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Badger Roadkill Risk in Relation to the Presence of Culverts and Jersey Barriers

Abstract

Roadkill is the main cause of mortality for the endangered subspecies of American badger found in British Columbia (*Taxidea taxus jeffersonii*). Badgers sometimes use culverts to pass under roads, so more culverts might be associated with less roadkill risk. Risk may also be associated with the presence of Jersey barriers, which potentially trap badgers on roadways. We compared 39 1-km highway segments where roadkills occurred to 39 random segments, to see if they differed in the number of culverts and bridges useable by badgers or in the presence or distance covered by Jersey barriers. About 18% of structures in random segments and 40% in roadkill segments were impassable to badgers. Compared to random segments, roadkill-associated segments were less likely to have at least two structures/km passable by badgers (26% of roadkill segments vs. 59% of random segments; $\chi^2 = 8.877$, $P = 0.003$). This supports the notion that badger roadkill risk is lower where an adequate supply of culverts or bridges exists. The presence or amount of Jersey barrier was not related to roadkill risk. This may reflect a lack of effect, or may relate to a difficulty in detecting trends given the few Jersey barriers in our study area and their apparently disproportionate use where badger habitat is poor and where options exist to avoid barriers. Increasing the opportunities for badgers to pass under highways through culverts should reduce mortality and aid recovery. We recommend repairing or retrofitting existing structures, making entrances more visible, installing drift fencing where appropriate, installing more culverts, and investigating culvert or landscape characteristics associated with the use of culverts by badgers.

Introduction

American badgers (*Taxidea taxus*) are "red-listed" in British Columbia (Cannings et al. 1999) and the subspecies present there (*T. t. jeffersonii*) is listed as endangered in Canada (COSEWIC 2006). Badger-vehicle collisions (hereafter "roadkills") are a significant, and sometimes the main, mortality source for badgers in three regions of British Columbia (Weir et al. 2004, Packham and Hoodicoff 2007, Kinley and Newhouse 2008) and elsewhere in their range (Davis 1946, Messick et al. 1981, Warner and Ver Steeg 1995). This may relate in part to the apparent selection by badgers of habitats near roads or other linear corridors (Warner and Ver Steeg 1995, Apps et al. 2002). Decreasing road mortality has been identified as a key recovery action in the Canadian recovery strategy for this subspecies (*jeffersonii* Badger Recovery Team 2008). Understanding factors contributing to roadkill risk would therefore aid in planning badger recovery actions.

European badgers (*Meles meles*) are also subject to heavy roadkill mortality (Clarke et al. 1998) and regularly pass under highways using culverts or pipes installed for that purpose (Bekker and Canters 1997, van der Grift et al. 2003). Other mustelids (e.g., American martens: *Martes americana* and weasels: *Mustela erminea* and *M. frenata*) often use drainage culverts for the same purpose (Clevenger and Waltho 1999, Clevenger et al. 2001), as do a variety of other species (Jackson and Griffin 2000, Krawchuk 2004). Informal observations indicate that American badgers sometimes use culverts for refuge or to pass safely beneath roads (Klafki 2002, Robert Forbes, Nature Conservancy of Canada, personal communication). These observations suggest that culvert presence may reduce American badger roadkill risk.

Another correlate of badger roadkill risk may be the presence of Jersey barriers, which are concrete traffic barriers typically 70 cm high used to separate opposing lanes of traffic or to prevent vehicles from leaving the roadway. Jersey barriers are difficult or impossible for badgers to climb and are often abutted in continuous lines for hundreds or thousands of meters. Badgers can enter sections of highway having barriers, such as by coming around the end of barriers then moving longitudinally down the highway or by attempting to cross in locations where barriers are on only one side of the road. In doing so, they may become trapped on the road surface or at least become

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panicked, increasing their chance of being hit by vehicles. Badger roadkill sites in the Thompson – Okanagan region of British Columbia have been predominantly in sections with Jersey barriers (Weir and Davis 2004, Weir et al. 2004).

As a first step in remedying the high rate of roadkill among badgers, we tested whether any correlation existed between roadkill sites and the presence of either culverts or Jersey barriers. We compared 1-km sections of highway surrounding known badger roadkill locations to an equal number of random highway locations, to determine whether roadkill locations differed from random locations in the number of culverts passable by badgers or the presence or amount of Jersey barrier present.

Study Area

We conducted our analysis in southeast British Columbia, in an area known as the East Kootenay. We targeted the British Columbia Ministry of Transportation and Infrastructure's (MOTI) service area 11, which closely matched the study area used for over 10 years in radio-tagging and monitoring study animals and recording reported sightings (Kinley and Newhouse 2008). To minimize potentially confounding factors relating to road design and volume, we limited our analysis to primary highways, namely provincial highways 3, 43, 93, 95 and 95A. Depending on the highway and time of year, mean annual volumes extrapolated to daily averages of ca. 3000 to 8000 vehicles/d where data were available (Ministry of Transportation and Infrastructure 2008). All roads were two-lane undivided highways, with occasional passing or turn lanes.

We investigated highways located primarily in the Rocky Mountain Trench but also included portions of the Rocky Mountains to the east and Purcell Mountains to the west. The highways traversed four biogeoclimatic zones, named for the climax tree species on zonal sites (Braumandl and Curran 1996). In the Trench, these included the Interior Douglas-fir (IDF) zone and the Ponderosa Pine zone, in the Rockies they were the Montane Spruce and the Interior Cedar – Hemlock (ICH) zones, and in the Purcells they included the IDF and ICH zones. Land adjacent to highways was primarily publicly owned and managed for timber, range and Christmas-tree production, but also included private land used for residences, recreation and agriculture.

Methods

We used roadkill records collected during earlier research, including both radio-tagged study animals (Kinley and Newhouse 2008) and records reported by the public or resource-management professionals (Newhouse and Kinley 2007). The spatial uncertainty associated with each sighting was considered <500 m if the observer referenced the site to within 1 km (i.e., "4 km" or "2.3 km" or "within 200 m", but not "1 or 2 km") from an unambiguous landmark. We eliminated sightings having spatial uncertainty greater than 500 m, falling within urban areas, or not occurring on primary highways. To compare conditions at roadkill sites to average highway conditions in the study area, we delimited primary highways outside of urban areas into 1-km segments using MapSource 6.0 (Garmin Ltd., Olathe, KS) then randomly selected a sample of these segments equal to the amount of the roadkill sample using JMP IN 5.1 (SAS Institute Inc., Cary, NC). To minimize any confounding effects relating to landscape or habitat quality, we eliminated random locations with a center point falling >2 km from a telemetry or sighting record of badgers or badger sign (Newhouse and Kinley 2007). Two km is slightly less than the 50^{th} percentile of sequential movements of radiotagged badgers (Apps et al. 2002) so by restricting random locations to within this distance of known badger activity we intended to keep them within areas inhabited by badgers. After eliminating sites beyond that distance, we selected additional random sites matching our criteria until the random sample again equalled the roadkill sample. We did not stratify our sample by highway type as all were primary highways. Clarke et al. (1998) found little difference in European badger mortality rate relative to traffic volume when considering only major roads.

For each of the roadkill and random sites, we inspected each side of the highway in 1-km segments centered on the roadkill location or the random segment center point. Starting at the Universal Transverse Mercator coordinates of each roadkill or random point, we walked along the roadside with a GPS unit (Etrex Legend C, Garmin Ltd., Olathe, KS) tracking our path until the unit indicated we had travelled 500 m. We then crossed the highway, returned to the center point and repeated this on the other side of the center point so that each sample included both sides of 1 km of highway. Whenever leaving the roadside to examine a culvert, we left the GPS unit at the point of departure to avoid overestimating the distance travelled. We recorded each culvert or bridge and recorded whether it was passable by badgers. We deemed culverts to be essentially impassable if at least one end was crushed or blocked by debris sufficiently to prevent entry or egress by a badger, at least one end was ≥30 cm above ground level (a hanging culvert), or a permanent stream ≥5 cm deep flowed through it. The two latter conditions would not necessarily completely prevent use of a culvert but we assumed they would dramatically decrease use. All bridges encountered spanned some dry land so we considered them to be passable, with each equivalent to a single culvert regardless of the distance spanned. Using the GPS unit, we also recorded the linear distance within each segment in which Jersey barriers had been placed on at least one side of the highway. Use of the term "structures" hereafter refers to both bridges and culverts. We recognize that the condition of some structures may have changed somewhat between the date of roadkills and the time of fieldwork, but expect that this would introduce random, rather than directional, error in our results.

We contrasted the number of passable structures in roadkill-associated segments to the number in random highway segments using the Wilcoxon test. We also compared the number of sites having one or no passable structures (i.e., fewer than average) to the number having at least two structures, by segment type, using a Pearson Chi-square test. Given the low density of culverts across our large study area and the expense of installing more of them, this latter test was intended to suggest whether slight differences in culvert numbers might be associated with differing roadkill risks. We used a Pearson Chi-square test to determine whether random segments differed from roadkill segments in the presence of Jersey barriers, and compared the length of Jersey barriers between random and roadkill sites using the Wilcoxon test. We used JMP IN 5.1 software (SAS Institute Inc., Cary, NC) for all statistical tests.

Results

Updating the results of Newhouse and Kinley (2006), we were aware of 72 roadkilled badgers in the East Kootenay to 20 April 2008 (7 from telemetry, 65 from reported sightings). Roadkills peaked during summer, especially August (Figure 1). Of these, 39 were known prior to the initiation of field work and met our screening criteria so we used them to establish sampling locations. An equal number of random sites was also chosen.

Including both passable and impassable structures, random segments contained 73 culverts and 4 bridges while roadkill segments included

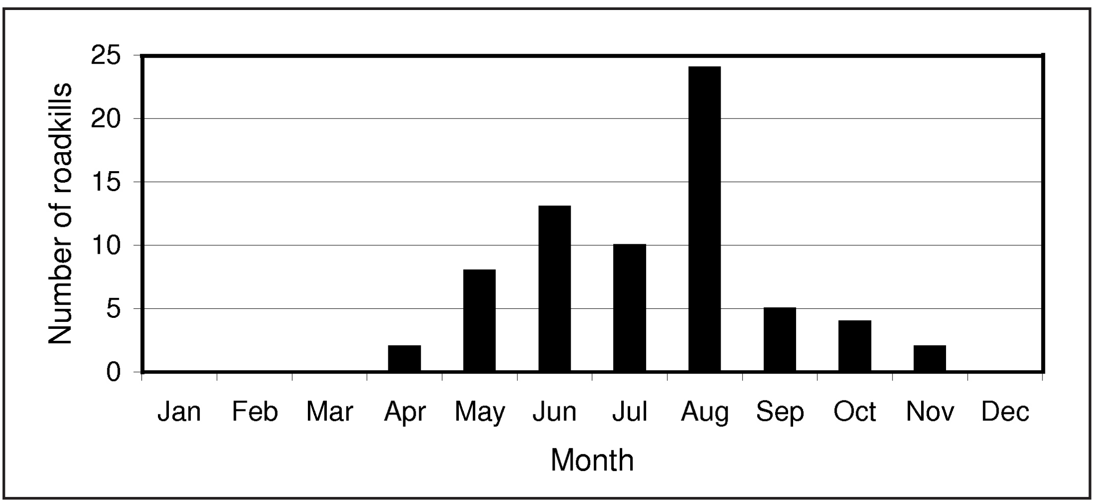

Figure 1. Timing of 68 badger roadkills in the East Kootenay area of British Columbia, September 1989 – August 2007. Data include 7 radio-tagged animals and 61 roadkills reported by the public.

84 culverts and 2 bridges. Based on the random segments, primary highways therefore had an average of 1.97 structures/km. All culverts were corrugated steel except three that were concrete. Nominal diameters were 30-240 cm, with a mode of 60 cm. Considering only structures passable by badgers, highway segments associated with roadkills were less likely to have at least two passable structures/km (26%) in comparison to random highway segments (59%; $\chi^2 = 8.877$, $P = 0.003$). The median number of passable structures/km may have been higher for random than roadkill segments, although the difference was not highly significant. The median and mean were, respectively, 1 and 1.33 (0.18 SE) structures for roadkill segments, and 2 and 1.62 (0.18 SE) structures for random segments; Z = -1.542, $P = 0.123$).

Only 26% of roadkill segments and 31% of random segments had any Jersey barriers present ($\chi^2 = 0.253$, $P = 0.615$). The median distance covered by barriers was 0 m for both random and roadkill segments (most segments had no barriers) while the mean for random segments was 104 m/km (39 m SE) and for roadkill segments was 44 m/km (19 m SE), which was non-significant (Z = -0.718, $P = 0.473$).

Discussion

Roadkill-associated highway segments typically had one or no culverts or bridges readily passable by badgers per kilometer whereas random segments generally had two or more. Our results support the notion that badgers, like other small to medium-sized carnivores, are less likely to be killed when there are adequate culverts or other structures available to provide safe passage (Hunt et al. 1987, Yanes et al. 1995, Bekker and Canters 1997, Rodriguez et al. 1996, Clevenger et al. 2001). The value of culverts was likely heightened by the timing of roadkills; all were between April and November so snow plowed from roads would not have obscured their entrances.

Badgers do not always use culverts when available. For example, one roadkill fell almost precisely at a 30-cm culvert. At the time of culvert assessment fieldwork there were recent badger tracks leading into the culvert and there were no obstructions to prevent its use. If this was the case at the time of death, it indicates that the badger likely had the opportunity to use a culvert to cross the road. More generally, our results showed that most roadkill sites had at least one culvert within 500 m. However, our results also showed a lower overall risk of roadkill when at least two passable structures were present per kilometer, even though culverts were (a) not designed with badgers in mind, (b) not associated with drift fencing or other devices to encourage their use, (c) seasonally obscured by vegetation, (d) most likely encountered at times by badgers (such as kits) unfamiliar with the landscape or unfamiliar with the safety afforded by culverts, (e) presumably inundated periodically, and (f) not generally on the most direct route for badgers.

Most 1-km segments contained no Jersey barriers. They were not used to separate lanes of traffic in our study area. Rather, they prevented vehicles from leaving the highway or rock from entering the highway in steep terrain, and funnelled traffic off shoulders into the main lane when approaching bridges or overpasses. Neither steep, rocky terrain nor streamside habitats are typical of badger habitat (Apps et al. 2002) so Jersey barriers may have been negatively correlated with locations where badgers were likely to occur. Furthermore, bridges and overpasses associated with barriers would offer opportunities for badgers to pass under the highway without encountering the barrier. Thus, in our study area, Jersey barriers were uncommon, sometimes associated with underroad passages, and potentially associated with non-habitat. Whether for those reasons or due to an insufficient sample to detect patterns, they did not appear to increase badger roadkill risk. This might not hold true under different circumstances. Jersey barriers associated with roadkills in the area studied by Weir and Davis (2004) and Weir et al. (2004) covered long stretches on relatively gentle terrain within a landscape used by badgers.

Management Implications

Given the lower roadkill risk associated with having even a modest frequency of culverts (≥2/km) that were not placed with badgers in mind, and considering the leading role played by roadkill in badger mortality, the judicious placement of more culverts should aid in badger recovery. Clevenger and Waltho (1999) recommended spacing of 150–300 m for a variety of small to medium-sized mammals. Applied to badgers in our study area, this would represent roughly a doubling or tripling of the current number of culverts, and would likely be prohibitively expensive across the hundreds of kilometers of highway in our study area. However a number of steps could be taken to increase the effectiveness of existing culverts and make the placement of new culverts more efficient:

1. Ensure more of the existing culverts are usable by badgers. Of culverts observed, 18 % and 40 % were not passable by badgers at random and roadkill segments, respectively. Creating more safe passage opportunities could be achieved by repairing those that are crushed, opening those that are blocked, and placing fill under the ends of those suspended above the ground surface. There may also be opportunities to retrofit large culverts containing permanent streams with shelves to permit movement on a dry, safe surface (Foresman 2004).
2. Maximize the likelihood of badgers encountering culverts. Many culverts were difficult to see behind vegetation that seasonally or permanently blocked entrances. Clearing a few square meters of vegetation would greatly increase their visibility. Though the presence of vegetation at culvert mouths may encourage use by some species (Rodriguez et al. 1996, Clevenger and Waltho 1999), badgers prefer open habitats (Apps et al. 2002) so would not likely be inhibited by clearing. The MOT installs fence posts with coloured tops to mark culvert locations, but those posts were frequently down or missing. Ensuring that they were consistently in place might help badgers to associate culverts with their presence. Installing drift fencing to guide badgers into culverts to increase their use (Bekker and Canters 1997) should be considered where opportunities exist. Permanent, badger-proof fencing over longer distances might be feasible where roadkills have been common, but it would have to be considered within the context of effects on other species and in relation to cost effectiveness.
3. Selectively install more culverts. In jurisdictions where knowledge exists on locations of roadkills, badger activity and preferred habitat, areas providing the greatest benefit should be identified. It is possible that badgers are more likely to see culverts where terrain dictates that they approach highways from below, so topographic considerations should help guide the selection of sites for new culverts. Installing culverts is likely to be expensive, but existing highway reconstruction projects offer the opportunity to do so with little incremental cost. Opportunities for boring under highways to retrofit them with culverts should also be explored.
4. Investigate preferred culvert characteristics. Where opportunities arise, researchers should investigate the characteristics or landscape contexts of culverts that encourage their use by badgers.

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Literature Cited

Apps, C. D., N. J. Newhouse, and T. A. Kinley. 2002. Habitat associations of American badgers in southeastern British Columbia. Canadian Journal of Zoology 80:1228-1239.

Bekker, G. J., and K. J. Canters. 1997. The continuing story of badgers and their tunnels. *In* K. Canters (editor), Habitat Fragmentation and Infrastructure. Proceedings of the International Conference on Habitat Fragmentation, Infrastructure and the Role of Ecological Engineering, 17-21 September, 1995, Maastricht and The Hague, The Netherlands. Ministry of Transport, Public Works and Water Management, Delft, The Netherlands. Pp. 344-353.

Braumandl, T. F., and M. P. Curran. 1996. A field guide for site identification and interpretation for the Nelson Forest Region. Land Management Handbook 20. Ministry of Forests, Victoria, BC.

Cannings, S. G., L. R. Ramsay, D. F. Fraser, and M. A. Fraker. 1999. Rare amphibians, reptiles and mammals of British Columbia. Ministry of Environment, Lands and Parks, Victoria, BC.

Clarke, G. P., P. C. L. White, and S. Harris. 1998. Effects of roads on badger *Meles meles* populations in south-west England. Biological Conservation 86:117-124.

Clevenger, A. P., B. Chruszcz, and K. Gunson. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal of Applied Ecology 38:1340-1349.

Clevenger, A. P., and N. Waltho. 1999. Dry drainage culvert use and design considerations for small- and medium-sized mammal movement across a major transportation corridor. *In* G. L. Evink, P. Garrett, and D. Zeigler (editors), Proceedings of the Third International Conference on Wildlife Ecology and Transportation, September 13-16, Missoula, Montana. Florida Department of Transportation, Tallahassee. Pp. 263-277.

COSEWIC. 2006. Canadian species at risk August 2006. Committee on the Status of Endangered Wildlife in Canada, Government of Canada, Ottawa, ON.

Davis, W. B. 1946. Further notes on badgers. Journal of Mammalogy 27:175.

Foresman, K. R. 2004. The effects of highways on fragmentation of small mammal populations and modifications of crossing structures to mitigate such impacts. Unpublished report on file at Department of Transportation, Helena, MT.

Hunt, A., H. J. Dickens, and R. J. Whelan. 1987. Movements of mammals through tunnels under railway lines. Australian Zoologist 24:89-93.

Jackson, S. D., and C. R. Griffin. 2000. A strategy for mitigating highway impacts on wildlife. *In* T. A. Messmer, and B. West (editors), Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. The Wildlife Society, Bethesda, MD. Pp. 143-159.

jeffersonii Badger Recovery Team. 2008. Recovery strategy for the badger (*Taxidea taxus*) in British Columbia. Ministry of Environment, Victoria, BC.

Kinley, T. A., and N. J. Newhouse. 2008. Ecology and translocation-aided recovery of an endangered badger population. Journal of Wildlife Management 72:113-122.

Klafki, R. 2002. Adult female badger use of culverts under Highway 93/3 south of Cranbrook, British Columbia, Canada. Unpublished report on file at Sylvan Consulting Ltd., Invermere, BC.

Krawchuk, A. 2004. Wildlife use of non-wildlife culverts and underpasses on the Trans-Canada Highway near Kamloops, British Columbia. Unpublished undergraduate essay on file at Thompson Rivers University, Kamloops, BC.

Messick, J. P., M. C. Todd, and M. G. Hornocker. 1981. Comparative ecology of two badger populations. *In* J. A. Chapman, and D. Pursley (editors), Proceedings of the Worldwide Furbearer Conference, Frostburg, MD. Pp. 1290-1304.

Ministry of Transportation and Infrastructure. 2008. Traffic Volumes Data. Province of British Columbia, Victoria. Available online at www.th.gov.bc.ca/trafficdata/tradas/inset3.asp (accessed 20 April 2008).

Newhouse, N. J., and T. A. Kinley. 2006. East Kootenay Badger Project 2005-2006 progress report: ecology, translocation, communication, sightings and habitat use. Unpublished report on file at Fish and Wildlife Compensation Program (Columbia Basin), Nelson, BC, and Parks Canada Agency, Radium Hot Springs, BC.

Newhouse, N. J., and T. A. Kinley. 2007. East Kootenay Badger Project 2006-2007 progress report. Unpublished report on file at Parks Canada Agency, Radium Hot Springs, BC.

Packham, R., and C. Hoodicoff. 2007. Cariboo Region Badger Project: year end report 2006-07. Unpublished report on file at Ministry of Environment, 100 Mile House, BC.

Rodriguez, A., G. Crema, and M. Delibes. 1996. Use of non-wildlife passages across a high speed railway by terrestrial vertebrates. Journal of Applied Ecology 33:1527-1540.

van der Grift, E. A., J. Verboom, and R. Pouwels. 2003. Assessing the impact of roads on animal population viability. *In* C. L. Irwin, P. Garrett, and K. P. McDermott (editors), Proceedings of the 2003 International Conference on Ecology and Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh. Pp. 173-181.

Warner, R. E., and B. Ver Steeg. 1995. Illinois badger studies. Division of Wildlife Resources, Illinois Department of Natural Resources, Springfield.

Weir, R. D., and H. Davis. 2004. Badger recovery: highway mortality mitigation trial. Unpublished report on file at Ministry of Environment, Victoria, BC.

Weir, R. D., H. Davis, C. S. Hoodicoff, and K. W. Larsen. 2004. Life on a highway: sources of mortality in an endangered British Columbia badger population. *In* T. D. Hooper (editor), Proceedings of the Species at Risk 2004 Pathways to Recovery Conference. March 2-6, 2004, Victoria, B.C. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, BC. Pp. 1-9.

Yanes, M., J. M. Velasco, and F. Suarez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217-222.

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