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Abstract: While investigating the American badger (*Taxidea taxus*) in eastern Colorado's wheatlands, we studied 3 badgers which were affected by a 2.1 km^2 man-made fire and compared them to 2 adjacent badgers unaffected by the fire. All badgers were equipped with radio-telemetry collars and generally located day and night for approximately 1 month pre-fire and 3 weeks post-fire. Three point triangulation locations were converted into a global information system database. Adaptive kernel analyses compared pre- and post-fire horizontal: home ranges (i.e. 95% utilization areas, UAs), core activity areas (50% UAs), movements, den and habitat use patterns. Mean ($\bar{\mathbf{x}}$) locations pre-fire (43.7) and post-fire (32.0) provided home ranges for affected badgers that averaged 8.3 km^2 and 9.2 km^2, respectively. While 2 badgers maintained one core area which was outside the burn, the third used 2 core activity areas, one remained the same after the fire and second changed. Diurnal to nocturnal movements (measured in 24 hrs cycles) were pre-fire $\bar{\mathbf{x}}$ = 1.2 km and post-fire $\bar{\mathbf{x}}$ = 1.3 km. Den use remained approximately 5, but some locations changed after the fire. Mean home ranges included 74% winter wheat or wheat stubble. Habitat use for all 5 badgers averaged: 81.4% wheat, 8% riparian, 7.2% sagebrush, and 3.4% burned. Unaffected badgers averaged 7.7 km^2 home ranges, 1 core area, 1.0 km diurnal-nocturnal movements, 4 dens, and 93% wheat crops and 7% riparian habitats. After the fire burned 10% of badger 4's home range, 1 of 3 core areas, and 3 of 5 dens, it moved > 3km northwest into another tributary and established 1 new den. However, it frequently revisited the northern portion of its home range and associated core area. After approximately1 month, it consolidated this UA into a new core area 1.7 km northwest and maintained 1 of 3 pre-fire core areas. The fire consumed 6% of Badger 2 home range, and post-fire it moved into the unoccupied southern portion of badger 4's pre-fire home range. It also moved slowly west into sagebrush probably in partial response to the tilling of approximately 1/3 of its home range which was completed on April 16. Only 1.0% of Badger 1's home range and its core area were not affected by the fire. However, it slowly moved its home range southeast approximately 1.0 km into the unoccupied area assumed to have been the home range of an un-collared badger found dead in early April. Its core area moved approximately 0.5 km southwest. In summary the movement ecology of affected badgers illustrated three themes: (1) home ranges and core areas moved initially away from the fire, (2) then adjustments were made by each badger in response to other badgers, the burned area, and habitat requirements, and (3) finally a new equilibrium of home ranges was established among these badgers post fire including the use of the burned areas after a few weeks.

Key words: badger, fire, movements, radio-telemetry, *Taxidea taxus*, utilization areas, wheat

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INTRODUCTION

Very little data has been published about the movement ecology of the North America badger (*Taxidea taxus*), a fossorial member of the weasel family. This medium sized carnivore is stocky and shaggy in appearance, and its activities are mainly nocturnal. Its head is shaped as a stout cone that facilitates digging (Long and Killingley 1983). It has an extensive history in the prairie grasslands associated with their prey species (Messick 1987). Although badgers primarily consume prairie dogs (*Cynomys* spp.) (Clark 1977), they are also opportunistic predators that eat deer mice (*Peromyscus maniculatus*), ground squirrels (*Spermophilus* spp.), pocket gophers (*Thomomys* spp. and *Geomys* spp.), and voles (*Microtus* spp.) (Fagerstone and Ramey 1995).

Because they are primarily nocturnal, badger studies have been greatly facilitated by the use of radio–telemetry. One such study was done by Sargeant and Warner (1964), and it described the extensive movements of a single badger. Later, Lindzey (1971) studied 7 badgers in pre-dominantly non-crop sagebrush in Utah and Idaho. More recent studies have viewed their population trends in relation to other prairie pothole carnivores (Greenwood and Sovada 1998) or studied their risk to dieldrin at the Rocky Mountain Arsenal National Wildlife Refuge in Colorado (Henriques 1997, Hoff 1998). One conclusion from these and other studies is that little is known about the badgers of the Great Plains especially in agriculture areas.

Badgers are considered occasional pests in North American agricultural habitats (Minta and Marsh 1988). Their interactions with humans, occur because their fossorial niche creates mounds from either digging deep burrows for dens or seeking rodent prey (Lindzey 1971, 1982). These activities sometimes have been hazardous to livestock that step into them and may fracture a leg (Burt and Grossenheider 1964, Long and Killingley 1983); therefore, such activities can damage rangeland pastures (USDA 1990). Badgers may also negatively impact farm equipment and water systems (Minta and Marsh 1988), because they may cause an increased need for maintenance. These sporadic negative interactions with humans make the badger economically a minor vertebrate pest to agricultural interests, but they may cause serious losses to individual farmers or ranchers (Minta and Marsh 1988).

Even though badgers in agricultural habitats have not been the focus of North American research, in Europe the Eurasian badger (*Meles meles*) has been involved in many studies in cultivated landscapes, particularly control measures (Kowalczyk et al. 2003, Fischer 2003, Rosalino and Santos-Reis 2004). For example, badger damage to field crops such as maize (*Zea mais*) has been studied in southwestern England with crop depredations decreasing after using an electric fence for exclusion purposes (Poole et al. 2002). In contrast, Eurasian badger removal in agricultural areas have had mixed results as a control measure. Initially, their spatial organization was severely perturbed during the first year; however, re-colonization occurred rapidly mainly by females thereafter (Tuyttens et al. 2000). In China, the constant harvest of the hog badger (*Arctonyx collaris*) has decreased their numbers to very low levels (Wang 1999) which are maintained year after year.

Natural fires from summer lightening storms on the Great Plains have long posed a danger to prairie residents both human and animal. More recently, man-made fires set for weed control have become a part of the prairie environment. Some rangeland fire investigators in the central Great Plains have shown fire suppression whether natural or man-made resulted in increased growth of herbaceous plants and woody vegetation. (Kaufman and Fleharty 1974, Kaufman et al. 1988) Some investigators have speculated

that as a result of fire there may have been increased habitat for badger prey and/or possible their transitory movements. In summary, the effect of fire whether natural or man-made on badger movement ecology has not been previously studied in agricultural habitats of the North American Great Plains.

The Wildlife Services (WS) program of the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) has identified the badger as one of 17 species that it needs to control in certain instances as an agricultural pest (USDA 1990). A two-ingredient gas cartridge (sodium nitrate and charcoal) producing high concentrations of carbon monoxide gas when burned has been suggested by Savarie et al. (1980) to be an effective pyrotechnic fumigant for vertebrate pests that live in burrows or dens. This predacide while undergoing re-registration with the EPA, was shown to be an ineffective tool to control problem badgers (Ramey 1995). Shooting and translocation has been used by farmers and ranchers with some success as reported to WS personnel. As a means of relocating some problem badgers, fire has been suggested. During our previous investigation (Ramey 1995), an accidental man-made fire in an agricultural area of the central Great Plains of Colorado used for livestock and wheat production was concurrently studied and is reported here.

STUDY AREAS

Field investigations were conducted approximately 30 km (19 mi) east of Byers in Arapahoe County, Colorado. Early settlers named the area Badger Creek, after the abundance of badgers found in the vicinity of Little Cheyenne Peak with a substantial prairie dog population. This area was selected for the first study of badgers in agricultural areas because of documented damage to livestock and wheat crops reported to Wildlife Services. (T. Thompson II, personal communication) Livestock losses had occurred and were due to leg fractures caused by stepping in badger's holes in pastures. In addition, a recent development at the study site had been the conversion of some of the prairies from livestock grazing to dry-land farming particularly for alfalfa or winter wheat. During harvest, the machinery is in need of frequent repair because they hit many earthen mounds and burrows that they strike that result from badger activities such as den excavation and foraging. For over 50 years private trappers and more recently WS personnel have intermittently controlled badgers in this area, but they remained a problem.

The study site was along both sides of Badger Creek (T 4 S, R 58 W, Sec. 1, 2) which flows from south to north at approximately 1,600 m above sea level. The area was comprised mainly of gentle hills and with some shallow canyons, sandy loam soil (Nunn Association), and semi-arid conditions. These features make some of the flatter terrain suitable for dry-land farming for winter wheat production with the more rugged areas left as rangeland for livestock production.

MATERIALS AMD METHODS

This study was a portion of a larger badger movement ecology investigation initiated in February, 1992 that was conducted in agricultural areas of Texas and Colorado. All badgers were captured using Woodstream Corp. Softcatch (padded) No. 3 Traps, (69 N. Locust St., Lititz, PA 17543). Traps were checked each morning and closed during daylight hours. They were reset during the during the day's second crepuscular period. Captured badgers were approached slowly and carefully so as to minimize additional stress before being anesthetized with a mixture of ketamine (15 mg/kg) and acepromazine (2 mg/kg) using a jab pole. Demographic data were obtained for each badger prior to instrumentation with a mortality-indicating radio transmitter built by

Advanced Telemetry Systems (ATS) (470 First Ave., Isanti, MN 55040). Each transmitter operated on one of 12 assigned channels (164 MHz band). Pulse-interval timers (AVM Instrument Co., 1213 South Auburn St., Colfax, CA 95713) were used to identify transmitter pulse rates. The radio-transmitter and a battery were attached to a leather collar and waterproofed using a Stycast 1090 case. The radio-tracking collar with transmitter and battery had a mean ($\bar{\mathbf{x}}$) weight of 126g. All badgers selected for study weighed > 5.69 kg; therefore, the collar, radio-transmitter, and battery represented 2% of the smallest badger's weight. The radio-collar equipment did not seem to affect the badger's behavior and all collars remained on their assigned animal through the end of the study (i.e. approximately 6 months). Radio-collared badgers were placed in a burlap sack and were released where they were caught. All final radio-tracking locations were obtained using portable telemetry receivers built by either the AVM Instruments Co. (Model CE-12) or Custom Electronics (2009 Silver Court West, Urbana, IL 61801) with a 3 element yagi antenna.

The broadcast frequency ranged from 164.4375 MHZ to 167.1575 MHZ with a normal operating pulse rate of either 60 or 90 pulses per minute (ppm) with a mortality mode of 150 ppm which was activated after 1 h of inactivity. Vehicles were equipped with dual beam, 3-element yagi antennas, and a peak null box. A Cessna airplane, equipped for radio-tracking was used to locate badgers in deep diurnal burrows especially in steep ravines or for badgers with more extensive movements especially after the fire.

Badgers were monitored generally day and night, except during severe spring weather, for the first 50 days and intermittently thereafter for up to 6 months. Locations were obtained using a fixed-winged airplane, trucks, all terrain vehicles, or on foot. Badger locations were plotted on 1990 aerial photographs recording the habitat and activity. When locating a badger the peak/null box was used. The peak signal was utilized first to locate the general area of the badger and then switched to null for more sensitive bearing data recording. Generally, three point triangulations were used to locate each badger and to minimize error. Location data were documented with the observation number, date, time, and habitat. Nocturnal locations were generally studied also on the next day for signs of the badger's activity including tracks, digging, and mound formation. Nocturnal locations were verified post hoc approximately 40% of the time including infrequent visible observations. These locations were combined with diurnal den locations and all were recorded directly as GIS coordinates. The latter were accomplished as quietly as possible because badgers have demonstrated sensitivity to den entrance disturbance (Minta and Marsh 1988). Final nocturnal GIS locations were often a combination of triangulation data with either an actual badger sighting or other signs of activity. All locations were digitized and transferred to GIS maps of the study area for analysis.

Data analysis was developed in ATLAS GIS and home ranges were calculated and illustrated using the 2 dimensional CALHOME Home Range Program in 1996. These databases were migrated to Environmental Systems Research Institute, Inc. (ESRI's) ArcView in 2001 (380 New York Street, Redlands, CA 92373). Home ranges were obtained using the ArcView's Animal Movement Analysis Program. In 2005, these databases were migrated to ESRI's ArcGIS 9.0. Adaptive kernel methods were used to estimate the 95% utilization distributions which were defined as the badger's home range. Using this estimate for the badger's home range, minimized the effects of outliers because badgers sometimes wander beyond their normal activity areas

especially in spring. The 50% core activity area was defined by Worton (1989) as that portion of each badger's home range that received the most consistent or intense use. Both the home ranges and the 50% core activity areas were analyzed further for badgers affected by the fire using the kernel method. This method was chosen to analyze movement ecology of badgers because it has fewer deficiencies than: (1) the minimum convex polygon method of Mohr (1947) which is substantially influenced by sample size and outliers (Harris et al. 1990), (2) the harmonic mean method (Dixon and Chapman 1980) which is mathematically less robust and sophisticated than the kernel method, or (3) a variety of elliptical methods which are based on unrealistic assumptions about the animal's use of space (Van Winkle 1975, Harris et al. 1990).

RESULTS

Of the 5 adult badgers captured, 4 males and 1 female, their average weight was 7.2 kg, with the nursing adult female the smallest badger weighing 5.7 kg. Only the home ranges of 3 adult males, caught on March 20, 21, and 24 were involved in the path of the fire. These badgers will be discussed first as a group then individually. The accidental man-made prairie fire occurred on April 19, 1993 and burned 2.1 km^2. It traveled 3.1 km mainly south along the riparian areas of Badger Creek with a soil fire barrier produced at crop field edges by disking in advance of the fire. This seemed to work well until the wind shifted and pushed the fire west another 3.4 km along a fence row and wheat stubble field before it could be extinguished by disking, water tankers, and shovels (Figure 1).

Affected badger movements were compared for a total of 45 days, and the 95% and 50% utilization areas (UAs) were calculated and compared pre- and post-fire for each badger. A range of 71-81 locations were obtained from radio-telemetry triangulation data and direct den fixes ($\bar{x}$ = 75.7). They yielded a $\bar{\mathbf{x}}$ = 61.7 different locations with some locations particularly dens used more than once. Pre- and post-fire analyses occurred after a $\bar{\mathbf{x}}$ = 43.7 locations and $\bar{\mathbf{x}}$ = 32.0 locations, respectively. The average pre-fire home range size was 9.0 km^2 and post-fire was 9.2 km^2. Generally, nocturnal movements or nocturnal movements to diurnal den locations averaged 1.0 km pre-fire and 1.3 km post-fire. The habitat for the 2 more severely affected badgers averaged 82% winter wheat or wheat stubble during the entire study with similar habitat use during the pre-fire and post-fire periods and neither core use area was burned. The third badger used only 46% agricultural areas both pre- and post-fire. Its home range and core activity area were on a fence line separating wheat fields from sagebrush. However, during the pre-fire period, some the wheat stubble that was initially part of its home range was disked and turned underground. The disking lasted approximately 3 weeks and was completed on April 16. It involved 35% of its home range but generally the dens or prey areas were not included, because they were more frequently located in riparian areas. The impact of disking was assumed to be the cause for the observed increase in the badger use of sagebrush as well as the effect of the fire. The fire burned through some of dens and riparian areas used by the badgers. The movement ecology of individual badgers follows.

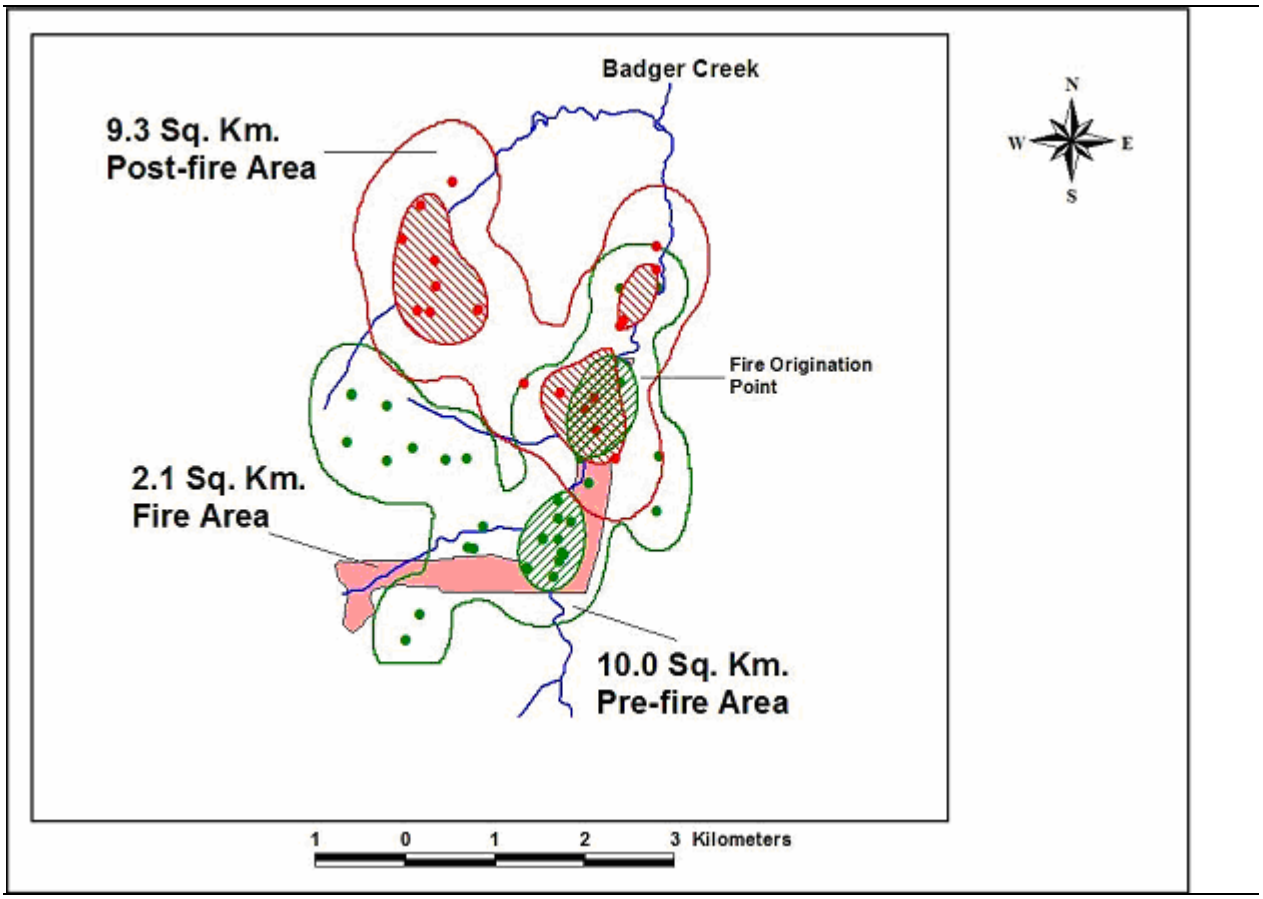

Figure 1. The movement ecology of 3 badgers involved in a prairie fire in wheatlands Byers, Colorado, 1993.

Badger 4 was an adult male weighing 7.8 kg and was captured on March 24. Its pre-fire home range was 10.0 km^2 in size consisting predominately of wheat (88%). Its movement patterns post-fire changed significantly when the fire burned through the eastern and southern boundary of its home range on April 19, including the den it was using at the time of fire (Figure 1). Its total home range (i.e. 95% UA), including pre- and post-fire areas, covered 18.3 km^2. However, its pre-fire home range measured 10.0 km^2. The latter area was divided into 3 major habitat types: (1) wheat and wheat stubble (88%), (2) riparian (9%) – mainly along Badger Creek, its tributaries, and (3) sagebrush (4%). The fire consumed predominately the riparian areas (67%) in its home range and the remainder was wheat stubble. Badger 4 was in a frequently used den when the fire burned over it on April 19. The smoke and heat from the fire did not cause it to move either in advance or during the fire, it chose to remain in this den until dark. Then it moved > 3km northwest into a new portion of the Badger Creek drainage that it previously had not used and dug another den that it used that night. This new area lacked badger sign prior to the fire. Although the fire burned through 3 of 5 dens it had used during the pre-fire phase, it kept revisiting the northern portion of its original home range

including the burned area. The frequency of the re-visitation pattern slowly increased during post-fire studies until it consolidated the northern part of its original home range and with this new area of use. The 95% UA prior to the fire was 10.0 km^2 and post-fire was 9.3 km^2 (Figure 1). It used 3 core areas prior to the fire. The southern most core areas were abandoned during its post-fire movements, but the northern core area although burned (80%) continued to be used and a new core area was established in the new area of use 1.7 km to the northwest. The proportions of the 3 major land use areas remained similar from pre-fire to post-fire excluding the habitats burned (Table 1). A comparison of pre-fire movements ($\bar{x}$ = 1,083m) to post-fire movements ($\bar{x}$ = 994m) were also generally similar. Five dens were used during the pre-fire period and the fire burned through the 3 southern most dens, and these were abandoned post-fire. Post-fire, badger 4 used 3 dens: it continued using 1 pre-fire den, plus the den it was in during the fire, and the new den in the tributary to the northwest. Its home range during the entire study stayed predominately west of Badger Creek with Badger Creek forming its eastern boundary. It also remained west of badger 1 with very little overlap in their home ranges.

Table 1. Badger number (no.) and channel (ch) with: (1) demographic information including age, sex, and weight, (2) movement ecology data including capture date, home range size (95% UA, sq km), number of core areas (50% UA), and total size and number of dens used, (3) the percentage of habitats utilized including agricultural (alfalfa), non-agricultural (sagebrush), riparian, and fire (burned), and (4) number of locations during March, April and May 1993. Comparisons were made to a similar pilot study completed in Pampa, TX in 1992.

Badger No.-Ch.	Age	Sex	Weight	Capture Date	Home Range	Core Areas No.-Size	Dens	Habitat Percentage				Locations Total-Diff.
								Ag	Non-Ag	Rip.	Fire	
Colorado 1993 in predominately wheat (with a prairie fire)												
1-8	Adult	Male	7.4	3/20/93								
1a					8.2	1-1.2	4	76	12	12	0	37-34
1b					9.0	1	4	74	14	11	1	38-22
2-1	Adult	Male	6.5	3/21/93								
2a					8.7	1-.4	5	46	46	8	0	49.38
2b					9.4	1	5	16	41*	7	6	32-28
3-12	Adult	Female	5.7	3/23/93	5.7	2*-.7	5	91	0	9	0	51-30
4-6	Adult	Male	7.8	3/24/93	18.3							
4a					10.0	2-1.2	5	88	4	9	0	45-43
4b					9.3	1-.7	3	88	0	6	10	26-20
5-10	Adult	Male	8.6	4/4/93	9.6	1-.7	5**	94	0	6	6	58-45
Texas 1992 in predominately alfalfa (without prairie fire)												
6-11	Adult	Male	6.4	2/12/92	4.9	3-.7	5	65	24	11	0	51-38
7-5	Adult	Male	7.6	2/13/92	3.8	1-.4	5	78	6	16	0	68.35
8-9	Adult	Female	6.1	2/16/92	3.3	1-.4	6	68	21	12	0	63-30

*** Adult female (no. 3) had a den containing young badgers and spent more time in this one den. It had established this den initially in the center of the 1 core area it was using while raising its young**

**** Some days we could not locate (CNL) the den(s) because they were south in a rugged canyon.**

Badger 2 was captured on March 21 and weighed 6.5 kg. During the pre-fire period it occupied the area south of badger 4 and east and southeast of badger 1. It abandoned the burrow it was captured in and used 3 other dens during the study. The pre-fire home range was 8.7 km^2 and post-fire 9.4 km^2. The fire burned through 6% of its home range predominately on the northeastern edge of its home range. The majority of its locations before and after the fire were west of Badger Creek, with Badger Creek again forming the eastern edge of its home range. The fire burned primarily through wheat stubble and pastures in its home range and did not burn the core riparian area. Therefore, its home range was minimally affected even though the fire burned 6% of its home range. Three land use categories were used during the pre- and post-fire home ranges: wheat and wheat stubble 46%, and 46%, pasture (weeds and sagebrush) 46% and 41%, and riparian 8% and 7%, respectively. A comparison of pre-fire movements ($\bar{x}$ = 1.2 km) to post-fire movements ($\bar{x}$ = 1.5 km) were 25% different (Table 1). Three dens were used during the pre-fire period, and they continued to be utilized after the fire, none were in the burned area.

Badger 1 was a male weighing 7.4 kg and was captured on March 20. The fire seemed to have a possible indirect affect on Badger 1 even though the fire burned only 1% of the western edge of its home range. During the post-fire period, its home range slowly changed, moving southeast approximately 1.0 km into the unoccupied area assumed to be the home range of an un-collared badger that had been found dead on March 25. It had pre- and post-fire home ranges of 6.2 and 9.0 km^2; 1 core activity area; den use of 4; and habitat use of 75% wheat and wheat stubble, 13% sagebrush, and 12% riparian (Table 1).

In summary, the movement pattern changes of these badgers illustrated three themes: (1) core activity movements initially away from the fire, (2) adjustments among the affected badgers and their original home ranges, other badgers, and habitat requirements in relation to the fire, and (3) the establishment of an new equilibrium of home ranges using the part of their original home ranges and burned areas after a few weeks.

Two other badgers studied in the immediate vicinity were compared and contrasted to the fire affected badgers. They were badgers numbers 3 and 5. Badger 3 was a female weighing 5.7 kg and it spent time nursing its young during the early part of the study. It was captured on March 23, 13 km south southeast of the previous mentioned badgers. Badger 5 was an old male (8.6 kg). It was located in the most rugged area of the study area and this area contained the deepest ravines. One of its core areas included an abandoned farm. It was captured on April 4, 1.5 km southeast of Badger 2 and 2.5 km southeast of the fire. These unaffected badgers had home ranges that were 5.7 and 9.6 km^2; used 2 and 1 core activity areas and 5 and 3 dens; and 91% and 94% wheat and wheat stubble, 0 % sagebrush, and 9% and 6% riparian areas, respectively (Table 1).

DISCUSSION

Radio-telemetry was a powerful technique for investigating this fossorial species and greatly assisted in determining their wide-ranging nocturnal movements and diurnal subterranean dens (Ramey 1995). Some similar benefits were observed by Sargeant and Warner (1972) in determining one badger's movements and den use. Radio-telemetry has also been shown to be helpful for the efficacy testing of predacides (Dodge 1967, Ramey 1995). However, a variety of differences occurred in this study that are not in the literature about the movement ecology of badgers of the Great Plains. First, some badgers stayed in the same dens over several days and if not for the use of mortality indicating transmitters, the badgers may have

been recorded as dead or shucking their radio-collars. Upon closer examination over several hours/days while the normal transmitter mode continued indicating some movement, they were obviously moving inside the den or that the mortality indicator would have been activated. Second, these badgers were studied in predominately agricultural habitats (i.e., home ranges included 78.8% wheat) and not predominately prairies or pastures. Third, besides employing 3 point triangulation polygons to decrease the size of the location errors, we verified approximately 40% of the locations the next day by observing either tracks, foraging activities, or den locations, then recording the exact GPS location. Fourth, we used the adaptive kernel methodology that provided useful home ranges and core activity areas for further analysis. The use of 50% core activity areas provided qualitative data that indicated strong badger preferences for riparian areas for den locations (55%) and associated movements (83%) than its availability (10.2%). Further research is required for other preferences, but badgers seemed to prefer field edges.

Our study may have also demonstrated the effects of den entrance disturbance as discussed by Minta and Marsh (1988), because Badger 1 was the only badgers not to reuse a den (i.e., capture site) during the entire study. After capturing this badger and noticing its level of agitation, more precautions were employed to calm down captured badgers. We limited human contact to the trapper and investigator. We moved slowly and deliberately, keeping instrumentation time to a minimum, and checking traps at daybreak. During the kernel analysis this location was included in its home range by the analysis software even though it appeared as a utilization island and probably should have been dropped. All other capture dens were burrow sites that were reused during the course of the study.

Our movement ecology study involved badgers from agricultural areas of the Great Plains, 5 from Colorado that were discussed above and 3 previously unpublished badgers from the Pampas, Texas (Table 1). The latter were part of a pilot study to test materials and methods and train study personnel in the spring of 1992. Therefore, similar materials and methods were employed. After summarizing the data from Texas, several discussion points appeared. First, although agricultural habitat differences were obvious with Colorado being primarily winter wheat and Texas alfalfa, the size of the core areas (1.4 km^2 vs. 1.7 km^2) and the percentages of habitat use were similar before the fire: agricultural (76.6 vs. 70.3), sagebrush (12.4 vs. 17), and riparian (8.8 vs. 13). However, home range size (8.0 km^2 vs. 4.7 km^2) and associated day-night movements (1.0 km vs. 0.4 km) were different. Texas home ranges were smaller averaging 5.2 km^2 for the adult males and 3.7 for the adult female. Home ranges reported in the literature from Utah and Idaho for adult males of 6.5 km^2 and about one half of that for adult females (Lindzey 1994) were similar. We estimated badger densities to be 1/6.1 km^2 for adult males and 1/4.0 km^2 for the nursing adult female in Colorado and 1/3.7 km^2 for adult males and 1/2.6 for the nursing adult female in the Texas panhandle. American badger densities have been reported to be as high as 1 per 0.4/km^2 and to a low of 5.8/km^2 (Lindzey 1994). Eurasian badger densities have been reported to vary from 1 per 8.4 km^2 to 25.5 km^2 with their distribution and densities influenced by the biomass of earthworms (*Lumbricus* spp.) and the mean annual temperature (Kowalczyk 2003). The agricultural practices and badger control activities at our study site may both have had an effect on our badgers' densities and home range size, but certainly they did not fit classification of "endangered" as in British Columbia due to mounting pressures from agricultural encroachment on their grassland habitat (Hoodicoff 2001).

MANAGEMENT IMPLICATIONS

Some farmers and ranchers have suggested that fire may be an effective method to control badgers by either eliminating or moving the pest badgers to other areas or more probably reducing their prey base for some transient period of time. Our results indicated fire is an ineffective management tool. Even though fire burned over one badger's core activity area, the den it was using, and habitat that supported a substantial portion of its prey base, the badger was using it again within days. In comparison, the practice of turning the wheat stubble underground seemed to have a similar effect as fire but may have been longer lasting. Other management strategies like habitat modification to reduce the badger's prey base may be useful in large scale population control; however, this approach is generally considered too slow and too expensive to resolve immediate or smaller scale conflicts. Thus, trapping and shooting (Minta and Marsh 1988) will probably continue to be the most effective management methods available for individual pest badger control.

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LITERATURE CITED

BURT, W.H., AND R.P. GROSSENHEIDER. 1964. A field guide to the mammals. Second edition, The Riverside Press, Cambridge, MA. USA.

CLARK, T.W. 1977. Ecology and ethology of the white-tailed prairie dog, (*Cynomys leucurus*). Milwaukee Public Museum, Published in Biology and Geology. No. 3.

DIXON, K.R., AND J.A. CHAPMAN. 1980. Harmonic mean measure of animal activity areas. Ecology 61:1040-1044.

DODGE, W.E. 1967. Bio-telemetry -- its use in vertebrate control studies. Proceedings of the Vertebrate Pest Conference 3:126-127.

FAGERSTONE, K.A., AND C.A. RAMEY. 1995. Rodents and lagomorphs in rangeland wildlife. Pages 83-132 *in* Paul R. Krausman, editor. The Society for Range Management. Denver, CO, USA.

FISHER, C., AND J. MARC. 2003. Distribution of badger setts and latrines in intensively cultivated landscape. Revue Suisse de Zoologie 110(3):661-668.

GREENWOOD, R.J., AND M.A. SOVADA. 1998. Highlight box: Populatiion trends for prairie pothole carnivores. Pages 461-463 *in* M.J. Mac, P.A. Opler, C.E. Puckett Haecker, and P.D. Doran, editors. Status and trends for the nation's biological resources, Vol. 2. U.S. Department of the Interior, U.S. Geological Survey.

HARRIS, S., W.J. CRESSWELL, P.G. FORDE, W.J. TREWHELLA, T. WOOLLARD, AND S. WRAY. 1990. Home-range analysis using radiotracking data - a review of problems and techniques particularly as applied to the study of mammals. Mammal Review 20:97-123.

HENRIQUES, W.D. 1997. A model of spatial and temporal exposure and effect of dieldrin on badgers at the Rocky Mountain Arsenal. Dissertation Abstracts International – Part B, Engineering and Biology 57(9):5559.

HOFF, D.J. 1998. Integrated laboratory and field investigations assessing contaminant risk to American badgers (*Taxidea taxus*) on the Rocky Mountain Arsenal National Wildlife Refuge. Dissertation Abst. International – Part B, Engineering and Biology, 59(5):2096.

KAUFMAN, D.W., AND E.D. FLEHARTY. 1974. Habitat selection by nine species of rodents in north- central Kansas. Southwestern Naturalist 18:443-451.

_____, G.A. KAUFMAN, AND E.J. FINCK. 1988. Influence of fire and topography on habitat selection by *Peromyscus maniculatus* and *Reithrodontomys megalotis* in ungrazed tallgrass prairie. Journal of Mammalogy 69:342-352.

KOWALCZYK, R., A. ZALEWSKI, B. JEDRZEJEWSKA, AND W. JEDRZEJEWSKI. 2003. Spatial organization and demography of badgers (*Meles meles*) in Bialowieza primeval forest, Poland and the influence of earthworms on badger densities in Europe. Canadian Journal of Zoology 81(1):74-87.

LINDZEY, F.G. 1971. Ecology of badgers in Curlew Valley, Utah and Idaho with emphasis on movement and activity patterns. MS Thesis, Utah State University, Logan, UT, USA.

_____. 1982. Badgers. Pages 653 - 663 *in* J.A. Chapman and G.A. Feldhamer, editors. Wild mammals of North America: Biology, management, and economics. The John Hopkins University Press, Baltimore, MD, USA.

LONG, C.A., AND C.A. KILLINGLEY. 1983. The Badgers of the world. Charles C. Thomas, Springfield, IL, USA.

MESSICK, J.P. 1987. North American badger. Pages 584 - 597 *in* M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Canada.

MINTA, S.C., AND R.E. MARSH. 1988. Badgers (*Taxidea taxus*) as occasional pests in agriculture. Proceedings of the Vertebrate Pest Conference 13:199-208.

MOHR, C.O. 1947. Table of equivalent populations of North American mammals. American Midland Naturalist 37:223-249.

POOLE, D.W., I.G. MCKILLOP, P.J. HANCOCKS, J.J. PACKER, AND G. WESTERN. 2002. Effectiveness of an electric fence to reduce badger (*Meles meles*) damage to field crops. Crop Protection 21:409-417.

RAMEY, C.A. 1995. Evaluating the gas cartridge for coyotes in controlling badgers. Proceedings of the Eastern Wildlife Damage Control Conference 6:79-84.

ROSALINO, L.M., D.W. MACDONALD, AND M. SANTOS-REIS. 2004. Spatial structure and land-cover use in a low–density Mediterranean population of Eurasian badgers. Canadian Journal of Zoology 82:1493-1502.

SARGEANT, A.B., AND S.W. WARNER. 1972. Movements and denning habits of a badger. Journal of Mammalogy 53:207-210.

SAVARIE, P.J., J.R. TIGNER, D.J. ELIAS, AND D.J. HAYES. 1980. Development of a simple two-ingredient pyrotechnic fumigant. Proceedings of the Vertebrate Pest Conference 9:215-221.

STUDIER, E.H., AND J.W. PROCTER. 1971. Respiratory gases in burrows of *Spermophilus tridecemlineatus*. Journal of Mammalogy 52:631-633.

SWINYARD, E.A. 1975. Noxious gases and vapors: Carbon monoxide, hydrocyanic acid, benzene, gasoline, kerosene, carbon tetrachloride, and miscellaneous organic solvents. Pages 900-904 *in* L.S. Goodman and A. Gilman, editors. The pharmacological basis of therapeutics. MacMillan, New York, NY. USA.

TUYTTENS, F.A.M., R.J. DELAHAY, D.W. MACDONALD, C.L. CHEESEMAN, B. LONG, AND C.A. DONNELLY. 2000. Spatial perturbation caused by a badger (*Meles meles*) culling operation:

Implications for the function of territoriality and the control of bovine tuberculosis *(Mycobacterium bovis*). Journal of Animal Ecology 69:815-828.

U.S. DEPARTMENT OF AGRICULTURE. 1990. Animal damage control program draft environmental impact statement-1990. APHIS DEIS 90-001., Washington, D.C., USA

VAN WINKLE, W. 1975. Comparison of several probabilistic home-range models. Journal of Wildlife Management 39:118-123.

WANG, H. 1999. Wildlife conservation in rural southeastern China: Wildlife harvest and the ecology of sympatric carnivores. Dissertation Abstracts International, Part B – Engineering and Biology 60(2):424.

WORTON, B.J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.