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ECOLOGY OF BADGERS NEAR A RANGE LIMIT IN BRITISH COLUMBIA

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Abstract: American badgers (*Taxidea taxus*) are red-listed in British Columbia, where they occur near their range limit. We radiotagged and monitored 20 badgers in southeast BC from 1996 to 2000. Annual home ranges were 4 to 225 times larger than reported from the USA, averaging 30, 40 or 51 km^2 for females, based on the 95% fixed kernel method (FK), 95% adaptive kernel method and 100% minimum convex polygon methods respectively, and 70, 106 or 450 km^2 for males. Using the most realistic estimator (FK), male and female home ranges did not differ. Males more commonly made forays beyond the core of their home ranges, though not only to breed. Low trap success, large home ranges, mainly adult captures and low natality indicated a low population. Survivorship of juveniles and adults matched other studies but few litters were recorded, so low natality or high newborn mortality may have been the proximal cause of the low population. We hypothesize that range-limit habitat conditions provide a ceiling for population density, and normal fluctuations within that limit have recently gone below the lower threshold for successful breeding, so the low population has lead to impaired reproduction, causing still lower populations, and so on. Badgers are therefore able to expand their home ranges into unoccupied habitat. Recent human-caused impacts to habitat and mortality may have initiated this situation. Burrows used were usually ones dug previously and were strongly associated with Columbian ground squirrels (*Spermophilus columbianus*) and the low-elevation Interior Douglas-fir or Ponderosa Pine

biogeoclimatic zones, though all available zones were used. Both sexes consumed ground squirrels, voles, beetles,

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sparrows, loons, and fish. Conservation will require education, landowner cooperation, habitat restoration, possibly translocation of badgers into depleted areas, and research into causes of low recruitment and relationships between range condition and ground squirrel abundance.

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In British Columbia, American badgers are limited to the south-central and southeast portions of the province (Rahme et al. 1995) and this represents the northwestern limit of total badger distribution. The subspecies present there (*Taxidea taxus jeffersonii*) has recently been listed as "endangered" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2000) and is provincially red-listed (Cannings et al. 1999). Large home ranges, declining populations, loss of habitat and prey, and potential for high mortality from roadkills and shooting are the principle cause of the badger's endangered status.

Badgers are adapted to capturing fossorial prey, which is their primary diet in most locations (Salt 1976, Lampe 1982). However, badgers are opportunistic feeders and supplement their diet with a wide variety of mammals, birds, eggs, reptiles, amphibians, invertebrates and plants (Messick 1987). Data from Idaho suggests that conception generally occurs in late July and August, with litters of 1 to 4 born from mid-March to mid-April (Messick and Hornocker 1981). There has been little research done to define badger habitat requirements. Generally, they have been studied in open, often agricultural landscapes (Todd 1980, Warner and Ver Steeg 1995) and shrub-steppe habitats (Messick and Hornocker 1981), although they are known to occur from below sea level to elevations over 3,600 m (Lindzey 1982). There is considerable regional variation in home range size, but all studies have found males to have larger home ranges than females (Messick and Hornocker 1981, Minta 1990, Goodrich 1994, Warner and Ver Steeg 1995, Hoff 1998). Despite their endangered status in British Columbia, there has been no previous radiotelemetry-based research there. The objectives of this project were to determine home range sizes, dispersal trends, habitat use patterns and reproductive and mortality trends. A two-scale habitat model was also developed for this study area (Apps et al. 2001) based on the same radiolocation data.

STUDY AREA

The study area was between 49°30'N and 50°50'N, and fell mainly within the East Kootenay Trench ecosection (Demarchi 1996), which lies between the Rocky Mountains and Purcell Mountains of southeastern British Columbia. The Columbia River flows northward from the north end of the East Kootenay Trench, while the Kootenay River flows southward at its southern end. Badgers were trapped in the Ponderosa Pine (PP), Interior Douglas-fir (IDF), and Montane Spruce (MS) biogeoclimatic zones. Monitoring extended beyond those boundaries to follow badger movements, including portions of the Engelmann Spruce – Subalpine Fir (ESSF) and Alpine Tundra (AT) biogeoclimatic zones, with the greater study area having elevations of 800 to 2700 m. The PP and then IDF occur at the lowest elevations, with zonal sites historically dominated by open forests of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudostuga menziesii*) respectively (Braumandl and Curran 1992), grasslands or grass-shrublands on more xeric sites, and extensive marsh and forested riparian habitat along the major rivers. However, human settlement within the region is restricted mainly to the IDF and PP, and has resulted in residential, recreational and road development along the valley bottoms, extensive tree ingrowth and encroachment into former open forest and grassland due to fire suppression, and patches of agricultural development. Much of the open forest in the IDF is managed for Christmas trees, which are naturally generated Douglas-firs that are pruned and harvested, around which the majority of overstory trees are removed. Upslope of the IDF is the MS and then the ESSF. Climax forests in the MS are closed-canopy stands of hybrid white spruce (*Picea glauca* x *engelmannii*), and in the ESSF are Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*). However, the portions of the MS and ESSF in the study area have had an extensive history of fire and timber harvesting, so now include cutblocks, burns, and forest stands of varying ages with a high proportion of lodgepole pine (*Pinus contorta*). The AT occurs at the highest elevations and is non-forested. Potential fossorial prey included Columbian ground squirrels, which occur in natural or human-caused openings in all biogeoclimatic zones, and northern pocket gophers (*Thomomys talpoides*), which are restricted to the lowest elevations in the PP and IDF at the southernmost end of the study area.

METHODS

Trapping and Monitoring

We identified trap sites by field-checking locations of previous sightings or known colonies of Columbian ground squirrels. We trapped badgers at burrow entrances using #$1^{1}/_{2}$ soft-catch leghold traps baited with ground squirrels, rabbits or beef liver and scented with *Carmen's Canine Call* (Russ Carmen, New Milford, Pennsylvania), and checked traps at least daily. We noosed and hand-injected trapped badgers with either 10 mg/kg of tiletamine hydrochloride/zolazepam hydrochloride mixed at 100 mg/ml, or a combination of 0.3 mg/kg of midazolam mixed at 1.0 mg/ml and 9 mg/kg of ketamine hydrochloride mixed at 100 mg/ml. Surgical implantation of intraperitoneal transmitters (Advanced Telemetry Systems, Isanti, Minnesota) was conducted either in a veterinary clinic or in the field following Hoff (1988). While badgers were immobilized, we took samples of blood, feces and hair, and an upper premolar tooth. When badgers were alert, we released them either at the original trap sites if the burrow was still intact, or at nearby burrows. Teeth of the 14 adult study animals, along with those from 6 roadkilled carcasses obtained from BC Environment, were sent to Matson's Lab (Milltown, Montana) for aging.

Monitoring frequency ranged from daily to monthly depending upon funding and weather. Generally, we located animals weekly from April to September and twice-monthly from October to March. We located animals from the air using a telemetry-equipped Cessna 172 aircraft. For 595 of the 779 locations used in this analysis, we then employed ground-based telemetry to locate badgers in their burrows. Locations were marked on 1:20,000 air photos and transferred to 1:20,000 provincial forest inventory planning maps. Universal Transverse Mercator (UTM) grid coordinates, forest cover type and soil type were identified from forest inventory maps and from Lacelle (1990) or Wittneben (1980). When snow cover was not present, we recorded the number of ground squirrel burrows within 1 m of either side of four 50-m perpendicular transects originating at the badger burrow and, when it was obvious whether burrows had been freshly dug or previously dug, they were classified as “new” or “old”. Ground squirrel burrows were also recorded at 201 random plots in the IDF using the same method. At each badger burrow we also recorded the slope, aspect, cover type, distance to nearest cover type, distance to nearest gravel road, distance to nearest paved road, and presence of trees, buildings or slash piles within 2 m of the burrow. With the possible exception of some air-only locations, all data points were burrow sites rather than above-ground activity. Radiolocations were considered independent and included in the sample only when study animals were known to have moved from a burrow between sequential fixes. Data reported in this document were collected from June, 1996 to August, 2000.

Survivorship Calculations

Survivorship of tagged juvenile badgers was calculated to the date of their assumed first birthday (April 1). Annual survivorship of tagged adults was determined from the date of capture. The year in which a mortality occurred was considered as a full year, in addition to any previous complete years of monitoring (e.g. an animal dying 3.3 years after being tagged contributed 1 mortality for 4 years of sampling). For animals whose transmitters failed and for animals being monitored at the time of writing, the exact number of years each was monitored was added to the total of sample years. One female hit by a vehicle was brought into captivity and recovered, but would otherwise have died so is calculated as a mortality.

Home Range

We used the program *Calhome* (Kie et al. 1994) to calculate home ranges using the minimum convex polygon (MCP) method, and *The Home Ranger* (Hovey 1999) to calculate adaptive kernel (ADK) and fixed kernel (FK) home range estimates. Fixed kernel has been found to have the lowest bias and lowest surface fit error (Seaman et al. 1999). We used the 95% FK estimate to minimize the effects of extraterritorial forays on home range size (Knick 1990). To facilitate comparisons with other studies that used other methods, we also calculated 100% MCP and 95% ADK home range estimates. Animals with less than 30 locations were not included in calculations of mean home range (Seaman et al. 1999). Home range was not calculated for dispersing juveniles.

Based on habitat suitability maps from a two-scale multivariate analysis (Apps et al. 2001), we tested the hypotheses that the amount and proportion of suitable habitat were correlated with home range size. We regressed the absolute amount of habitat within each 95% FK home range against home range size, defining "habitat" at $P > 0.5$ (Ibid.), and reported the Pearson correlation coefficient.

Diet Analysis

Four gut samples and 14 scat samples from roadkills and study animals were sent to Pacific Identifications (Victoria, British Columbia) for analysis. They compared skeletal remains from the samples to collections from the University of Victoria and the Royal British Columbia Museum to identify prey items.

RESULTS

Badger Capture and Status Summary

Twenty badgers were radiotagged, including 7 adult males, 6 adult females, 1 juvenile male and 6 juvenile females. No significant trap-related injuries were detected. Ages of 13 adults at the time of capture were 1 to 10 years ($\bar{x}$ = 4.8, SD = 2.8). Among tagged animals, seven adult males weighed 7.7 to 11.8 kg ($\bar{x}$ = 10.6, SD = 1.4) and 6 females weighed 5.9 to 8.6 kg ($\bar{x}$ = 6.7, SD = 1.0). Of the 7 juveniles radiotagged, 5 died in their first year of life (1 of apparent cougar predation, 1 after being hit by a train, and 3 of unknown causes). A sixth juvenile was killed by a vehicle at 13 months. The seventh juvenile was 10 months old and still alive at the time of writing. Of the 13 adults tagged, 4 transmitters failed and 7 died (or would have died if not treated by a veterinarian) over the course of the study. One died of surgery complications, 2 were hit by vehicles, 1 died of predation, 1 died in a burrow in the alpine, probably of age or weather related causes, and 2 died of unknown causes. Combining data from all years, the annual survival rate was 27% for tagged juveniles and 72% for tagged adults.

Reproductive Success

Five of the adult females were monitored for 1 to 4 summers, when kits would normally be present, resulting in 12 possible litter occurrences. Only 4 litters were recorded, 3 of which were from the same badger over 3 years. She had single female kits when she was 3, 5 and 6 years old. Another female had a male and a female kit when she was 7 years old. It is possible that other kits were born but died before they emerged from natal burrows.

Home Ranges and Movements

The average home range size of males was larger than that of females when based on the 100% MCP (t = 2.7, P = 0.03; Table 1; Appendix 1), but not when based on the 95% FK method (t = 1.6, P = 0.15). When the breeding season (July 20 to August 31) was excluded from home range calculations, male home ranges decreased by 74% and female home range sizes decreased by 77% (Table 1). Distances of greater than 20 km between sequential locations for adults occurred in all months from April to September (n = 25), with 36% occurring in August. There was a greater rate of long distance movement among males than females (χ^2 = 24.4, 1df, P < 0.001), with 92% being made by males. When each individual's longest 3 movements were assessed, they collectively occurred in every month from April to November.

The absolute amount of home range that was habitat was positively correlated to home range size (R = 0.98, P < 0.001; Figure 1). While proportionately less of the home range was composed of suitable habitat in larger home ranges (as indicated by the asymptotic nature of the trend line), the largest home ranges still had 5 to 10 times more suitable habitat than the smallest home ranges.

Periods of winter inactivity were highly variable. For the 12 study animals for which winter activity data was available, 3 individuals demonstrated no detectable inactivity, although the long sampling interval may have prevented detection of short bouts of inactivity. For other individuals, inactivity periods ranged from 4 to 105 days. Some individuals were inactive for several different periods during the winter months. Periods of inactivity, presumably torpor (Harlow 1981), occurred from December through April.

Of the 6 juvenile females radiotagged, 2 dispersed 19 km, 1 dispersed 5 km, 1 dispersed 4 km and 2 did not disperse from their natal area, as defined by the point of capture. Three of the dispersals occurred in August and 1 in October. Dispersal distances may have been longer if the animals had lived longer, but all dispersing juveniles died within 3 months of dispersal. Of the 2 that did not disperse, 1 died in early August, so might otherwise have dispersed later. The juvenile male was captured in October, presumably after dispersal.

Habitat Use

Radiotagged badgers used all 5 of the biogeoclimatic zones in and around the study area, but 64% (n = 847) of the locations were in the IDF while an additional 27% were in the PP. Of the 6 females, 5 were recorded only in the PP or IDF, and one made minor use of the MS and extreme lower ESSF. Of the 7 males, 4 were recorded only in the PP or IDF, but 1 resided entirely in the MS and ESSF, and 2 were generally in the PP or IDF but made occasional forays to the AT. Of these latter 2 males, 1 traveled from the IDF at about 800 m to the AT at 2200 to 2400 m on 3 occasions in July, September and November, while the other traveled to the AT once in July.

Badgers used old burrows 1.8 as many times as they dug new ones (binomial test, $P < 0.001$; n = 393). Many burrows appear to be used year after year, and in two cases 2 badgers used the same burrow at different times.

Columbian ground squirrel holes occurred on at least 1 of 4 transects for 81% of badger burrows (n = 397, binomial test $P < 0.001$). There were ground squirrel burrows more often near badger burrows in the IDF zone (80%, n = 272) than in a random sample of the IDF zone landscape (5%, n = 201; $\chi^2 > 28.2$, $P < 0.001$).

Among cover types, burrows occurred most commonly in open range and upland forests (46% and 25%, n = 518; Figure 2). Most of the remaining locations were in cover types with limited or no forest cover and created or maintained by human activities. Burrows were frequently near a change in cover. For example, 82% (n = 515) were within 50 m of a change in cover, half of which were within 10 m. About 49% of the burrows (n = 516) were within 2 m of trees, buildings or slash piles. Relative to gravel roads, 50% of burrows (n = 514) were within 200 m and 6% within 10 m, while relative to paved roads 37% were within 200 m and 3% within 10 m. Burrows occurred on a variety of terrain, but typically were on gentle slopes ($\bar{x}$ = 18.6%, SD = 22.3), with 53% (*n* = 521) on slopes ≤ 10% and only 2% on slopes > 80%. Of 349 burrows occurring on a discernible aspect, 18% faced NE, 27% SE, 36% SW and 19% NW.

Diet

Of the 18 gut or scat samples, 5 had no bone or hair. These may have contained meat, soil, or other material. The 13 remaining samples contained Columbian ground squirrels (5), voles appearing to be red-backed voles (*Clethrionomys gapperi;* 4), beetles (Coleoptera; 3), sparrows or a similar species (Passerinidae; 2), common loons (*Gavia immer*; 2), a small salmonid (Salmonidae; 1) and a large sucker (*Catostomus* sp.; 1). All food types occurred in both male and female samples.

DISCUSSION

Habitat Use

The 16-fold difference in Columbian ground squirrel burrow occurrence between badger burrows and random plots, and the occurrence of ground squirrels as the most common item in scat and gut samples, are consistent with findings elsewhere that badger activity is positively correlated with the number of prairie dog (*Cynomys* spp.; Clark et al. 1982) and Townsend's ground squirrel (*Spermophilus townsendii*; Johnson et al. 1977) holes.

While badgers in this study were most commonly found in open range within the IDF or PP zones on flat to gentle terrain with southerly aspects, they occurred over a wide range of habitat conditions. The high proportion of burrows in very close proximity to ecotones that we observed suggests that badgers are intentionally selecting edges, rather than occurring there by chance due to fragmented habitat (Rahme et al. 1995) or naturally heterogeneous habitat in montane areas. The range in prey items we recorded indicates that badgers use a variety of foods found in different cover types and are therefore more likely to be found near ecotones, either intentionally or by chance as they move between foraging patches. Burrows were also near finer-scale "edges", with about half associated with trees, buildings or slash piles. Such structures may have provided support for ground squirrel or badgers burrows, or security cover for ground squirrels from avian predators. The typically close proximity to roads was not due to chance, as Apps et al. (2001) showed using the same data that badgers were positively associated with highways at a broad scale, while at a fine scale, 5 of 12 were positively associated and 7 were neither positively nor negatively associated. The association may be related to the use of areas near cover type edges, or may reflect the ground squirrel habitat and ease of movement associated with open habitats on road rights-of-way. It may also be correlated with the frequent vehicle and train collisions we observed. The observation that most faced southerly aspects likely relates to thermal advantages and perhaps to the more open cover types associated with these slopes.

The IDF and PP collectively represented only 18% of the analysis area in a habitat model developed for this study area (Apps et al. 2001), so the 91% of telemetry locations occurring there indicates the importance of these biogeoclimatic zones. The use of the AT zone by 2 males could have been a result of searching for Columbian ground squirrel or hoary marmot (*Marmota caligata*) colonies. Verbeek (1965) reported observing a badger at 3100 m in Wyoming hunting a young yellow-bellied marmot (*M. flaviventris*). Alternatively, while none of the radiotagged females were recorded in alpine habitats, there may have been other resident females in the AT zone to which males traveled for breeding. We observed fresh badger digging at 2400 m in August while recovering the carcass of a male, and another observer noticed tracks of 3 badgers, probably a mother and 2 kits, along the same ridge. We speculate that there may be resident females living in the alpine, but this requires further field verification.

The high degree of reuse of burrows by badgers may be part of a predation strategy, because we also noted frequent use of badger burrows by Columbian ground squirrels. Alternately, reusing burrows might reflect badgers repeatedly occupying certain locales and simply conserving energy by not digging new holes. Messick and Hornocker (1981) also found that in their Idaho study areas, old burrows were investigated consistently. They suggest that badger foraging is highly exploratory. The highly individualistic patterns of winter inactivity we observed were consistent with patterns observed in Idaho (Messick and Hornocker 1981). They suggest that winter inactivity is an adaptation to food and cold stress and that individual patterns reflect the fact that badgers depend on food that does not completely disappear in winter, but merely becomes more energetically expensive to secure.

Population Density

While we do not know the precise number of badgers inhabiting the study area, indications from the first 5 years of trapping and radiotelemetry suggest that the badger population was very low, particularly in the northern portion. This statement is based on the following observations:

1. Only 7 of 20 badgers trapped (35%) were juveniles, and 5 of these were specifically targeted at den sites of a radiotagged female or had been visually observed prior to trapping. Only 2 of 15 untargeted captures (13%) were juveniles. In contrast, Messick and Hornocker (1981) found that juveniles comprised roughly 50% of their Idaho population, while 55% of badgers captured in an Illinois study were juveniles (Warner and Ver Steeg 1995).
2. Of the 13 adults, average age was 4.8 years whereas most adult badgers examined in the Illinois study were 3 years old or younger (Ibid.) and the average age of adult badgers in a Wyoming study was 4 years (Goodrich 1994).
3. Adult mortality exceeded observed natality, with only 2 of 6 tagged females known to have borne kits, and far exceeded recruitment. Messick and Hornocker (1981) found that fecundity rose with age and the proportion of productive females of all ages in a given year averaged 57%, compared to the 33% we observed. The females trapped in this survey were all between the ages of 3 and 6, so higher fecundity would be expected.
4. Despite intermittent trapping efforts, no additional badgers were captured in the northern half of our study area from 1997 to 2000, and there was no confirmation of additional badgers occurring there.
5. Home ranges were much larger than in other studies (Table 2).

The annual survivorships of tagged juveniles and adults (27% and 72%) were comparable to those reported by Hoff (1998) and Warner and Ver Steeg (1995) for other populations that were at apparently higher densities and not known to be declining (25 and 27% for juveniles, 68 and 75%

for adults). Therefore, based on our limited sample, the low population appeared to be due to: (1) low initial reproduction; (2) high mortality of newborn kits; (3) higher mortality of adults and juveniles in the past; or (4) differences between the tagged sample and the population in general. Of these, the first is most likely, given the scarcity and small size of known litters, good body condition of tagged females, reasonable juvenile survivorship, and the potential that conception rate is positively related to population density. Messick and Hornocker (1981) speculated that if badgers are induced ovulators, as suggested for other mustelids, then frequent copulation over an extended period might ensure a high conception rate. The low population density in our study area may have resulted in reduced frequency of copulation and hence low natality.

Home Range and Space Use

Mean home range size documented in this study was 4 to 225 times larger than any reported in the literature (Table 2). Harestad and Bunnell (1979) noted that increasing latitude is broadly associated with decreasing primary productivity, so there is a trend toward larger home ranges at higher latitudes. Thus, large home range may have been due to a dispersed prey base, as indicated by the few ground squirrel burrows on random transects, an extremely varied diet in our study area near the northern limit of badger distribution, and the relative scarcity of treeless habitat, dominant across badger range (Lindzey 1982), in our greater study area. Alternatively, large home ranges may have been a secondary result of a low badger density unrelated to food abundance. Apps (1996) noted for bobcats (*Lynx rufus*), another species near its range limit in southern British Columbia, populations are likely limited by mortality and low fecundity, so simply spread into the available space. In support of this latter possibility, the absolute amount of suitable habitat in the largest home ranges was greater than that in the smallest home ranges by more than 10 times. This would not likely be the case if there was a threshold amount of habitat that badgers needed to encompass to meet their foraging requirements, unless there was great variation in quality within areas considered to be suitable habitat. Minta (1993) predicted that male competition for females should result in larger territories that encompassed multiple female territories. In his sagebrush-grassland study area in Wyoming, he observed that male badger movement rates doubled and home range areas nearly tripled during the breeding season to overlap those of females. Although we found that males were more likely than females to make long-distance movements, we did not find males to have larger FK home ranges than females, and we did not observe home ranges to differ in size with or without the breeding season included. Furthermore, long-distance movements by males were not concentrated in the breeding season, but occurred from April through September. This suggests that male home range sizes were unrelated to searching for mates, or else this occurred year-round in our study area rather than just during the breeding season as found in Wyoming. We therefore found no explanation for the dramatic variation in home range size within our study. There appeared to be nodes of concentrated activity (reflected in relatively small 95% FK home ranges) mixed with periodic long forays (as indicated by the much larger 100% MCP home ranges, especially for males). It is possible that certain critical requisites which were not assessed by Apps et al. (2001) varied in availability between home ranges, necessitating varying degrees of movement to secure them.

Rather than very large home ranges being the result of a deterministic mechanism (i.e. home ranges are extremely large because that is the amount of area required to meet life requisites), our results and the ecological conditions within the study area suggest the following scenario. Habitat availability translates to an ultimate carrying capacity and associated mean minimum home range size for badgers, and this carrying capacity is likely lower in southeast British Columbia than in areas more central to badger distribution. The population then fluctuates below that level according to inter-annual habitat variation and random events. At low points within this variation, the population is even more susceptible to random events, and conception rates become impaired. Even if induced ovulation (Messick and Hornocker 1981) does not occur, the chances of males and females meeting at appropriate times is reduced at lower population levels. This situation creates a positive feedback loop, in which a lower population leads to lower reproduction, which leads to still lower populations. The result of the very low populations is that there is abundant space and little ability to maintain exclusive home ranges, so badgers simply expand their ranges into the available habitat. Thus, current home range sizes are much larger than those theoretically required. The likelihood of this occurring is increased by there being a low maximum population level locally, and may have been initiated only in recent years by the loss of habitat in valley bottom locations and the introduction of vehicle collisions as a significant source of mortality. The 20% of study animals killed by vehicles or trains represent a mortality source additive to natural mortality. Despite the relatively low number of badgers present, at least 12 untagged badgers were killed by vehicles in or adjacent to the study area from 1996 through 2000 (unpublished data). Similarly, in a project under progress 300 km west of our study area, also near a badger distributional limit, at least 3 of 8 tagged badgers were hit and killed by vehicles (R. D. Weir. 2000. Thompson/Okanagan Badger Project Interim Progress Report, Artemis Wildlife Consultants, Armstrong, BC, Canada). For the population with the next largest home ranges reported in the literature (from Illinois), habitat loss and human-caused mortality are also important factors but the population appears to be stable (Warner and Ver Steeg 1995). If the above hypothesis is correct, the density in Illinois may have been reduced from historic levels, but still remain above the threshold at which conception rates become seriously impaired, and the self-perpetuating downward cycle may not yet have occurred.

MANAGEMENT IMPLICATIONS

We assume that the local badger population was historically viable rather than being a product of ongoing spillover from areas with higher densities to the south and east, based on there formerly being more grassland and less forest, fewer roads and automobiles, and based on subjective assessments of former abundance by long-term residents. If so, and if our hypothesis that the population has dropped below a density threshold for successful reproduction is true, then translocation may now be an appropriate short-term measure, because the population appears to no longer be self-sustaining, particularly to the northern portion of the study area. Unless future research indicates a much greater population elsewhere in British Columbia, source animals should probably originate out of province, subject to genetic and disease considerations. Longer-term maintenance of local badger populations will require restoration of habitats. Programs now underway to reverse forest ingrowth in the PP and IDF zones should increase the grassland and open forest habitats, thereby setting a higher carrying capacity ceiling, decreasing the effect of random events and lowering the risk of reproductive failure, while providing alternative areas for badger activity away from roads and settled areas, and possibly decreasing predation upon badgers by reducing forested stalking cover for cougars and coyotes. Such potential benefits of restoring the historically open habitats are somewhat speculative, and should be monitored.

Badger overlap with human-inhabited areas also makes them susceptible to shooting, trapping, loss of prey and poisoning, either directly or by scavenging poisoned ground squirrels. Extensive movements over large areas may increase sightability and create a perception of there being a high population, leading to less conservation concern and greater control effort. Education and stewardship initiatives should emphasize low population densities, the importance of not killing badgers, and the need to maintain ground squirrels and existing burrows. Significant conservation value could be gained by protecting known burrows during construction, forest harvesting or agricultural operations.

To test our hypothesis that low recruitment is due primarily low conception, carcasses of roadkilled female badgers or dead female study animals should be examined for placental scars or other signs of pregnancy. Evidence of there being few fetuses would be consistent with the low-density population leading to reduced conception. If the number of fetuses appeared to be normal, it might imply that they had been aborted or died at a young age.

Improved information about Columbian ground squirrel habitat preferences, population trends, and sensitivity to habitat alterations would clarify management needs. There may be a relationship between grazing intensity and ground squirrel population density, which may in turn affect the upper limit of carrying capacity. Although data on grazing intensity was not collected, we observed that many of the ground squirrel colonies exploited by badgers were on lands that had been heavily grazed. Todd (1980) found more Belding's ground squirrel (*Spermophilus beldingi*) holes in more heavily grazed stands of crested wheatgrass. Likewise, Koford (1958) observed that heavy grazing tended to reduce plant barriers and allow the spread of black-tailed prairie dogs (*Cynomys ludovicianus*). Continual cropping by domestic livestock encourages a more constant supply of succulent, nutritious vegetation for ground squirrels (Wikeem 1976). Compositional changes in range flora from perennial grasses to annual grasses and forbs associated with high grazing intensity may also provide a more abundant supply of preferred forage. Bond (1945) suggested that heavy stands of tall grasses discourage ground squirrels because of poor visibility. Conventional range management has minimized the level of very heavy grazing through rotational grazing systems. Further research on the relationship between grazing and ground squirrel abundance should be conducted, including determining the effect of wild versus domestic ungulates, native versus exotic range plants, and simple versus complex topography, to determine if grazing regimes could be designed that would benefit ground squirrels and therefore badgers.

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Table 1. Home ranges (km^2) and standard deviation of radiotagged adult American badgers, southeast British Columbia, 1996 – 2000, based on 100% minimum convex polygon (MCP) and 95% fixed kernel (FK) estimates. MCP comparisons are significant at $P < 0.05$, FK is not.

Sex	*n*	95% FK[a] annual	100% MCP[b] annual	100% MCP[b] without breeding season[c]
F	4	30 (29)	51 (41)	39 (31)
M	5	70 (72)	450 (342)	333 (230)

[a] calculated using *The Home Ranger* (Hovey 1999)

[b] calculated using *Calhome* (Kie et al. 1994)

[c] i.e. excluding 20 July to 31 August

Table 2. Comparison of mean home ranges (km^2) of adult American badgers, southeast British Columbia, 1996 – 2000, to those found in other studies, based on 100% minimum convex polygon (MCP) and 95% adaptive kernel (ADK) methods[a].

Study Location	Source	100% MCP		95% ADK	
		F	M	F	M
Idaho	Messick and Hornocker (1981)	2	2		
Wyoming	Goodrich (1994)			3	12
Wyoming	Minta (1990)	3	8		
Colorado	Hoff (1998)			8	25
Illinois	Warner and Ver Steeg (1995)	13	44		
British Columbia	this study	51	450	40	106

[a] MCP calculated using *Calhome* (Kie et al. 1994); ADK calculated using *The Home Ranger* (Hovey 1999)

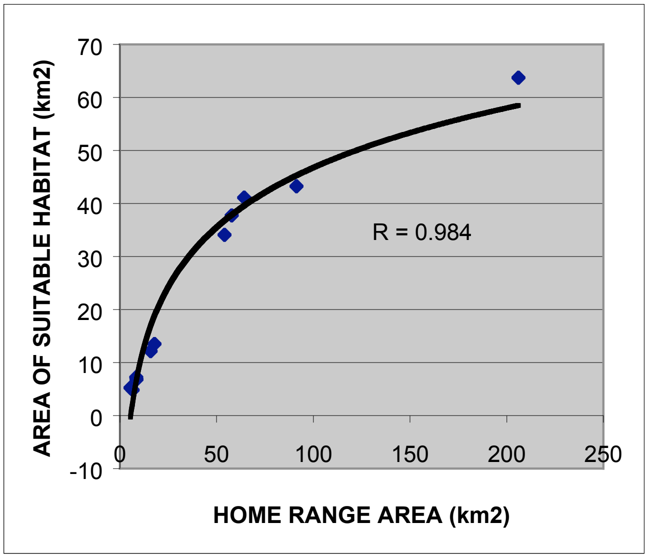

Figure 1. Total habitat area (km^2) within home ranges as a function of American badger home range size (km^2), southeast British Columbia, 1996-2000. Based on Apps et al. (2001), with "suitable habitat" defined as lands with a habitat probability > 0.5, and home range defined using 95% fixed kernel method.

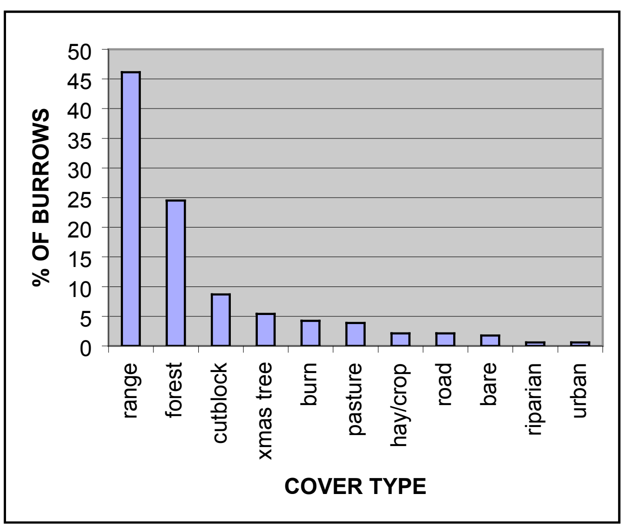

Figure 2. Cover types in which American badger burrows occurred, southeast British Columbia, 1996 – 2000 (n = 19 badgers, 518 radiolocations).

Appendix 1: Badger Telemetry Locations and 100% Minimum Convex Polygon Home Ranges to August, 2001.