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TRAFFIC KILLS OF BROWN BEARS IN GORSKI KOTAR, CROATIA

DJURO HUBER, Biology Department, Veterinary Faculty, Heinzelova 55, 10000 Zagreb, Republic of Croatia, email: huber@mavef.vef.hr
JOSIP KUSAK, Biology Department, Veterinary Faculty, Heinzelova 55, 10000 Zagreb, Republic of Croatia, email: kusak@mavef.vef.hr
ALOJZIJE FRKOVIC, Croatian Forests, Delnice Forestry Office, Supilova 32, 51300 Delnice, Republic of Croatia

Abstract: At least 73 European brown bears (*Ursus arctos*) have been killed by vehicles in the forest region (1500 km²) of Gorski kotar, Croatia, from 1963 to 1994. Fifty-one (70%) were killed by trains along the Zagreb–Rijeka railway and 22 (30%) were killed by motor vehicles along roadways in Gorski kotar. Several parameters were measured at known collision sites ($n = 46$) and at an appropriate number of random sites ($n = 61$) along roads and railroads. Slope angle and length, as well as longitudinal and perpendicular visibility at accident and random sites were not significantly different. We concluded that microsite topography had little or no influence on the occurrence of bear traffic accidents. Instead, food sources related to human activities, such as garbage along roads, may have served as local attractants to bears and were found near at least 15 (33%) accident sites, but at only 5 (8%) of the random sites. We found that 3 main corridors for bear movements were cut by traffic lines. Provisional mitigation measures were proposed to reduce conflict between bears and traffic, and an artificial tunnel or green bridge (100.5 m long) was added to a new highway project.

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The brown bear (*Ursus arctos*) population in Gorski kotar, Croatia, has grown substantially from its 1946 low to a density of approximately 1 bear/10 km² by the early 1980s (Frkovic et al. 1987) and seems to be stable since then. Loss of habitat and direct human-caused mortality may cause the population to decline in the future. The more humans influence bear range, the more bear deaths occur from human factors such as shooting, den disturbance and abandonment of cubs, nuisance bear control, and traffic. Roads and railroads can lead to habitat fragmentation and deaths due to collisions with motorized vehicles. Bears need large ranges because of their feeding regime, reproductive behavior, and denning requirements (Huber and Roth 1993). Bears' opportunistic food-finding behavior may attract them to discharged human foods, carrion, or preferred vegetation frequently located along travel routes.

Ueckermann (1964) published data on traffic kills of 11 mammalian species in Germany. Traffic induced bear mortality has been documented in Europe (Frkovic et al. 1987 in Croatia, Kaczensky et al. 1996 in Slovenia), but no analyses of such incidents have been published. Wooding and Brady (1987) and Warburton et al. (1993) reported on American black bears (*U. americanus*) killed on roads in Florida and North Carolina, respectively (both USA).

Traffic kills of European brown bears in Croatia comprised 11% of total recorded mortality from 1946 to 1985 when 31 (of 281) were killed by traffic in 40 years or 0.78 bears/year (Frkovic et al. 1987). In recent years (1986–95) traffic induced mortality rose to 19% of total recorded mortality when 42 (of 217) were killed by traf-

fic or 4.2 bears/year. This alarming data prompted us to study traffic accidents involving bears. We wanted to determine why some sites had more bear–vehicle accidents than others and to propose feasible mitigation measures. Our hypothesis was that the higher local bear mortality was related to: (1) low visibility associated with vegetation density, slope, and curves on travel routes, (2) interruption of bear travel corridors, (3) various food sources attracting bears to travel routes.

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STUDY AREA

The Gorski kotar region (1,500 km²) comprises the western edge of occupied bear range in Croatia (Fig. 1). The region is mountainous, with elevations ranging from 0 to 1,500 m. Forest covers about 70% of the area, and the main road and railroad run from the Croatian capitol, Zagreb, to the Adriatic seacoast through the middle of the Gorski kotar area. From 6,600 to 13,100 vehicles/day use this road. Construction of a new highway connecting Zagreb to the Adriatic Sea is underway presently.

METHODS

Records of traffic-killed bears have been kept by A. Frkovic since 1963. The records included the exact site and date of collision, sex and age of the bear, and the

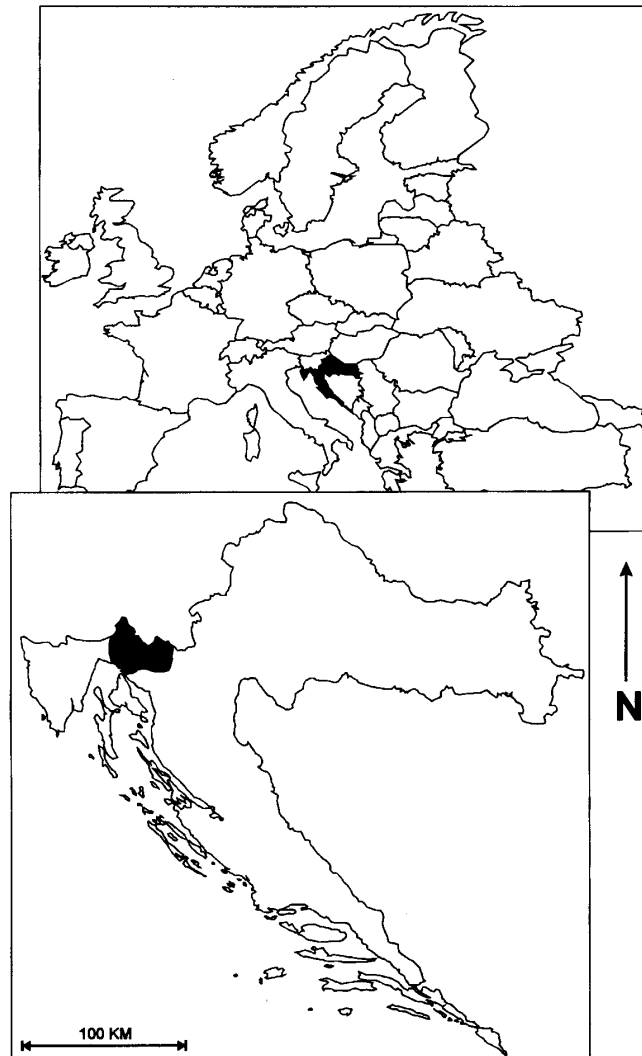


Fig. 1. Location of Croatia in Europe and the Gorski kotar study area in Croatia.

type of vehicle involved in each collision. Bears were classified as subadults (≤ 3 years) and adults (> 4 years old) by size and appearance, but since 1981 have also been aged by counting the cementum layers on the first premolar tooth root (Stoneberg and Jonkel 1966).

At each known collision site ($n = 46$) and at 61 random sites along roads and railroads we measured several parameters: longitudinal and perpendicular visibility, slope angle and length, distance to the nearest house, and the length of time that trains are audible before reaching the

collision site. Recent collision sites were visited within a few days of the accident and the older ones in the same season in which the accident happened years before. Random points were selected at each full kilometer of road and railroad in the bear range. If a known collision site appeared to be between 2 random kilometer points, the distance to the closer one was rounded off to the next full kilometer. Longitudinal visibility was determined based on curves in the roads and railroads, and perpendicular visibility by vegetation cover and topography. We

considered the limit of visibility the distance at which >90% of a standing person's body was no longer visible. The length of a slope was measured from our site to the first ridge or valley bottom. Local attractants for bears were defined as (1) any food source related to human activities and included garbage along roads and grain spills from trains, and (2) presence of fruit-bearing vegetation along the road or railroad right-of-way.

Chi-square (χ^2) tests were used to compare the differences between habitat variables at bear kill and random sites. Alpha levels were 0.05.

RESULTS

At least 73 bears were killed by traffic in Gorski kotar, Croatia from 1963 to 1994 (Fig. 2). Fifty-one (70%) were killed along the Zagreb–Rijeka railroad, and 22 (30%) were killed on roads in Gorski kotar (Fig. 3). Of all bears killed, 26 (36%) were male, 33 (45%) were female, and 14 (19%) were of unknown sex. Forty-six (63%) bears were subadults (≤ 3 years), 17 (23%) were adults (> 4 years), and 10 (14%) were of unknown age. Collisions with bears occurred in all months of the year (Fig. 4). In 6 cases, > 1 bear died in an incident: 3 cases involved mother and cub(s) and 3 cases involved 2 cubs each. All multiple deaths of bears were train-related accidents. On

2 occasions, bears were known to have survived an automobile collision and escaped from the site.

Means of longitudinal and perpendicular visibility between accident and random sites were not significantly different. The slope at the accident sites was not significantly steeper than at randomly selected sites (36° vs. 33° , respectively). Mean lengths of the slope at accident and random sites were both 51 m. On average, trains at accident sites were not heard until 4 seconds later than the trains at random sites (31 vs. 35 seconds, respectively) but this difference was not significant.

Foods that could attract bears were present on at least 15 (33%) of the accident sites compared to only 5 (8%) of the random sites ($P < 0.01$, $\chi^2 = 8.74$). Furthermore, fresh bear sign (unrelated to the accident) was found at 4 accident sites, whereas none was found at the random sites.

Bear–vehicle collisions occurred most frequently at 6 sections of roads and railroads (Fig. 5). These sections were: (1) Railroad Gomirje–Vrbovsko (9 bear collisions), (2) Railroad Vrbovsko–Moravice (7 collisions), (3) area from Delnice to Dedin (6 collisions on road, 1 railroad), (4) area of Lokve (road, 2; railroad, 4), (5) Railroad Lic–Drivenik (5 collisions), and (6) Kvarner area (road, 4; railroad, 7).

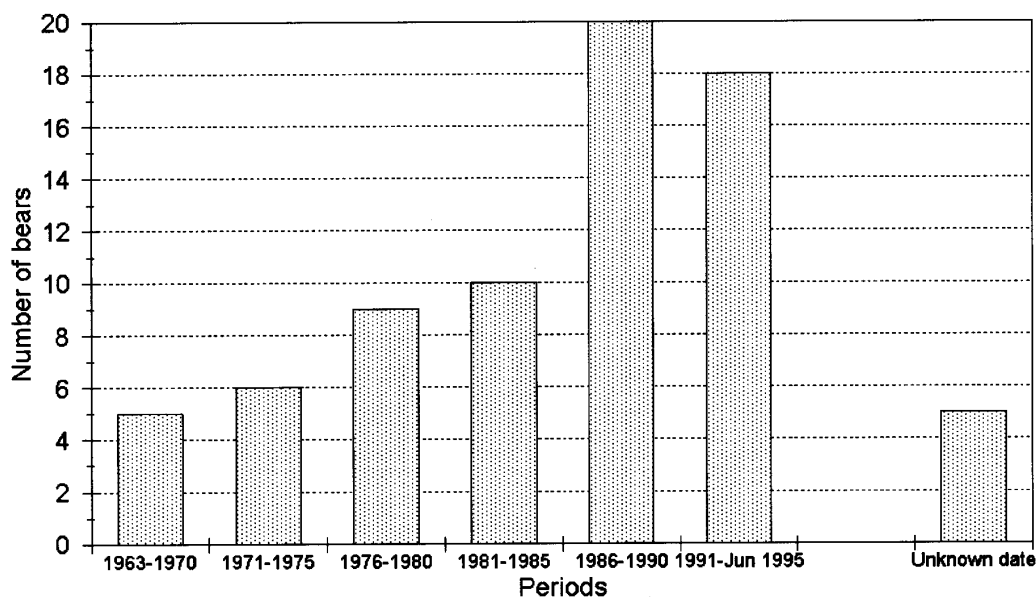


Fig. 2. Five-year averages of traffic-caused brown bear mortality in Gorski kotar, Croatia, from 1963 to 1995.

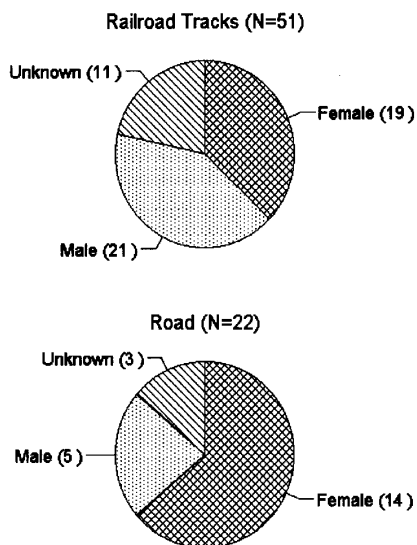


Fig. 3. Sex distribution of brown bears killed on railroad tracks and roads in Gorski kotar, Croatia.

DISCUSSION

We concluded that microsite topography had little or no influence on bear traffic accidents. Although not significant, the slight tendency for accidents to occur at steeper and more forested places reflects areas less suitable for human settlements and therefore more likely to be used as bear travel corridors. Sites of frequent accidents indicated the existence of 3 bear movement corridors that have been cut by human traffic ways (Fig 5).

Provisional mitigation measures have already been proposed to reduce the conflict of bears and traffic on roads and railroads. For a highway currently under construction through bear habitat in Gorski kotar, we proposed at least 6 tunnels or viaducts in addition to those planned due to topographic reasons. So far, 1 artificial tunnel or "green bridge" (100.5 m long) was incorporated into the highway project. A number of railroad tunnels should be constructed at critical points.

Bears feed on variety of food items (Cicnjak et al. 1987) and are attracted to any abundant or renewable food source. Because 1/3 of the accidents could be related to food attractants, we recommend removing all human-created bear food sources from along travel ways.

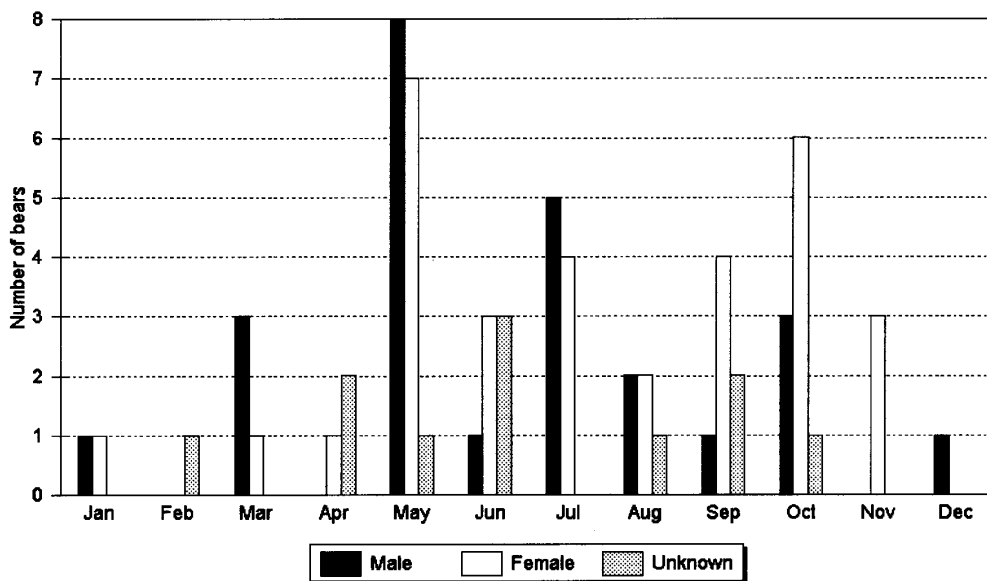


Fig. 4. Cumulative number of brown bears killed by vehicles by month in Gorski kotar, Croatia, from 1963 to 1995.

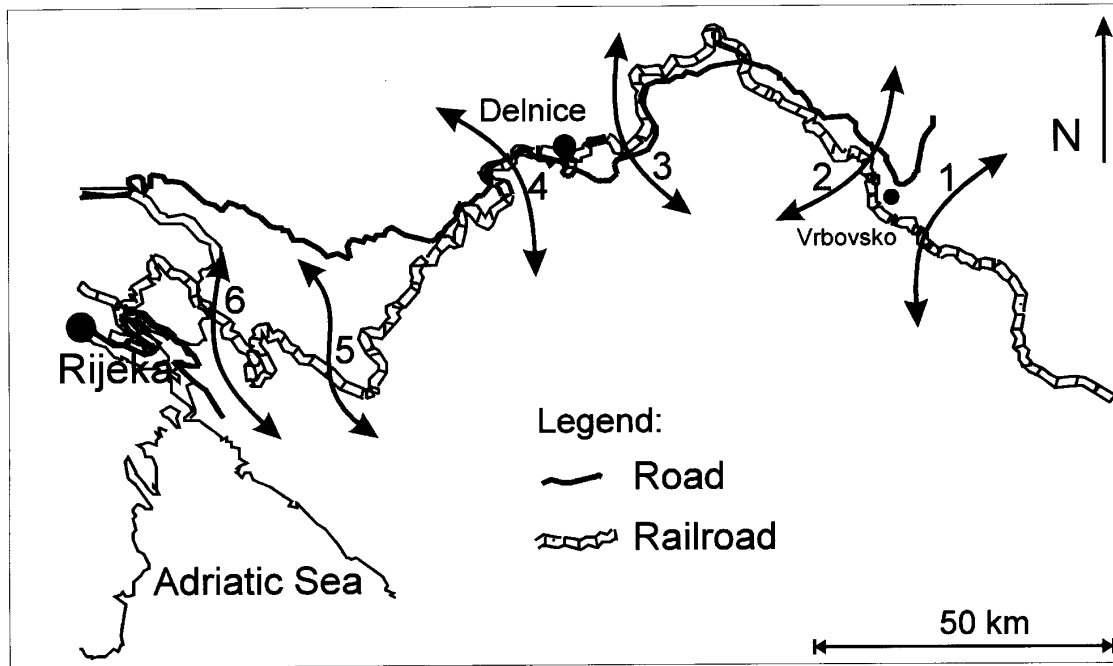


Fig. 5. Main brown bear traffic accident points in Gorski kotar, Croatia: (1) Railroad Gomirje–Vrbovsko, (2) Railroad Vrbovsko–Moravice, (3) area from Delnice to Dedin, (4) area of Lokve, (5) Railroad Lic–Drivenik, and (6) Kvarner area. Also indicated are 3 main movement corridors over the main road and railroad through Gorski kotar.

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