 19.4°C in August. Mean precipitation is 1,102.8 mm and the maximum accumulated snow depth is 2.5 m. Most of the study area is rugged and the southwestern part of the study area includes the Shiretoko-renzan mountains, which range in elevation from 1,300 m to 1,661 m. The coastline consists mostly of cliffs facing the Sea of Okhotsk.

Lowland and mid-slope forests include todo fir Abies sachalinensis, Mongolian oak Quercus mongolica var. grosseserrata, Erman's birch Betula ermanii and maples Acer spp. Above 500-600m, Japanese stone pine Pinus pumila is dominant. Grasslands along coastal cliffs include patches of Urtica Urtica platyphylla, Ligusticum Ligusticum hultenii and Japanese butterbur Petasites japonicus. Ligusticum and butterbur are important foods for bears during summer (Yamanaka and Aoi 1988).

Kamuiwakka hot spring and Shiretoko-Goko lakes are popular sightseeing destinations in Shiretoko NP. Roads extend to these sites at 200-300m above sea level. Earlier studies of radio-collared brown bears in the area showed that their home ranges partially overlapped with these roads (Yamanaka et al. 1995). We monitored a 15 km section (A–B, Fig. 1) of 6.1 m wide unpaved road for both traffic volume and bear activity. This section of the road (A–B) is closed to visitors from early November until late May. The annual number of visitors to the study area was esti-

Fig. 1. Map of Shiretoko NP study area showing roads and tourist attractions. The broad line is the road section along which we measured traffic volume.
estimated to be over 1.8 million (Nakagawa et al. 1988).

METHODS

1) Measurement of detectable movement rates during four time periods

Detectable movement rates were assessed for seven radio-collared bears (six adult females and one sub-adult female), previously captured and monitored by the Shiretoko Nature Center, during each of four daily time periods: morning (03:00–09:00), daytime (09:00–15:00), evening (15:00–21:00) and nighttime (21:00–03:00). Bear movements were monitored every 180 minutes during 24-hour tracking sessions. Tracking sessions were conducted six times from July to September in 1995, and ten times from July to August in 1996. At the beginning of each 24-hour session, a decision was made to monitor two or three bears of the seven radio-collared bears. Over the course of the study, we attempted to monitor each bear for an equal number of day periods.

To locate bears along road section A–B, we traveled by car at intervals (within ±30 min.) of 180 minutes (09:00, 12:00, 15:00, 18:00, 21:00, 00:00, 03:00, 06:00, and 09:00). Bear locations were determined by triangulation within twenty minutes, using a hand held Yagi antenna (Maldol Inc., Washington, USA), and an FT290mkII receiver (Yaesu Musen Inc., Tokyo). Locations were plotted on 1:25000 topographic maps (Geographical Survey Institute of Japan).

We estimated the minimum movement rates between two consecutive locations for each bear by dividing the distance between locations by the 180 minute intervening period. Estimates of the 99% confidence interval of distances between actual and estimated locations yielded a potential error of 321.4 m in this study area (Murakami and Mano 1998). Consequently, movement rates below 3.57 m/min. (642.8 m/180 min.) were not considered to be detectable movements, and only detectable movements were used in the analysis of the four time periods.

2) Measurement of road crossing time periods

We used two sampling methods to determine road crossing rates for the seven radio-collared bears. In the first sampling approach, 24 hour sessions, we traveled the road by car at intervals (within ±30 min.) of 180 minutes (09:00, 12:00, 15:00, 18:00, 21:00, 00:00, 03:00, 06:00, and 09:00) and determined the side of the road on which each bear was located by reading the bearings of the radio signals. For example, if a bear was located on one side of the road at 09:00 and on the other side of the road at 12:00, the bear is presumed to have crossed the road at least once during the period 09:00–12:00. The reliability of our method in determining the side of the road on which each bear was located, was confirmed by a blind test during the previous study of location error (Murakami and Mano 1998). The possibility that each bear crossed the road more than once in 180 minutes was considered to be negligible based upon the low total number of crossings detected during the study. Bearings were determined using a hand held Yagi antenna and an FT290mkII receiver. When we were unable to confirm from a single point on which side of the road the bear was, we took complementary bearings from other points.

Our second sampling method involved measuring the number of road crossing incidents involving all bears during 12 hour periods. Using the same tracking protocol as during the 24 hour tracking sessions, we monitored crossings from 09:00 to 21:00 (daytime and evening) for four consecutive days, and then from 21:00 to 09:00 (nighttime and morning) for the next four consecutive days.

Twenty four hour sessions were conducted six times from July to September in 1995, and ten times from July to August in 1996, while 12 hour sessions were conducted 16 times from July to September in 1994, and 24 times from July to September in 1995.

3) Measurement of Traffic Volume Index (TVI)

When traveling road section A–B (Fig. 1) in order to log radio locations, we also measured traffic volume. The number of vehicles travelling in the oppo-
site direction to our own vehicle was divided by the
time it took to move between points A and B. As we
counted the number of vehicles from a moving ve-
cicle, our counts were biased by our velocity. Con-
sequently, we converted Xobs to Xo by the follow-
ing equation,

\[
X_0 = \frac{X_{obs}}{D(1/V+1/V_x)}
\]

where Xobs is the number of vehicles counted per
minute, and Xo is the number of vehicles per minute
expected to pass a fixed point on the road section A–B,
traveling in the opposite direction to our vehicle.
The variable D is the distance between A and B (15
km), V is the velocity of our car, and Vx is the mean
velocity of visitors’ vehicles, which are assumed to
be 30 (km/h), in compliance with the posted speed
limit. The resulting traffic volume index (TVI) is the
estimated number of vehicles traveling in either di-
rection which would pass a stable point between
points A and B, in each three hour period. Xo was
converted to TVI by a regression derived from counts
of vehicles at point A for 10 days in the summer of
1996. TVI was compared with road crossing rates
for each bear. The mean TVI, when road crossing inci-
dents were detected, was also compared with that
when road crossing incidents were not detected.

RESULTS

1) Detected movement rates in each time period

A total of 69 movements was detected for seven
bears during 16 days of research. The detected move-
ment rates (number of detected movements per num-
ber of measurements) for the morning 0.43±0.32
(SD), daytime 0.54±0.34 (SD) and evening 0.40±0.21
(SD) periods were higher than that during the night-
time 0.21±0.26 (SD), although these rates did not
differ significantly among the four time periods (Fig.
2, Friedman’s test, \(X^2 = 4.75, \text{df} = 3, p = 0.19\)). How-
ever, the movement rates of the seven bears fell into
two types. The movement rates of five of the seven
bears differed significantly among the four time pe-
riods: 0.51±0.34 (SD) during the morning, 0.51±0.29
during daytime, 0.33±0.19 during the evening and
0.09±0.09 during nighttime (Friedman’s test, \(X^2 =
9.53, \text{df} = 3, p<0.05\)). In contrast, the remaining two
bears showed movement rates that were as high dur-
ing nighttime as during both daytime and evening,
while movement rates during the morning were the
lowest (the mean detected rates for each time period
of the two bears were: 0.23 morning; 0.60 daytime;
0.58 evening, and 0.52 nighttime (the small sample
size precluded statistical testing).

2) Road crossing rates during each time period

We detected 43 road crossing incidents among the
seven bears. The road crossing rates of these seven
bears (number of road crossings per number of mea-
surements) were, in decreasing order, daytime
0.15±0.11 (SD) > morning 0.10±0.10 (SD) > evening
0.08±0.11 (SD) > nighttime 0.00, and these rates dif-
fered significantly among the four time periods (Fig.
3, Friedman’s test, \(X^2 = 8.36, \text{df} = 3, p<0.05\)). All
seven bears showed similar patterns in road cross-
ings, and no road crossings were detected during the
nighttime period. The road crossing rates of the five
bears that were inactive during nighttime, were
0.10±0.10 (SD) during the morning, 0.14±0.13 (SD)
during daytime, 0.06±0.09 (SD) during the evening,
and 0.00 during nighttime (Friedman’s test, \(X^2 = 6.30,
\text{df} = 3, p = 0.10\) and those of the two other bears
were 0.10 during the morning, 0.17 during daytime, 0.13 during the evening and 0.00 during nighttime (the small sample size precluded statistical testing).

3) Traffic volume index (TVI) during each time period

TVI 1.58±1.14 (SD) during the daytime was higher than during the other three periods, while TVI during the nighttime was the lowest (Fig. 4; morning = 0.40±0.57 (SD); evening = 0.84±0.81 (SD); nighttime = 0.02±0.06 (SD)). The mean TVI during summer was 0.72 (0.62 in July, 1.23 in August, and 0.35 in September). The mean TVI during periods when bear crossings were detected averaged 1.05±0.95 (SD), while those during periods when no road crossings were detected averaged 0.68±0.89 (SD), however, these two TVIs did not differ significantly (Student’s t-test, df = 241, p = 0.05).

**DISCUSSION**

Five of the seven bears in our study were diurnal, with relatively higher movement rates in the morning, daytime, and evening than during the nighttime. Garshelis et al. (1983) studying diel movement patterns of American black bears, also reported more bears moving in the daytime (06:00–20:00) than at night (20:00–06:00). Lariviere et al. (1994) reported that the activity patterns of 15 female black bears were also mainly diurnal, and suggested that diurnal activity would be beneficial for effective foraging.

The remaining two bears in our study had higher movement rates during the daytime, evening and nighttime than during the morning. Roth (1983) and Roth and Huber (1986) found the two brown bears in their study to be mainly nocturnal, although one of these bears had changed its activity pattern from diurnal to nocturnal after its mother was killed by hunters. Ayres et al. (1986) also reported that American black bears feeding on camp ground garbage were essentially nocturnal, whereas other individuals were more diurnal in their behavior patterns. These results demonstrate that human activities can change bear activity or movement patterns. Nevertheless, we do not believe that the two bears in our study had changed their movement pattern as a result of human disturbance, because they were most active during daytime, when human activity is also greatest. Activity patterns of bears may typically show some variation, thus further investigation is necessary in order to clarify the extent of this variation.

Road crossing rates of the seven bears were highest during daytime, when the traffic volume index was also highest. The road crossing rates of the five diurnal bears seemed to reflect general activity patterns. They made more road crossings during periods when they were most active. In contrast, there appeared to be no relationship between the activity patterns and road crossing rates of the two other bears. They did not cross the road at night even when they were active. Perhaps this discrepancy was due to the small samples of road crossings by these two bears, and
further sampling may have detected more nighttime crossings.

Even in August, when visitor traffic volume is highest, bears did not seem to be averse to crossing roads. We propose two hypotheses to explain these counter intuitive results.

First, road traffic volume in Shiretoko NP may not be high enough to inhibit road crossings by bears. Beringer et al. (1990) indicated that bears cross class 2 and class 3 roads, (50-100 and 5-20 vehicles per day, respectively) more frequently than class 1 roads, (> 10,000 vehicles per day). The average number of vehicles each day in Shiretoko NP during August, was estimated to be 1,768 (range 654–3,330; converted from our TVI).

Second, bears in Shiretoko NP may have become habituated to vehicles. In Yellowstone NP, USA, grizzly bears habituated to human activity were located within two km of roads 2.1 times more frequently than non-habituated bears (Mattson et al. 1992). Since the bears that we tracked had home ranges intersected by the road, some may have become habituated to increasing traffic volume. In fact, we observed one bear feeding in a roadside meadow, apparently unconcerned about passing vehicles.

Traffic volumes in Shiretoko NP do not appear to inhibit bears from crossing roads. Brown bears in our study area utilize various habitats including coastal grasslands and mid-slope riparian areas in summer (Yamanaka and Aoi 1988), and these feeding sites are distributed along both sides of the road. If traffic volume along the road is maintained at the current level, then bears may use feeding sites along both sides of the road. However, if traffic volume increases, bears may learn to avoid the road, as Beringer et al. (1990) reported. Mace et al. (1999), who analyzed the cumulative effect on grizzly bear habitat use, also reported that the area of high-use road density was avoided even though there were suitable feeding sites in that area. If traffic volume increases beyond the bears' tolerance level, then movements across the roads will decrease and habitat utilization by bears will also decrease. A quantitative study, determining the Brown bear's threshold of tolerance of road traffic, is necessary.

If bears do not avoid or learn not to avoid the road through Shiretoko NP, then encounters between visitors and bears are likely to increase. Most visitors do not know how to behave when they encounter bears. In order to prevent accidents, which may lead to injury or death of both humans and bears, more proactive management of roadside areas is encouraged.

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