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Chapter 7

American Badger Predation on Richardson's Ground Squirrels in Southwestern Saskatchewan, Canada

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Abstract – This study investigated the correlation between American badger (*Taxidea taxus*) hunting ground distribution and food habits, and the relative distribution and abundance of Richardson's ground squirrels (*Urocitellus richardsonii*) in grasslands and annual crops of southwestern Saskatchewan. I hypothesized that: (H_1) the distribution of badger hunting grounds would be related to that of Richardson's ground squirrels across habitats; and (H_2) Richardson's ground squirrels would be a relatively more important prey of badgers, independently of the ground squirrels' activity cycle and environmental conditions. There was a significant difference between observed and expected frequencies of Richardson's ground squirrel burrow entrances per habitat type. Burrow entrances were significantly less frequent ($p < 0.05$) in annual crops but more abundant ($p < 0.05$) in grasslands and summer fallow. The study of 3 adult American badgers in different habitats and seasons showed that these carnivores established their hunting grounds in fields with the highest densities of Richardson's ground squirrel burrow entrances. Within these fields, mean densities of burrow entrances/ha of Richardson's ground squirrels and American badgers were significantly greater ($p < 0.05$) in badger hunting grounds than in control areas. There was a significant linear relationship (r ranging from 0.65 to 0.98, $p < 0.05$) between the densities of burrow entrances/ha of American badgers and those of Richardson's ground squirrels. The collection and analysis of fresh scats from 2008 to 2010 in southwestern Saskatchewan showed that the diet of American badgers consisted mainly of Richardson's ground squirrels in spring and summer. Although the badgers' diet became more diversified in late summer

and early fall when most ground squirrels have entered hibernation, from a biomass point of view, Richardson's ground squirrels were still the dominant prey. This study suggests that 1) there is a correlation between the distribution of badgers and Richardson's ground squirrels, thus supporting H_1; and 2) Richardson's ground squirrels are consistently an important food item for badgers, particularly in spring and summer, thus partly supporting H_2. Because of the importance of Richardson's ground squirrels in the diet of American badgers, pest control programs aiming at decimating ground squirrel populations may have a major impact on the survival of the badger in the Canadian Prairies, where it is listed as a "Species of Special Concern".

INTRODUCTION

The American badger (*Taxidea taxus*) is reported to be an opportunistic predator that consumes small mammals, invertebrates, and plant material (Errington 1937; Snead and Hendrickson 1942; Jense 1968; Messick and Hornocker 1981; Lampe 1982; Long and Killingley 1983). On the other hand, some studies have emphasized the importance of fossorial sciurids in the diet of the American badger (Koford 1958; Johnson *et al*. 1977; Messick *et al*. 1981; Lampe 1982; Murie 1992). Accordingly, American badgers are morphologically and behaviourally specialized to excavate soil rapidly and efficiently (Lampe 1976; Quaife 1978; Moore 2011; Proulx and MacKenzie 2012a) and are known to use specific hunting techniques (Michener 2004) and search movements (Proulx and MacKenzie 2012a) when preying on Richardson's ground squirrels (*Urocitellus richardsonii*).

In order to better understand the importance of Richardson's ground squirrels in the diet of the American badger, I investigated the distribution and characteristics of the hunting grounds (areas of intense hunting repeatedly used for several days by badgers; Proulx and MacKenzie 2012a) and the diet of American badgers in southwestern Saskatchewan, Canada, from 2008 to 2010. During the study period, Richardson's ground squirrel abundance increased according to the occurrence of drought conditions, or declined according to the occurrence of intense spring rains and flooding. However, relatively higher densities of Richardson's ground squirrels are found in southwestern Saskatchewan than in other regions of the province (Proulx *et al*. 2012).

I hypothesized that: (H_1) the distribution of badger hunting grounds would be related to that of Richardson's ground squirrels across habitats; and (H_2) Richardson's ground squirrels would be a relatively more important prey of badgers, independently of the ground squirrels' activity cycle and environmental conditions.

STUDY AREAS

This study was carried out in the Brown Soil Zone of southwestern Saskatchewan, which is characterized by warm temperatures, lack of moisture, and lack of organic matter (Harrison 2000), and higher densities of Richardson's ground squirrels than in other soil zones of the province (Proulx *et al*. 2012). I studied the hunting grounds of 3 adult badgers in a 60-km^2 area near the town of Hazenmore, immediately north of Mankota (Figure 1). I collected badger scats in various grasslands within a 1,400-km^2 area that encompassed the towns of Mankota, Hazenmore (including the study area of the hunting grounds), Aneroid, and Ponteix (Figure 1b). These rural

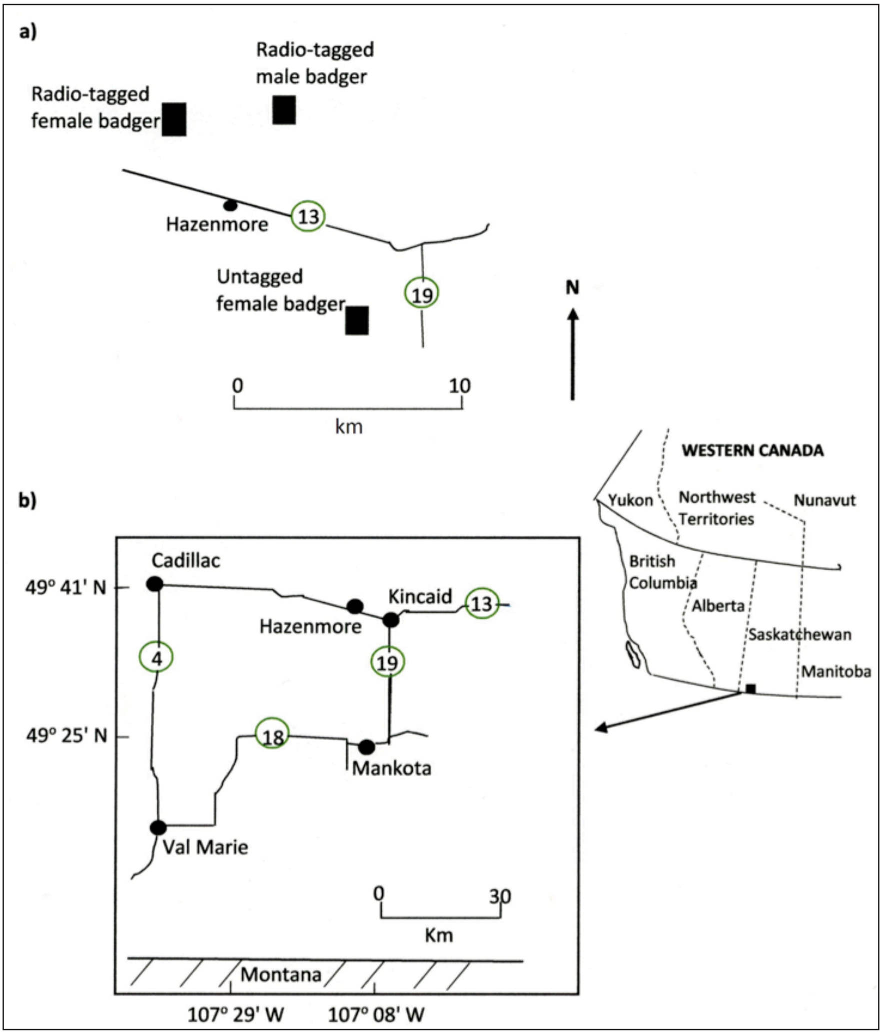

Figure 1. Location of the study area.

communities belong to an agricultural region of grain crops, mainly wheat (*Triticum* spp.), and mixed grasslands of crested wheat (*Agropyron cristatum*), brome (*Bromus* spp.), slender wheat grass (*Elymus trachycaulus*), and alfalfa (*Medicago* spp.).

In 2008, drought conditions were extensive and high densities of Richardson's ground squirrels often exceeding 40 adults/ha in spring (Proulx *et al*. 2010) were found throughout southwestern Saskatchewan. In 2009, heavy spring rains and flooding occurred. Richardson's ground squirrels declined in abundance and high population densities were usually found in grasslands with <15-cm-high vegetation, often where overgrazing occurred (Proulx 2010; Proulx *et al*. 2012).

In 2010, southwestern Saskatchewan received abnormally high amounts of rain, which flooded agricultural fields and caused a major decrease in Richardson's ground squirrel population densities due to high natural mortality rates (Proulx 2012).

METHODS

Hunting grounds

The study of badger hunting grounds was limited to a small number of animals during different seasons and years. This was due to the fact that it was difficult to find animals that would be protected from rodenticide secondary poisoning, which was common in southwestern Saskatchewan (Proulx 2011; Proulx and MacKenzie 2012b), and constant persecution by some landowners who drove at night and killed them (e.g., shooting and road-killing; G. Proulx, unpublished data). Hence, this study focused on the hunting grounds of 3 American badgers, which inhabited fields that were protected from poisoning and persecution.

One adult female was captured on 29 September 2008 in a 36 × 36 × 92 cm wire-mesh trap (model HD X-large, Duke Traps, West Point, Missouri, USA). It was equipped with a 25-g dorsal radio-transmitter implant with mortality mode, coiled whip antenna, and 3-year battery life (model AI-2M, Holohil Systems Ltd, Carp, Ontario, Canada) (Proulx and Mackenzie 2012c). Its movements were monitored during 16 nights (see below) from 29 September to 28 November 2008 (she was not active afterwards when the temperature dropped to -20 °C), and during irregular night visits from 2 May to 5 July 2009 (Proulx and MacKenzie 2012a). A total of 1,953 min of spotlighting observations were recorded on the hunting behaviour and movements of this female.

In 2009, another female (seen with 2 kits in summer), which was identified on the basis of its appearance and recurring activities, was observed in fall. It was not equipped with a radio-transmitter. A total of 170 min of spotlighting observations were recorded from 26 to 30 July 2009, and on 19 May 2010. The badger inhabited the same sites in summer 2009 and spring 2010.

An adult male was captured with a snare pole on 17 May 2010, and it was also equipped with a dorsal radio-transmitter implant (Proulx and MacKenzie 2012c). This badger's activities were monitored during 8 spotlighting sessions of <15 min from 25 July to 22 November 2009, and during 195 min from 17 May to 23 June 2010. The badger inhabited the same sites in fall 2009 and spring 2010 (Proulx and MacKenzie 2012a).

The determination of badger hunting ground boundaries was done with 12 × 42 binoculars and a 400,000 candle-power search light (Golight, Inc., Culbertson, Nebraska) with a reach of ≤800 m (see Proulx and MacKenzie 2012a, for detailed methodology). Hunting ground boundaries were determined on the basis of spotlight observations and radio-signals, mostly in fall 2008 for the radio-tagged female, fall 2009 for the untagged female, and April 2010 for the radio-tagged male. Hunting grounds were mapped on 1:50,000 orthophotos (geometrically corrected aerial photographs; Geomatics Corp., Lethbridge, Alberta) using features such as fence posts, rock piles, and terrain characteristics. The day after each spotlighting session, I visited hunting grounds to investigate specific locations where badgers had been active the night before, and to record signs of digging and the presence of Richardson's ground squirrel burrow entrances that had been enlarged by badgers. The boundaries of the hunting grounds encompassed badger digging areas. Within these boundaries, I determined the number of Richardson's ground squirrel burrow entrances/

ha. Only entrances that were well opened and without collapsed dirt or vegetation growing in the entrance were counted (Schmutz and Hungle 1989; Finger *et al*. 2007; Proulx *et al*. 2012). Although the densities of burrow entrances are not absolute estimates of Richardson's ground squirrel population densities (e.g., Van Horne *et al*. 1977), Proulx *et al*. (2012) demonstrated a positive relationship between the number of active entrances and the number of Richardson's ground squirrels. American badger burrow entrances were recognized by their enlarged size, and the presence of fresh digging, tracks and scats.

Richardson's ground squirrel and American badger burrow entrances were counted in hunting grounds and in control plots of similar size located at random, 30 m on each side of the hunting grounds. In some cases, it was not possible to use 2 control plots per hunting ground, either because they overlapped with a nearby hunting ground or were located in a vegetation cover that differed from that of hunting grounds. Student's *t* tests were used to compare mean densities of burrow entrances/ha in hunting grounds and control plots (Zar 1999). Simple linear regression models were used to determine the relationship between the mean densities of Richardson's ground squirrel and American badger burrow entrances. Tests of statistical power were done using Fisher z transformation for the critical value of r and for the sample n (Zar 1999). The coefficient of determination, r^2, was calculated to determine the portion of the total variation that was explained by the fitted regression. I did not pool data from the different badgers' study areas because an analysis of covariance indicated that there was a significant difference between the slopes of the regression lines. A 0.05 level of significance was used for all tests.

To assess habitat preference by Richardson's ground squirrels, and understand the distribution of badger hunting grounds, I estimated the relative abundance of Richardson's ground squirrels in various habitat types by counting active burrow entrances along parallel, linear transects laid out (using 70-m-long rope sections) across fields surrounding and including badger hunting grounds: 5 200–404-m equidistant transects for the radio-tagged female badger; 4 290–404-m equidistant transects for the radio-tagged male; and 4 200-m equidistant transects for the untagged female. The length of transects varied according to field dimensions. All burrow entrances that were well-opened, and without collapsed dirt or growing vegetation in the entrance, within 30 cm from transect lines, were counted. In the case of the radio-tagged female, I was not able to carry out this study until early July 2009 because of cold temperatures and snow precipitations in late fall 2008 and flooded roads in spring and early summer 2009. During this winter period, Richardson's ground squirrels were in hibernation, and the badger was inactive due to very cold temperatures. In early summer, fields and hunting grounds were saturated with water, or even flooded, and I found that new digging activity did not appear to be extensive. For the untagged female adult, I surveyed all fields prior to the study of hunting grounds in order to avoid delays that may be caused by bad weather in late summer or fall. In the case of the radio-tagged male, I conducted the inventory a few days after the study of the hunting grounds in April 2010. During the surveys of burrow entrances, no farming activity disturbed the fields.

The proportion of inventory transects within each habitat type was used to determine the expected frequency of Richardson's ground squirrel burrow entrances per habitat type. Goodness-of-fit tests (Zar 1999) were used to compare observed to expected frequencies of burrow entrance intersects per habitat type. If chi-square analyses suggested overall significant differences between the distributions of observed and expected frequencies, a G test for correlated proportions (Sokal and Rohlf 1981) was used to compare observed to expected frequencies for each habitat class.

Scat collection and analysis

I collected fresh American badger scats from spring to fall 2008, and in spring and summer 2009 and 2010 during various Richardson's ground squirrel population studies in Hazenmore, Mankota, Aneroid and Ponteix (e.g., Proulx *et al*. 2011; Proulx 2012). The identification of badger scats was based on personal notes gathered in previous studies with animals in captivity (e.g., Proulx and MacKenzie 2012c), and on Lampe's (1982) criteria, i.e., location of scats on or near the perimeter of a badger-like excavation, presence of badger tracks near scats, and presence of a radio-tagged badger near the site of scats. Because scats were found as I walked across grasslands at irregular intervals, it is unlikely that consecutively produced scats were obtained, and that single prey items contributed to more than 1 collected scat (Lampe 1982). Also, I assumed that the presence of a prey species in 1 scat did not influence its appearance in another one.

Scats were dated, bagged, and kept frozen until they were processed. Scat analyses were conducted at the Alpha Wildlife Research & Management laboratory in Sherwood Park, Alberta. Scats were soaked overnight in a mild water-bleach solution, washed through a sieve, and oven-dried at 75 °C (R. T. Golightly, Humboldt State University, personal communication, 2008). The analysis of hairs from scats first involved the examination of cuticular scales, which constitute the surface pattern of the hair. Scale casts were made by squeezing hair between a microscope slide with a fresh acetone smear and a clean slide for approximately 1 min to obtain an impregnation of the hair surface pattern. A 3-dimensional view of the hair surface was also obtained by wiping the hair with methyl salicylate (Fisher Scientific, Fair Lawn, New Jersey, USA). Casts and hairs were examined with a compound light microscope. Hairs briefly soaked in methyl salicylate were examined under microscope to identify medulla configuration in the basal area (the area of the hair shaft containing the root end) and the shield (the widened, flattened area located at various positions on the hair shaft) and to note the absence or presence of strictures (Moore *et al*. 1974). When bone remnants and teeth were found in a scat, they either corresponded to the species identified with hairs, or were "unidentifiable" and recorded as unknown. Feathers were identified to genus level using Chandler (1916) and Day (1966).

Contents of scats are presented both as percentage of occurrence (percentage of total scats in which an item was found) and relative percentage of occurrence (number of times a specific item was found as percentage of all items found). Although percentage of occurrence indicates how common an item is in the diet, relative percentage of occurrence provides a better indication of the relative frequency with which each item is consumed because it accounts for more than one of a given item being found in a scat (Ackerman *et al*. 1984). Percent volume of remains of each food item in scats was estimated visually to the nearest 5% (McDonald and Fuller 2005). I also reported estimated biomass in the diet attributed to each food item to obtain an estimate of the relative importance of a given prey category. Biomass may be more meaningful than relative percentage of occurrence when prey size varies (Floyd *et al*. 1978; Steenhof 1983). For example, 1 ground squirrel weighing 325 g clearly contributes more calories to a badger diet than a sagebrush vole (*Lemmiscus curtatus*) weighing 30 g. I estimated biomass by multiplying the relative frequency of a prey item by mean prey mass (Steenhof 1983; Poole and Graf 1996). Percent biomass resulted from dividing the product by the total biomass of all food items. In the case of Richardson's ground squirrels, mean prey mass was based on weights taken from specimens in the field at time of collection of scats (G. Proulx, unpublished data, 2008–2010). Average weights of other prey were obtained from Borror and White (1970), Banfield (1974), Burt and Grossenheider (1976), and Sibley (2003). As the presence of badger hairs in scats was infrequent and represented relatively low volumes, it was considered to be an artefact of individual grooming (Hoodicoff 2003; Duquette 2008) and was not considered in the calculation of ingested biomass. A biomass of 2,000 g (corresponding to 6 ground squirrels, i.e., 2–3 times more than what a badger may eat in 1 day; Proulx and MacKenzie 2012c) was assigned to carrion which was rare in the study areas. I considered that the average weight of deer and cattle in the calculation of ingested biomass would not be representative of the real world. For example, only 1 scat had cattle hairs and it was found by the carcass of a cow that was nearly intact when the scat was collected.

Differences between seasonal diets were tested with Fisher's exact test and chi-square tests on the occurrences (Reynolds and Aebischer 1981; Proulx *et al*. 1987). An analysis of variance followed by the Tukey test was used to compare volumes of Richardson's ground squirrel remnants among seasons and years (Zar 1999).

RESULTS

Abundance of Richardson's ground squirrel burrow entrances per habitat type

Between 158 and 288 Richardson's ground squirrel burrow entrances were recorded in each habitat type (Table 1). There was a significant difference between observed and expected frequencies of Richardson's ground squirrel burrow entrances per habitat type (Goodness-of-fit test, $\chi^2 \geq 50.2$, $df = 2–3$, $p < 0.001$). Richardson's ground squirrel burrow entrances were always significantly less frequent than expected in annual crops (G-test, $G \geq 4.7$, $df = 1$, $p < 0.05$), but significantly ($p < 0.03$) more frequent in grasslands, pastures and buckbrush areas (Table 1).

Badger hunting grounds

Badger hunting grounds were located in habitats with significantly more ground squirrel burrow entrances (Table 1). In the habitats of the radio-tagged badgers, the mean densities of burrow entrances/ha of Richardson's ground squirrel and American badger were significantly greater (t-tests, $t \geq 3.1$, $df = 1$, $p < 0.05$) in hunting grounds than in control areas (Table 2). In the habitats of the untagged female, the mean densities of burrow entrances/ha of Richardson's ground squirrel and American badger were markedly greater in hunting grounds than in control plots (Table 2), but the differences were not statistically significant ($t \geq 1.9$, $df = 1$, $p > 0.05$).

Relationships between densities of burrow entrances of badgers and Richardson's ground squirrels

There was a significant linear relationship between the densities of burrow entrances/ha of the radio-tagged female badger ($r = 0.977$, $p < 0.0005$; statistical power: 1; $Y = -1.82 + 0.09X$; $r^2 = 0.94$), the radio-tagged male badger ($r = 0.651$, $p < 0.05$; statistical power: 0.73; $Y = -2.63 + 0.08X$; $r^2 = 0.42$), and the untagged female badger ($r = 0.970$, $p < 0.005$; statistical power: 1; $Y = -4.87 + 0.23X$; $r^2 = 0.95$) and the density of Richardson's ground squirrel burrow entrances/ha (Figure 2).

Badger scat analyses

Richardson's ground squirrel remains were the dominant food items in percentage of occurrence, volume, and biomass during all seasons and years except in August–November 2008 (Tables 3 and

Table 1. Distribution of Richardson's ground squirrel *(Urocitellus richardsonii)* burrow entrances and American badger (*Taxidea taxus*) hunting grounds across habitat types, southwestern Saskatchewan, Canada, 2008–2010.

Habitat type	*Length – m (%)*	*Number of Richardson's ground squirrel burrow holes (%)*	*Density of ground squirrel burrow entrances/100 m*	*Distribution of hunting grounds*
		Radio-tagged adult female American badger		
Wheat	5,035 (84.6)	101 (63.9)	2.0	0
Grass	547 (9.2)	32 (20.2)*	5.9	4§
Buckbrush	370 (6.2)	25 (15.8)*	6.8	0
Total	*5,952 (100)*	*158 (100)*	*2.7*	*4*
		Radio-tagged adult male American badger		
Wheat	2,096 (43.9)	25 (15.3)*	1.2	0
Pasture	1,922 (40.3)	114 (69.9)*	5.9	4
Meadow	206 (4.3)	4 (2.5)	1.9	0
Seeded grassland	549 (11.5)	20 (12.3)	0.4	0
Total	*4,773 (100)*	*163 (100)*	*3.4*	*4*
		Untagged adult female American badger		
Fallow	768 (11.9)	65 (22.6)*	8.5	2
Alfalfa	360 (5.6)	38 (13.2)*	10.6	1
Wheat	2,128 (32.9)	50 (17.4)	2.4	0
Pasture	3,216 (49.7)	135 (46.9)	0.4	0
Total	*6,472 (100)*	*288 (100)*	*4.5*	*3*

*Significant ($p < 0.05$) difference between observed and expected frequencies.
§3 hunting grounds in grass, and 1 overlapping grass and wheat.

Table 2. Mean densities of burrow entrances/ha of Richardson's ground squirrel and American badger in hunting grounds and control plots, southwestern Saskatchewan, Canada, 2008–2010.

Individual badger	**Mean density of burrow entrances/ha (standard deviation)**					
	Hunting grounds			**Control plots**		
	n	**Richardson's ground squirrel**	**American badger**	***n***	**Richardson's ground squirrel**	**American badger**
Radio-tagged female	4	1,307.7 (608.4)	105.0 (68)	6	229.4 (156.3)	21.8 (12.6)
Radio-tagged male	4	824.3 (211.6)	76.2 (47.1)	8	158.4 (81.3)	4.0 (4.6)
Untagged female	3	161.2 (110.0)	35.0 (20.6)	5	39.4 (16.8)	2.0 (3.6)

4). The frequencies of the ground squirrel remains in scats collected in April–July 2008, 2009 and 2010 were similar (Fisher's exact test, $p > 0.05$) but they were all greater than in August–November 2008. Mean volumes of Richardson's ground squirrel remnants in scats differed significantly among seasons and years (Anova, $F_{3,70} = 6.1$, $p < 0.05$). Mean percent volumes were similar ($p > 0.05$) in April–July 2008, 2009, and 2010. However, the mean volume of Richardson's ground squirrel remains in August–November 2008 scats was significantly lower (Turkey test, $q \geq 4.4$, $p < 0.05$) than those of April–July 2008 and 2010. The mean percent volume of ground squirrel

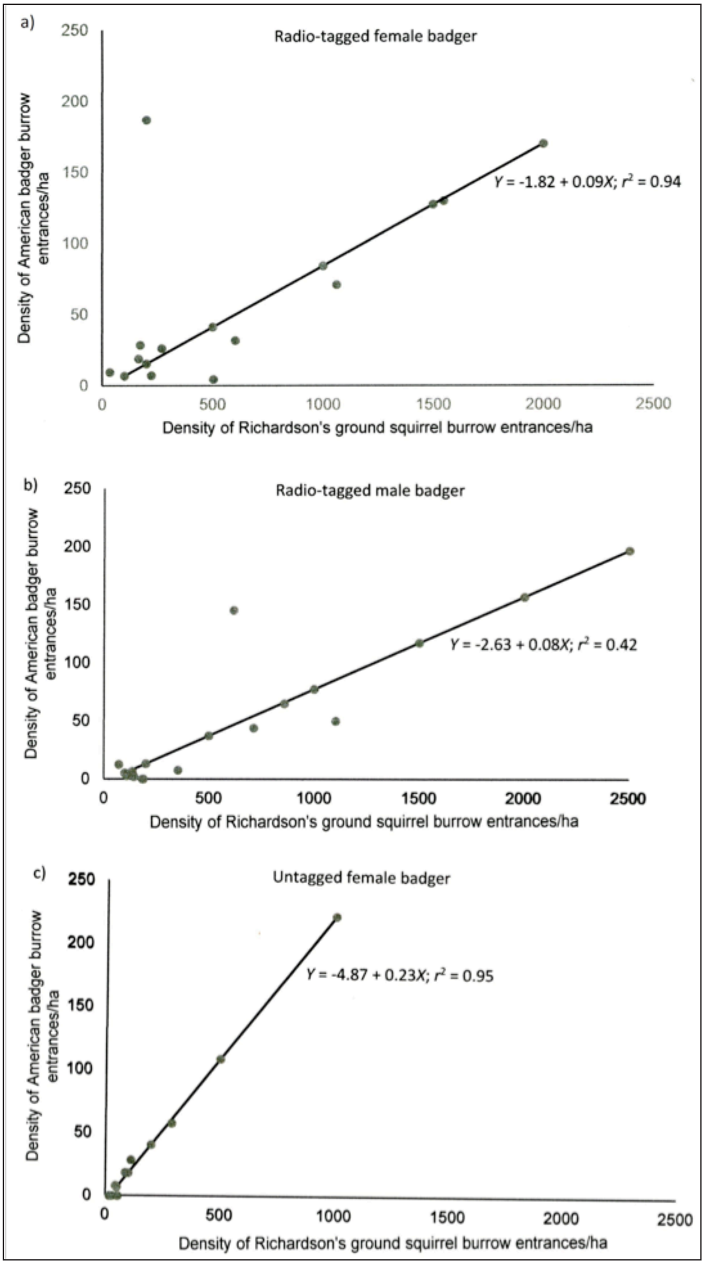

Figure 2. Relationship between the densities of burrow entrances/ha of American badgers (*Taxidea taxus*) and Richardson's ground squirrels (*Urocitellus richardsonii*), southwestern Saskatchewan, Canada, 2008–2010.

Table 3. Frequencies, volumes and biomass of food items by season and year in American badger scats, southwestern Saskatchewan, Canada, 2008 (PO: percentage of occurrence; RPO; relative percentage of occurrence; SD: Standard deviation; PV: percent volume).

Food item		2008							
		April–July (n = 20 scats)				August–November (n = 21 scats)			
		PO (n)	RPO (n)	Mean PV (SD)	Biomass* in g (%)	PO (n)	RPO (n)	Mean PV (SD)	Biomass* in g (%)
Mammals									
Richardson's ground squirrel	*Urocitellus richardsonii*	85 (17)	81 (17)	85 (36.6)	5,525 (93.3)	33.3 (7)	19.4 (7)	29.5 (45.9)	2,275 (51.7)
Deer mouse	*Peromyscus maniculatus*					4.8 (1)	2.8 (1)	4.7 (21.4)	25 (0.6)
Western harvest mouse	*Peithrodontomys megalotis*					4.8 (1)	2.8 (1)	3.8 (17.5)	13 (0.3)
Sagebrush vole	*Lemmiscus curtatus*					9.5 (2)	5.6 (2)	2.9 (11)	60 (1.4)
White-tailed deer	*Odocoileus virginianus*					4.8 (1)	2.8 (1)	4.8 (21.8)	2,000 (45.4)
American badger ¥	*Taxidea taxus*	10 (2)		1.1 (45)		23.8 (5)		7 (22.1)	
Birds									
Galliformes (partridge)		5 (1)	4.8 (1)	5 (22.4)	390 (6.6)				
Athropods									
Coleoptera (beetles)						9.5 (2)	5.6 (2)	4.8 (21.4)	2 (0.05)
Caelifera (grasshoppers)						42.9 (9)	25 (9)	37.4 (45.5)	18 (0.4)
Field cricket	*Gryllus* spp.	5 (1)	4.8 (1)	4 (17.9)	2 (< 0.1)	9.5 (2)	5.6 (2)	3.9 (17.4)	4 (0.09)
Plants									
Grass/grain		5 (1)	4.8 (1)	4 (19.9)	2 (< 0.1)	19.1 (4)	11.1 (4)	1 (2.6)	8 (0.2)
Others									
Unknown		5 (1)		0.5 (–)		9.5 (2)	5.6 (2)	0.3 (1.1)	
Total			**100 (21)**	**100**	**5,919 (100)**		**36**	**100**	**4,405 (100)**

* Beetle: 1 g; Deer mouse: 25 g; Field cricket: 2 g; Grass/grain: 2 g; Grasshopper: 2 g; Galliformes: 390 g; Richardson's ground squirrel: 325 g; Sagebrush vole: 30 g; Snowshoe hare: 1,400 g; White-tailed deer: 2,000 g; Western harvest mouse: 13 g (Borror and White 1970; Burt and Grossenheider 1976; Sibley 2003; G. Proulx, unpublished data for Richardson's ground squirrel).

¥Not considered in biomass calculations.

Table 4. Frequencies, volumes and biomass of food items by season and year in American badger scats, southwestern Saskatchewan, Canada, 2008 (PO: percentage of occurrence; RPO; relative percentage of occurrence; SD: Standard deviation; PV: percent volume).

Food item		2009 April–July ($n = 9$ scats)				2010 August–November ($n = 24$ scats)			
		PO (*n*)	RPO (*n*)	Mean PV (SD)	Biomass* in g (%)	PO (*n*)	RPO (*n*)	Mean PV (SD)	Biomass* in g (%)
Mammals									
Richardson's ground squirrel	*Urocitellus richardsonii*	7.8 (7)	70 (7)	67.7 (44)	2,275 (96.8)	70.8 (17)	63 (17)	69.8 (45.9)	5,525 (56.4)
Deer mouse	*Peromyscus maniculatus*	33.3 (3)	30 (3)	29.4 (48.4)	75 (3.2)	8.3 (2)	7.4 (2)	6.7 (23.3)	50 (0.5)
Western harvest mouse	*Reithrodontomys megalotis*					12.5 (3)	11.1 (3)	12.5 (33.8)	39 (0.4)
Snowshow hare	*Lepus americanus*					4.2 (1)	3.7 (1)	4.2 (20.4)	1,400 (14.3)
Cattle	*Bos taurus*					4.2 (1)	3.7 (1)	4.2 (20.4)	2,000 (20.4)
American badger ¥	*Taxidea taxus*	22.2 (2)	20 (2)	2.8 (8.3)					
Birds									
Galliformes (partridge)						8.3 (2)	7.4 (2)	2.5 (9)	780 (8)
Athropods									
Coleoptera (beetles)						4.2 (1)	3.7 (1)	0.3 (1.2)	1 (0.01)
Total			**12**	**100**	**2,350 (100)**		**27**	**100**	**9,795 (100)**

*Beetle: 1 g; Deer mouse: 25 g; Field cricket: 2 g; Grass/grain: 2 g; Grasshopper: 2 g; Galliformes: 390 g; Richardson's ground squirrel: 325 g; Sagebrush vole: 30 g; Snowshoe hare: 1,400 g; Cattle carrion: 2,000 g; Western harvest mouse: 13 g (Borror and White 1970; Burt and Grossenheider 1976; Sibley 2003; G. Proulx, unpublished data for Richardson's ground squirrel).

¥Not considered in biomass calculations.

remains in April–July 2009 was greater than that of August–November 2008, but the difference was not statistically different ($q = 3.1, p > 0.05$). In late summer and fall 2008, there was a marked increase in small mammal prey and in insects, which coincided with the hibernation of ground squirrels. However, from a biomass point of view, Richardson's ground squirrel remains were still the most important in the diet of American badgers. During all years, Richardson's ground squirrel remnants had the highest biomass percentages in the diet of badgers (Tables 3 and 4).

DISCUSSION

H_1

It is unlikely that American badgers use habitats at random. At landscape level, their hunting grounds were found in fields with the highest densities of Richardson's ground squirrel burrow entrances. Thus, H_1, that the distribution of badger hunting grounds would be related to that of Richardson's ground squirrels across habitats, was supported. This suggests that American badgers associate with larger concentrations of Richardson's ground squirrel burrow entrances to maximize their foraging activities. This is in agreement with Johnson *et al*. (1977) and Yensen *et al*. (1992) who also found a significant, positive correlation between transect counts of badger burrows and Townsend's ground squirrel (*Urocitellus townsendii*) holes.

American badgers also chose sites where ground squirrels were likely more accessible. For example, while the observed frequencies of Richardson's ground squirrel burrow entrances in grass and buckbrush were not significantly different from each other, the radio-tagged adult female established its hunting grounds exclusively in grass patches. Digging out Richardson's ground squirrels in buckbrush is difficult due to dense stems and root systems. The female badger used buckbrush to escape danger (G. Proulx, unpublished data), but she did not hunt ground squirrels in these grounds.

This study showed that the American badgers' hunting activities focused on areas with the densest densities of Richardson's ground squirrel burrow entrances. This is similar to Sargeant and Warner (1972) who noticed that a female badger was more active in areas with the densest populations of the fossorial Plains pocket gopher (*Geomys bursarius*). In this study, badgers returned regularly to the same hunting grounds, thus suggesting a cognitive knowledge of their grounds (Powell 2004) and the location of higher density of prey. American badgers are known to reuse the same areas for denning and prey on animals that occupy their dens (Hetlet 1968). Knopf and Balph (1969) described selective hunting by badgers on Uinta ground squirrels (*Urocitellus armatus*) within a specific area over a 30-day period. American badgers are effective predators of Richardson's ground squirrels, particularly in spring and early summer when juvenile ground squirrels are born, and in fall when they are hibernating (Michener 2004). However, our observations of the radio-tagged male and the untagged female hunting activities, and scat analyses, confirmed that badgers also prey on juvenile and adult ground squirrels in summer.

The strong linear relationship ($r^2 \geq 0.94$) observed between the density of burrow entrances of adult female American badgers and Richardson's ground squirrels may be due to the fact that female badgers are more sedentary than males (Sargeant and Warner 1972; Lindzey 1978; Lampe and Sovada 1981), and better select their hunting ground sites to secure a more accessible and stable supply of prey (Goodrich and Buskirk 1998). In the case of the adult male, however, the relationship between burrow entrances of badgers and ground squirrels was weaker ($r^2 = 0.42$), but similar to that determined by Eldridge (2004; $r^2 = 0.41$), and greater than that determined by Yensen *et al*. (1992; $r^2 = 0.26$), for badger populations. This suggests that factors other than the density of Richardson's ground squirrel burrow entrances may also impact on the abundance and distribution of the adult male burrow entrances. The boundaries of most of the adult male's hunting grounds were near a meadow that the animal used for travel and escape. It is possible that the adult male compromised hunting success for security, and included in its hunting grounds areas that were less populated in ground squirrels. Male American badgers have home ranges that are larger than those of females and they move greater straight-line distances than females (Lindzey 2003); thus, they may not be as selective as females when establishing their hunting grounds. Finally, Richardson's ground squirrel population densities are known to vary considerably within and between agricultural regions (Proulx *et al*. 2012), thus resulting in a variable relationship between mean densities of burrow entrances/ha of ground squirrels and badgers. Although the overall experimental design that I used was adequate to test the correlation between the distribution of badgers and ground squirrels, my conclusion is based on 3 individual badgers only. I therefore recommend that investigations on badger and Richardson's ground squirrel relations be conducted in the future.

H_2

Data relative to the frequency and volume of food remains in badger scats showed that Richardson's ground squirrels are the main food item in the diet of badgers in spring and summer, and when ground squirrels enter in hibernation. In fall, both frequency and volume dropped in importance. However, biomass data suggest that, in the fall, badgers still focus their hunting activities on ground squirrels, even when they are in hibernation and more difficult to access because they are isolated in a hibernaculum disconnected from the main burrow system (Michener 2012). This partly supports H_2 that Richardson's ground squirrels would be a relatively more important prey of badgers, independently of the ground squirrels' activity cycle and environmental conditions. It is well known that badgers will dig out sleeping and hibernating ground squirrels (Michener 2004). Also, Proulx and MacKenzie (2012a) described unique hunting movements by badgers that were searching and digging out hibernating ground squirrels. The scat sample size in 2009 was too small to draw solid conclusions. In 2010, however, a larger sample of scats showed that, with heavy rains and a decrease in abundance of ground squirrels across landscapes (Proulx 2012), American badgers fed on a greater diversity of mammals. In fact, from a diversity point of view, the April–July 2010 and the August–November 2008 diets were similar. Since mice and voles are abundant in agricultural fields (Duquette 2008; Witmer and Proulx 2010), particularly when green vegetation is abundant (e.g., MacCracken *et al*. 1985; Klatt and Getz 1987), American badgers likely change their foraging effort to compensate for a decrease in Richardson's ground squirrel availability by consuming a range of secondary foods opportunistically. Similarly, in Scotland, Kruuk and Parish (1981) found that, although European badgers (*Meles meles*) feed mainly on earthworms (*Lumbricus terrestris*), they changed their foraging effort to compensate for fluctuations in earthworm availability, opportunistically taking other prey. In spite of their low abundance, ground squirrels represented the greatest biomass of prey remains in August–November 2008 and summer 2010. In southwestern Saskatchewan, during 3 years with different environmental conditions, the food habits of the badgers consisted mainly of Richardson's ground squirrels but were supplemented by an array of small rodents, birds and arthropods. This finding is in agreement with Rosenweig's (1966) statement that there is a clear trend for larger predators to seek larger prey. Badgers who are seeking food in preparation of long cold winter days have more to gain in searching and killing hibernating ground squirrels than feeding on fast-moving small mammals. The occurrence of cattle and white-tailed deer (*Odocoileus virginianus*) provides evidence of scavenging by badgers, as previously reported by Sovada *et al*. (1999). However, even in August–November when carrion would be an important source of proteins for badgers, it did not appear to be a frequent food item.

MANAGEMENT IMPLICATIONS

Conserving American badgers requires a better understanding of their relationship with their prey. Many farmers believe that these mustelids hunt at random and invariably dig large holes across grasslands and annual crops. As a result, badgers are often shot or purposely killed on roads (Messick and Hornocker 1981; G. Proulx, unpublished data). In southwestern Saskatchewan, massive poisoning campaigns with strychnine- and anticoagulant-treated baits were conducted across private land during 2000–2010 (Proulx 2011). This resulted in the secondary poisoning of predators. Proulx and MacKenzie (2012d) found that the density of American badgers/km of road crossing grasslands and crops was significantly lower in landscapes with high poisoning (89.7% of the area) than in landscapes with low poisoning (19.6% of the area).

This study showed that American badgers focus their predation, and therefore their digging activities, in sites with a greater abundance of Richardson's ground squirrel's burrow entrances. Also, badgers feed mainly on Richardson's ground squirrels in spring and summer, and still dig them out in fall when they are hibernating. American badgers definitely contribute to a reduction of ground squirrel numbers. Campaigns to control ground squirrels with non-selective methods endanger the persistence of American badger populations. The subspecies *T. t. taxus* is now listed as a "Species of Special Concern" (COSEWIC 2013). Instead of killing American badgers, farmers should implement an Integrated Pest Management program (e.g., Proulx 2014) to keep Richardson's ground squirrel populations at acceptable density levels and maintain American badger populations across landscapes.

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