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ECOLOGY OF AMERICAN BADGERS NEAR THEIR RANGE LIMIT IN SOUTHEASTERN BRITISH COLUMBIA

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Abstract: American badgers (*Taxidea taxus*) are red-listed in British Columbia. We radiotagged 15 animals in southeastern British Columbia from 1996 to 1999. We summarize badger home range size, reproductive success, habitat use and diet. Annual home ranges were 5 to 270 times larger than reported from studies in the USA. For females, they averaged 38 km^2 (95% fixed kernel method; FK), 53 km^2 (95% adaptive kernel method; ADK) or 65 km^2 (100% minimum convex polygon method; MCP), while for males they averaged 69 km^2 (95% FK), 114 km^2 (95% ADK) or 541 km^2 (100% MCP). Based on the most realistic estimator (FK) annual male home ranges did not differ from those of females (t = 0.27, P = 0.228) and did not decrease when calculated without the breeding season. Males did appear to have a stronger tendency to make forays beyond the core of their home ranges. Large home ranges in this study area may relate to low productivity or other factors associated with the range-limit location. Within the study area, variability between individuals did not appear to reflect an attempt to achieve a threshold area of suitable habitat within home ranges. Low trap success, large home ranges, predominantly adult captures, high mortality and low natality suggest a small population, particularly in the northern part of our study area. Burrows used by radiotagged badgers were more commonly re-used than recently excavated (binomial test, P < 0.001). Most (79%) had Columbian ground squirrel (*Spermophilus columbianus*) burrows within 50 m, which exceeded their relative availability by 16 times (binomial test, P < 0.001). All available biogeoclimatic zones were used, including the Ponderosa Pine, Interior Douglas-fir, Montane Spruce, Engelmann Spruce-Subalpine Fir and

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Alpine Tundra, but 71% of radiolocations were in the Interior Douglas-fir zone. Diet analysis revealed that both males and females consumed ground squirrels, voles, beetles, sparrows, loons, and fish. We suggest that grazing may enhance ground squirrel populations. Conservation of badgers is hindered by lack of information on them and their prey, and the degree of change occurring in their primary habitat of open forest and grassland. A successful conservation plan will require education, cooperation with private landowners, protection or enhancement of key habitat elements, and potentially translocation of badgers into depleted areas.

Key words: badger, British Columbia, carnivore, Columbian ground squirrel, diet, ecology, endangered species, home range, *Spermophilus columbianus*, *Taxidea taxus*

In British Columbia, American badgers are limited to the south-central and southeastern portions of the province (Rahme et al. 1995) and this represents the northwestern limit of total badger distribution. They have recently been up-listed to “red” status in British Columbia, meaning that they are considered threatened or endangered (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 badger’s “red list” 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 in 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 (Warner and Ver Steeg 1995, Todd 1980) and shrub-steppe habitats (Messick and Hornocker 1981), although they are known to occur from below sea level to elevations over 3,660 m (Lindzey 1982). Despite their threatened 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 and Newhouse in prep.).

STUDY AREA

Badgers were trapped in portions of the upper Columbia and upper Kootenay valleys of southeastern British Columbia (Appendix 1). The study area was between 49°30’N and 50°50’N, and fell mainly within the East Kootenay Trench ecosection of the Southern Rocky Mountain Trench ecoregion, which is part of the Southern Interior Mountains ecoprovince (Demarchi 1996). This included the Ponderosa Pine (PP), Interior Douglas-fir (IDF), and Montane Spruce (MS) biogeoclimatic zones (Braumandl and Curran 1992). Monitoring extended beyond the boundaries to follow badger movements, including portions of the Engelmann Spruce – Subalpine Fir (ESSF) and Alpine Tundra (AT) biogeoclimatic zones (Ibid.). The IDF and PP have historically been dominated by open forests and grasslands or grass-shrublands, with extensive marsh along the Columbia Rivera and forested riparian areas along much of the Kootenay River. However, human settlement within the study area is restricted to the IDF and PP, and has resulted in residential and road development along the valley bottoms, extensive ingrowth of forest through fire suppression, and patches of agricultural clearing in those zones. The MS and ESSF historically contained mixes of mature closed-canopy forest, burns, and fire-successional stands. Outside of parks, they are now managed for timber so also include forest stands of varying ages following logging. The AT is non-forested. Elevations ranged from about 800 to 2700 m. Potential fossorial prey included Columbia ground squirrels, which are widespread in the PP, IDF and AT and in disturbed areas of the MS and ESSF, 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 (1998). Blood, fecal, upper premolar tooth and hair samples were taken. 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 study animals, along with those from 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. For 535 of the 679 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 4 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. With the possible exception of some air-only locations, all data points represent 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 the summer of 1996 to October of 1999.

Home Range Calculations

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 90% MCP, 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.

Badger Space Use versus Habitat Aggregation Analysis

Based on habitat suitability maps from a two-scale multivariate analysis (Apps and Newhouse in prep.), we tested the hypothesis that habitat aggregation influenced space use by badgers. We regressed both the relative and absolute amounts of habitat within each 95% FK home range against home range size, defining “habitat” at $P > 0.4$ (Ibid.). We also regresssed the relative spatial dispersion coefficient (Clark Labs 1997) of radiolocations for each badger against habitat aggregation within a defined radius around each animal’s weighted geographic center of use. The radius for calculating habitat aggregation was 4.0 km, corresponding to the radius of an average circular 95% FK home ranges.

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

Fifteen badgers were radiotagged, including 6 adult males, 5 adult females, 1 juvenile male and 3 juvenile females. No significant trap-related injuries were detected. Ages of 11 adults at the time of capture ranged from 1 to 10 years (mean = 5.1, SD = 2.8). Six adult males weighed 7.7 to 11.8 kg (mean = 10.2, SD = 1.5) and 5 females weighed 5.9 to 8.6 kg (mean = 6.7, SD = 1.1). All 3 juvenile females died in the year of capture (1 of apparent cougar predation, 1 of apparent starvation or coyote predation, 1 of possible predation). Of the 11 adults tagged, 4 transmitters appeared to have failed after 1 to 3 years of use. In addition, 5 adults died. One adult male was roadkilled, 1 adult female appeared to have been killed by a cougar and 1 adult male died in a burrow in the alpine, probably of age or weather-related causes. The cause of death of the remaining 2 adults (1 male, 1 female) was unknown because their only remains were small pieces of hide and the transmitters.

Reproductive Success

Four of the adult females were monitored for 1 to 3 summers, when kits would normally be present, resulting in 10 possible litter occurrences. Only 2 litters were recorded, both from 1 badger. She had single female kits when she was 3 and 5 years old. It is possible that other kits were born, but died before they emerged from the burrow.

Home Ranges and Dispersal

Average home range size did not differ between males and females based on the 95% FK method ($t = 0.27$, $P = 0.228$) but did when based on the 100% MCP ($t = 0.49$, $P = 0.026$; Table 1; Appendix 1). When the breeding season (July 20 to August 31) was excluded from home range calculations, average male home ranges did not decrease (Table 1). Of the 3 juvenile females radiotagged, 1 dispersed 21 km, 1 dispersed 5 km, and 1 did not disperse from her natal area. Both dispersals occurred in August. The juvenile male was captured in October, presumably after dispersal.

Habitat Use

On 3 occasions, in July, September and November, 1 male traveled from valley bottom (c. 800 m) to the alpine (2200 to 2400 m). Another male also traveled to the alpine once in July. Radiotagged badgers used all 5 of the biogeoclimatic zones in and around the study area, but 71% (n = 708) of the locations were in the IDF.

Badgers used old burrows at least twice as many times as they dug new ones (binomial test, $P < 0.001$; n = 390). Many burrows appear to be used year after year, and in 2 two cases 2 badgers used the same burrow at different times.

Columbian ground squirrel holes occurred on at least 1 of 4 transects for 79% of badger burrows (n = 346, binomial test $P < 0.001$). The proportion of telemetry locations having ground squirrels did not differ between the IDF and the ESSF/AT/MS ($X^2 = 1.05$, $P = 0.31$) or the PP ($X^2 = 0.709$, $P = 0.40$). Therefore, transect data from radiolocations in all biogeoclimatic zones were compared to random plots in the IDF, in which only 5% had ground squirrel holes (n = 201). There were ground squirrel burrows significantly more often near badger burrows than in a random sample of the landscape ($X^2 > 28.2$, $P < 0.001$).

Badger Space Use versus Habitat Aggregation

The proportion of home range that was “habitat” declined with increasing home range size (Figure 1), but the absolute amount of home range that was habitat was positively correlated to home range size (Figure 2). There appeared to be a slight negative relationship between habitat aggregation and radiolocation dispersion (Figure 3), although the correlation was weak and was driven by one individual with the greatest radiolocation dispersion coefficient.

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 squirrel (5), voles appearing to be red-backed vole (*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 supports the notion that ground squirrels are a primary food source. This is consistent with the appearance of ground squirrels as the most common item in scat and gut samples.

The use of alpine tundra 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, there may have been resident females in the alpine which males traveled to for breeding. We observed fresh badger digging at 2400 m in August when we recovered the carcass of a male that had died the previous November. Another observer noticed tracks of 3 badgers, probably a mother and 2 kits, along the same ridge.

The high degree of re-use 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, re-using burrows might reflect badgers repeatedly occupying certain locales and simply conserving energy by not digging new holes.

Home Range and Space Use

Mean home range size documented in this study was 5 to 270 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 regardless of trophic status or weight of the species there is a trend toward larger home ranges at higher latitudes. A dispersed prey base in our study, as indicated by the few ground squirrel burrows on random transects and an extremely varied diet, may have contributed to these large home ranges. Alternately, large home ranges may have been a secondary result of low badger density caused by high mortality and low reproductive output. As Apps (1996) noted for bobcats (*Lynx rufus*), another species near its range limit in southern British Columbia, it is likely that populations are limited by mortality and low fecundity, so simply spread into the available space. Thus, the resulting large home ranges may not necessarily reflect total resources required by individuals.

While it is not clear to what extent habitat quality explains home range differences between our study and those farther south, there is evidence that it did not explain the variation in home range size within our study. Larger home ranges contained less suitable habitat on a relative basis, but the absolute amount of habitat increased by more than an order of magnitude with increasing home range size. This indicates that there was probably not a threshold amount of habitat which badgers needed to encompass by increasing their home ranges. Furthermore, animal movements, as measured by the dispersion coefficient, were linked only weakly, if at all, to the amount of habitat in the home range centroid. The low population density (indicating relatively little competition for home ranges and therefore little need to travel to find unoccupied areas) gives further evidence that, within this study, larger home ranges were likely a result of non-habitat factors.

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. Thus, one possibility for differences in home ranges between individuals in our study is that males might need to move great distance to access females, and each male might have to move a different distance to do so. However, we did not find males to have larger home ranges than females, and we did not observe increases in home range when the breeding season was included in annual calculations. This suggests that if male home range sizes were related to searching for mates, this occurred year-round in our study area rather than just during the breeding season as found in Wyoming (Ibid.). We therefore found little evidence for why home ranges varied so dramatically within our study. There appeared to be an activity pattern of having 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 and Newhouse (in prep.) varied in availability between home ranges, necessitating varying degrees of movement to secure them. Alternately, badgers may have simply made regular reconnaissance forays searching for potential new home ranges or food sources, with the length of such forays varying between individuals.

Indications of Population Density

Indications from the first 4 years of trapping and radiotelemetry suggest that the badger population in the study area was very low, particularly in the northern portion (upper Columbia valley). This statement is based on the following observations:

1. Only 4 of 15 badgers trapped (27%) were juveniles, and 2 of these were specifically targeted at den sites of a radiotagged female. 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 11 adults, average age was 5.1 years whereas most adult badgers examined in the Illinois study were 3 years old or younger (Ibid.). Average age of adult badgers in a Wyoming study was 4 years (Goodrich 1994).
3. The 3 radiotagged juvenile females all died before their first winter.
4. Of the 11 adults radiotagged, 5 died. This mortality exceeded observed natality.
5. Out of 10 possible litters among tagged females, only 2 juveniles were known to have been born. 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%. The females trapped in this survey were all between the ages of 3 and 6, so higher fecundity would be expected. 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 productivity.

6. Despite extensive trapping efforts in 1997, no additional badgers were captured in the northern half of our study area.
7. Home ranges were much larger than in other studies.

MANAGEMENT IMPLICATIONS

Badgers in British Columbia present conservation challenges. They occur at a low density, use large home ranges, and concentrate their activity in valley-bottom habitats. Such areas are often heavily impacted by human development and forest ingrowht, resulting in loss of habitat and burrows. Preferred habitat characteristics and areas of high quality habitat indicated by Apps and Newhouse (in prep.) provide guidance for habitat protection and management actions. We noted many burrows on road cut-banks and Apps and Newhouse (in prep.) found that even at the fine scale of habitat selection (25 m resolution) badgers did not avoid highways. This may lead to high direct mortality. Since 1996, 1 radiotagged male badger has been hit by a vehicle and at least 6 untagged badgers have been killed in or adjacent to the study area (Nancy Newhouse, Sylvan Consulting Ltd., Invermere, British Columbia, unpublished data). Even though it is not certain that enhancing habitat quality by reversing forest ingrowth would increase recruitment, it would at least provide alternative areas for badger activity away from roads and might decrease predation upon badgers by reducing stalking cover. 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. Members of the public may mistakenly assume that multiple sightings of badgers over a wide area represent many individuals. This may result in unrealistically-high population estimates and lead to either a lack of concern for population and habitat conditions or outright control actions. 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. Based on the distribution of good quality badger habitat, Apps and Newhouse (in prep.) demonstrated that private stewardship initiatives, including with First Nations, are a key element to badger conservation in southeast British Columbia. Significant conservation value could be gained by protecting known burrows during construction, forest harvesting or agricultural operations. Translocation to the northern portion of the study area may also be required, as the population may no longer be self-sustaining.

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. 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. In a study in south-central Idaho, Todd (1980) found that the number of Belding's ground squirrel (*Spermophilus beldingi*) holes were significantly greater in heavily grazed stands of crested wheatgrass than in light to moderately grazed areas. Likewise, Koford (1958) observed that heavy grazing tended to reduce plant barriers and allow the spread of black-tailed prairie dogs (*Cynomys ludovicianus*). Compositional changes in range flora from perennial grasses to annual grasses and forbs commonly occur as grazing intensity increases, which may provide a more abundant supply of preferred forage for ground squirrels. Furthermore, continual cropping by domestic livestock encourages continual re-growth, thereby creating a more constant supply of succulent, nutritious vegetation for ground squirrels (Wikeem 1976). Bond (1945) also 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, in an effort to maintain forage for livestock and wild ungulates and to minimize weed introduction. Further research on the relationship between ground squirrels, ungulates and grazing should be conducted to determine if grazing regimes and other methods of vegetation management, such as controlled burning, 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 badgers, southeast British Columbia, 1996 – 1999, based on 100% minimum convex polygon (MCP) and 95% fixed kernel (FK) estimates.

Sex	*n*	100% MCP[a] (annual)	95% FK[b] (annual)	95% FK[b] (without breeding season[c])
F	3	65 (36)	38 (28)	39 (29)
M	4	541 (313)	69 (79)	77 (82)

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

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

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

Table 2. Comparison of mean home ranges (km^2) in southeast British Columbia, 1996 – 1999, to those found in other studies, based on 100% minimum convex polygon (MCP) and 95% adaptive kernel (ADK) methods.

Study Location	Source	100% MCP		95% ADK	
		Females	Males	Females	Males
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	65	541	53	114

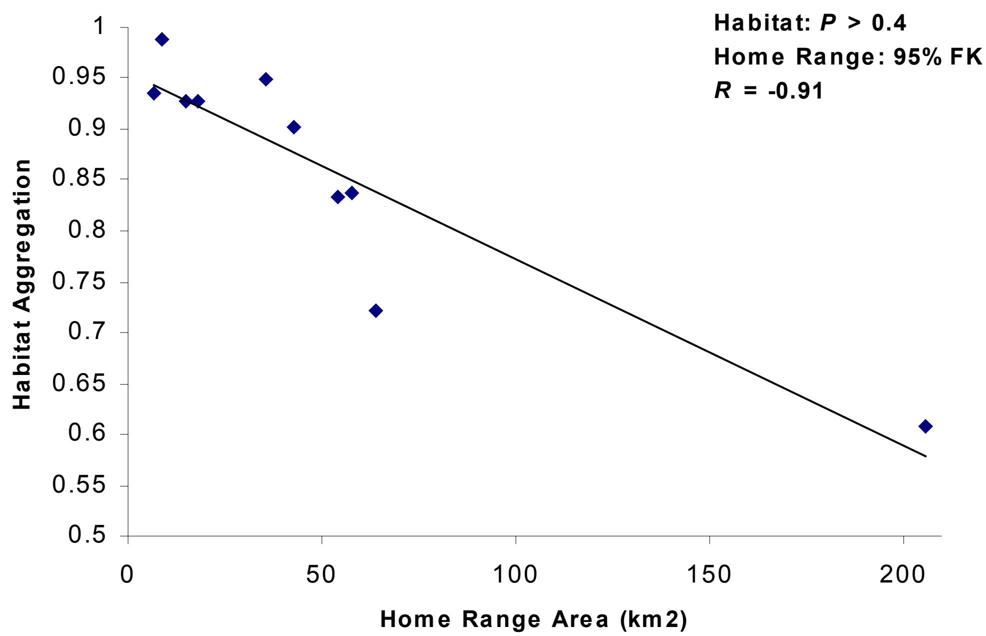

Figure 1. Relative habitat area within home ranges as a function of badger home range area, southeastern British Columbia, 1996 – 1999. Habitat defined as habitat probability > 0.4 (Apps and Newhouse in prep.).

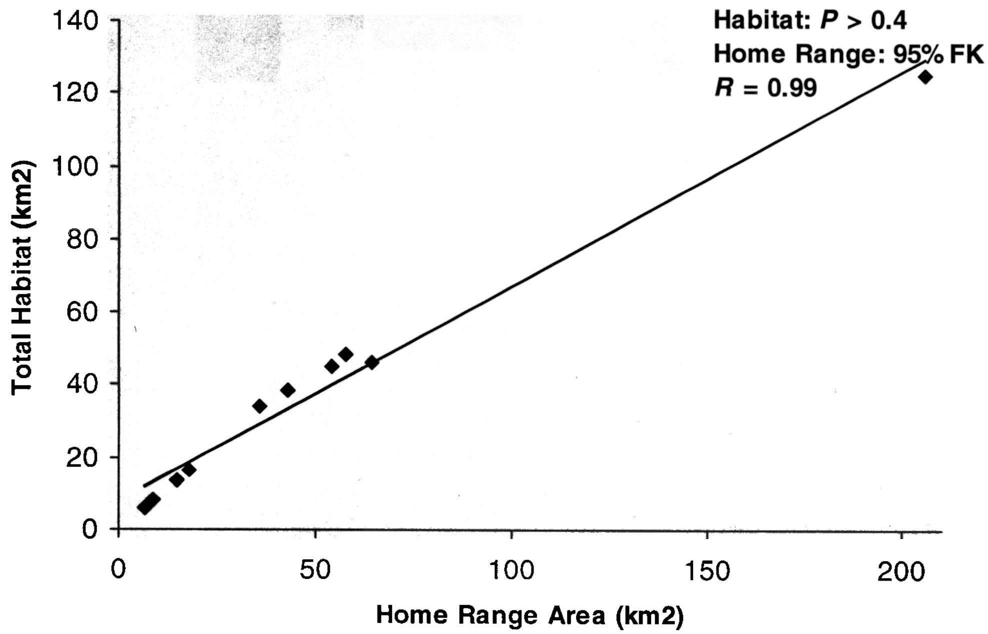

Figure 2. Total habitat area within home ranges as a function of badger home range area, southeastern British Columbia, 1996 – 1999. Habitat defined as habitat probability > 0.4 (Apps and Newhouse in prep.).

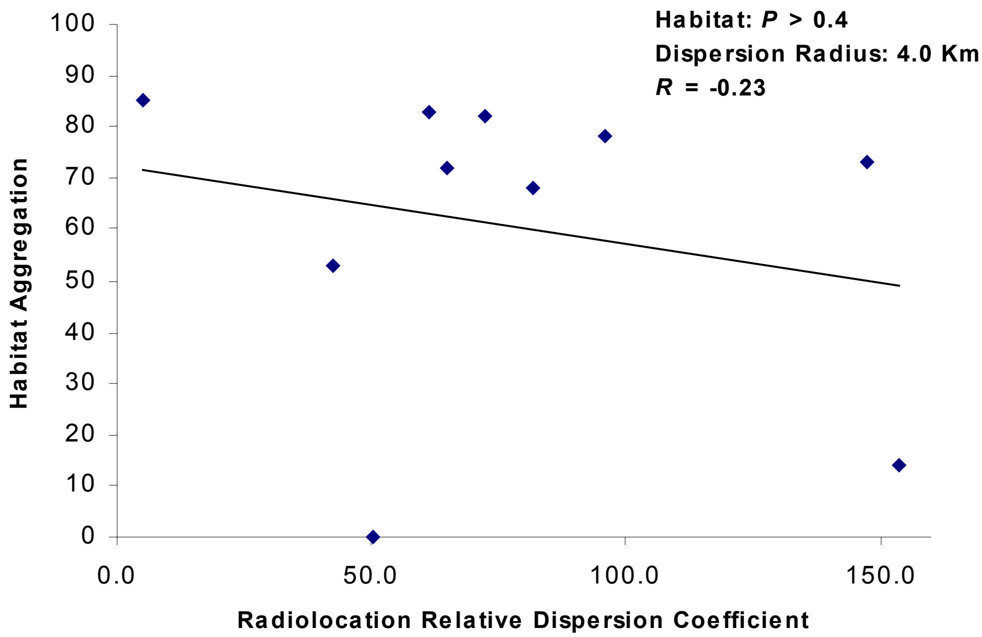

Figure 3. Habitat aggregation as a function of badger radiolocation dispersion coefficent (Clark Labs 1997), southeastern British Columbia, 1996 – 1999. Habitat defined as habitat probability > 0.4 (Apps and Newhouse in prep.).