Short-term Response of Eastern Cottontails to Prescribed Fire in East-central Mississippi

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Abstract: Prescribed burning is an often used and economical management tool to manage for northern bobwhite *(Colinus virginianus)* and eastern cottontail rabbit *(Sylvilagus floridanus)*. Although prescribed fire creates and maintains early successional plant communities that benefit cottontails, short-term effects (direct and indirect) of prescribed burning on cottontails are unclear. To document cottontail response to fire, we examined pre- and post-burn home range (HR) and core area (CA) size, post-burn movement rates, and post-burn survival and cause-specific mortality rates for 10 cottontails (BURN) that inhabited sites burned with prescribed fire on Black Prairie Wildlife Management Area in Mississippi during 1998 and 10 cottontails (UNBURN) selected randomly that inhabited unburned sties. We observed no direct mortality from prescribed burns. Cottontails moved a mean distance of 84.9 m (SE=18.0) immediately after the burn, with 9 of 10 marked cottontails emigrating from burned fields. We observed no statistical differences between treatments (BURN vs. UNBURN) for pre-burn home range (HR; 3.57 ha vs. 3.58 ha) and core area sizes (CA; 0.46 ha vs. 0.45 ha), post-burn HR (6.17 ha vs. 3.76 ha) and CA (0.94 ha vs. 0.58 ha), overall movement rate (23.8 m/hour vs. 19.5 m/hour), diurnal movement rates (8.2 m/hour vs. 6.0 m/hour), crepsuscular movement rate (26.5 m/hour vs. 24.3 m/hour), survival rate (0.200 vs. 0.480), mammalian cause-specific mortality rate (0.296 vs. 0.206), and unknown predator cause-specific mortality rate (0.000 vs. 0.206). We did observe treatment effects on post-burn nocturnal movement rate (58.1 m/hour vs 28.8 m/hour) and avian cause-specific mortality rate (0.493 vs. 0.103). Percentage use of individual fields that were burned declined following the fires (pre- vs. post-burn) for all locations (0.887 vs. 0.265), diurnal (0.948 vs. 0.141), and nocturnal (0.827 vs. 0.390) periods. Our observations provide information on responses of cottontails during the first year following pre-

scribed fire and a framework for additional research regarding long-term benefits and impacts of this useful management tool.

Prescribed burning is an often used and economical management tool for species such as northern bobwhite and eastern cottontail rabbit that inhabit early successional habitats (Stoddard 1931, Rosene 1969, Hill 1981, Chapman et al. 1982). Prescribed burning alters wildlife habitat by reverting succession, stimulating growth of herbaceous plants, creating openings, reducing amount of litter layer, and perpetuating fire-dependent plant species (Stoddard 1931, Rosene 1969, Wade and Lungsford 1988). Our belief is that fire may effect wildlife through altering vegetation which potentially alters space-use, increasing vulnerability to predation, or causing direct mortality during the burn.

Information regarding the effects of prescribed fire on cottontail populations is limited. Hill (1981) provided a review of the direct and indirect effects of prescribed fire on cottontails in southeastern forests and identified potential research needs. He suggested that the net effects of prescribed burning were beneficial for cottontails and that there was only a minor immediate detrimental effect. Few, if any, scientists have precisely identified beneficial components of prescribed burning. However, Hill (1981) stated that the immediate effects such as direct mortality or the destruction of late winter cover might be detrimental. Hill (1981) also stated that, with the small home ranges of cottontails, the destruction of late winter cover through prescribed burning could bring heavy predation pressures on a population. Two studies (King et al. 1991, Lochmiller et al. 1991) examined cottontail densities on burned and unburned sites 1 to 2 years post-burn.

To our knowledge, no study has examined impacts of prescribed fire on cottontail home range dynamics, movements, survival, or cause-specific mortality. For this reason we collected data from cottontails that inhabited burned habitat (BURN) and those that did not inhabit burned habitat (UNBURNED) on Black Prairie Wildlife Management Area (BPWMA) in Mississippi. Our objectives were to measure direct mortality from the burn itself and indirect effects such as changes in home range (HR) and core area sizes (CA), movement rates, survival, and cause-specific mortality between treatments.

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Methods

The 2,234-ha BPWMA was located approximately 10 km southwest of Columbus in Lowndes County, Mississippi, in the Black Prairie physiographic region and was comprised of row crop (28.0%; corn [*Zea mays*] and soybean [*Glycine max*]), pasture (10.5%; predominately fescue [*Festuca arundinacea*], Johnson grass [*Sorghum halepense*], broomsedge [*Andropogon virginicus* and *A. glomeratus*], and verbena [*Verbena* sp.]), grassland habitat (28.0%; Conservation Reserve Program [CRP] fields and old field; predominantly broomsedge, goldenrod [*Solidago* sp.], Illinois Bundleflower [*Desmanthus illinoensis*], fescue, and Johnson grass), woody habitat (30.0%; linear woody corridors and wood lots; predominately trumpet creeper [*Campsis radicans*], Japanese honeysuckle [*Lonicera japonica*], poison ivy [*Toxicodendron radicans*], Eastern red cedar [*Juniperus virginiana*], and blackberries and dewberries [*Rubus* sp.]), and odd areas. Average annual rainfall was 150.0 cm, with mean monthly rainfall ranging from 8.4 cm in October to 16.3 cm in March (Owensby and Ezell 1992). Mean annual temperature was 16.8 C, with monthly mean temperature ranging from 5.1 C (Jan) to 27.0 C (Jul) (Owensby and Ezell 1992).

Two grassland CRP fields were prescribed burned in late winter 1998 (25 Feb [25.7 ha; with winds 16.1–32.2 k per hour, 42% humidity, and 17.2 C] and 3 Mar [20.5 ha; winds 16.1–24.1 k per hour, 25% humidity, and 8.9 C]). We defined 2 treatments: BURN=cottontails that experienced a prescribed burn (i.e., they were actually in the field when it was burned) and UNBURN=cottontails that did not experience the burn (i.e., cottontails that were monitored simultaneously with cottontails in the BURN treatment, but did not have any section of a burned field within their home range). We randomly selected an UNBURN cottontail of the same gender for each, to balance the comparison and minimize any potential gender bias within and between treatments. We examined treatment differences in pre- and post-burn HR and CA size, post-burn movement rates, and post-burn survival and cause-specific mortality rates.

Capture and Marking

We used wire cage traps (Tomahawk Live Traps, Tomahawk, Wis.) and wooden Mosby box traps (Mosby 1955) baited with fresh apples or apple extract. We trapped daily from mid-January through February 1998. Cottontails were restrained within a cloth sack for processing and not anesthetized. Each cottontail was marked with 2 numbered ear tags (monel metal ear tag model 1841 with 3/8-inch aluminum washer [Natl. Band and Tag Col, Newport, Ky.]) and a passive integrated transponder (PIT tag) injected subcutaneously, intrascapular. Cottontails >800 g were fitted with radio-collars (35–40.2 g, with 4-hour mortality sensors, Advanced Telemetry Systems [ATS], Isanti, Minn.). Individuals ≤800 g were not radio-collared to ensure the collar weight was ≤5% of the cottontail's body weight. Radio-collars and attachment

methods are described in Bond et al. (2000). Cottontails were released at the capture site ≤2 hours after traps were checked.

Telemetry

We conducted trianulation from geo-referenced (i.e., GPSed) telemetry stations (*N*=260). We recorded cottontail locations starting 3 days post-release allowing an adjustment period to the collar. We assumed that mortality associated with capture and handling would be restricted to a brief period (3 days) following capture and all mortalities >3 days represented natural mortality events.

We collected individual cottontail locations separated by 29 hours to ensure independence and to adequately estimate HR and CA throughout the diel period. We separated locations by 29 hours instead of 24 hours to systematically sample all diel periods (e.g., day 1=0500, day 2=1000, day 3=1500, day 4=2000, day 5=0100, day 6=0600, etc.). Telemetry data were entered into dBase III and Universal Transverse Mercator (UTM) coordinates were calculated using TELEBASE (Wynn et al. 1990).

Home Range and Core Area Estimation

We used CALHOME (Kie et al. 1996) to calculate 50% (CA) and 95% (HR) adaptive kernel (AK) home ranges by treatment for pre- and post-burn. We also examined proportion of telemetry locations (overall, diurnal, and nocturnal [includes crepuscular diel period]) within burned fields for the BURN cottontails pre- and post-burn. For statistical inference, we conducted a Kruskal-Wallis nonparametric test (α=0.05) because of non-normal data (SAS Inc. 1990).

Movement Rate Estimation

We monitored BURN cottontails before and after burns to observe movement distances on the day of the burns. We collected movement data from intensive monitoring (focal runs). Focal runs involved relocating an individual or group of cottontails at hourly intervals over a 3-hour observation period to characterize movement patterns and rates (m/hour). One focal run was performed weekly for each cottontail throughout the annual cycle or life of the cottontail and transmitter. Focal runs were distributed equally across nocturnal, diurnal, and crepuscular time periods for each cottontail. The nocturnal time period was from 2 hours after sunset to 2 hours before sunrise, crepuscular time period was from 2 hours before sunset to 2 hours after sunset and from 2 hours before sunrise to 2 hours after sunset, and diurnal time period was from 2 hours after sunrise to 2 hours before sunset. We did not analyze pre-burn movements because we were capturing cottontails during late January and early February and did not perform focal runs.

Minimum movements rates were estimated as the straight-line distance between coordinates of successive locations. Mean movement rates were calculated for each individual cottontail. For statistical inference, we conducted a Kruskal-Wallis nonparametric test (α=0.05) because of non-normal data (SAS Inc. 1990).

Survival and Cause-specific Mortality Rate Estimation

We estimated survival rates and tested for differences ($\alpha=0.05$) between survival distributions of each treatment using the log-rank chi-square statistic computed from the non-parametric Kaplan-Meier product limit estimator in SAS (PROC LIFETEST; Allison 1995). Our analysis interval was from the date the first field was burned (25 Feb 1998) to the end of the breeding season (30 Sep 1998). Because we did not always know the exact date of mortality, we used the midpoint between detection of mortality and the last known telemetry location as date of death (ranged 1–5 days between locations). We assumed the following about our sample population: cottontails were sampled randomly; survival times for cottontails were independent; left censored cottontails had survival distributions similar to cottontails collared previously; right censored mechanisms were independent of animal fate; and trapping, handling, and radio-collaring did not affect survival probability (Pollock et al. 1989, Allison 1995).

We estimated cause-specific mortality rates (25 Feb–30 Sep 1998) using MICROMORT (Heisey and Fuller 1985*a*). All mortalities of the BURN and UNBURN cottontails were found and characterized by one observer. We determined mortality factors as avian predation if there were talon marks on the radio-collar, the bones of the carcass were picked clean and fur spread around the remaining skeleton, the collar was found around avian scat under a perch tree, feathers were found at the scene, or most of the time we used a combination of these. However, we categorized mortalities as mammalian predation if there were teeth marks on the radio collar; the collar or antenna had been chewed; only the stomach or digestive tract was left; the carcass was cached under twigs and other debris; mammalian tracks, hair, and/or scat were present at the scene of mortality; or a combination of these. We assumed constant daily survival rate within the study interval and each cottontail radio-day was an independent event (Heisey and Fuller 1985*b*). We tested cause-specific mortality rates between treatments with a general chi-squared hypothesis testing procedure (Saucer and Williams 1989) within program CONTRAST (Hines and Sauer 1989).

Results

We used location and survival data from 10 cottontails that experienced a prescribed burn (BURN: 4 female and 6 male) and 10 randomly selected cottontails out of 20 that were currently monitored during the same time interval and did not experience a prescribed burn (UNBURN: 4 female and 6 male). Home range, core area, movement rate, and survival parameters reported within this study are a subset of the data collected from radio-collared cottontails used to study the effects of fire; for parameter estimates from the entire sample of radio-collared cottontails on BPWMA, see Bond et al. (2001*a*, 2001*b*). Pre-burned core area estimates are based on slightly less number of locations then previously reported minimum used (Bond et al. 2001*a*).

Home Range and Core Area

Mean number of telemetry locations used for pre-burn HR was 19.8 and 18.2 for BURN and UNBURN, respectively. Low survival of cottontails and the timing of our cottontail trapping allowed us to monitor very few cottontails prior to February. The short amount of time between trapping and implementation of the burns resulted in few telemetry locations collected during the pre-burn period. However, the mean number of locations was close enough to the minimum (20) previously calculated as adequate to estimate cottontail home ranges (Bond et al. 2001a), and we believe the number of locations we used adequately estimated pre-burn HR and CA. Home range (BURN: 3.57 ha, SE=0.64; UNBURN: 3.58 ha, SE=1.13; χ_1^2=0.463, P=0.496) and CA (BURN: 0.46 ha, SE=0.08; UNBURN: 0.45 ha, SE=0.19; χ_1^2=1.853, P=0.174) did not differ between treatments for the pre-burn period.

Mean number of telemetry locations used for post-burn were 71.5 and 103.4 for BURN and UNBURN, respectively. Fewer locations were obtained for BURN cottontails because their mortality rate was greater. Even though mean BURN HR (6.17 ha, SE=1.36) and CA (0.94 ha, SE=0.23) appeared to be almost twice as large as UNBURN HR (3.76 ha, SE=0.84) and CA (0.58 ha, SE=0.16) for the post-burn period, they did not differ statistically (HR: χ_1^2=1.202, P=0.273; CA: χ_1^2=1.120, P=0.290).

For the BURN treatment, proportion of locations for the pre-burn period within the burned fields was 0.948 (SE=0.035) for diurnal and 0.827 (SE=0.055) for nocturnal periods. The post-burn proportions were 0.141 (SE=0.048) for diurnal and 0.390 (SE=0.066) for nocturnal periods. Overall, 88.7% (SE=3.5%) of cottontail locations were in fields pre-burn and 26.5% (SE=4.9%) of locations were in these fields post-burn. We observed differences in proportions of locations in fields pre- and post-burn for each diel period (diurnal: χ_1^2=14.717, P<0.001; nocturnal: χ_1^2=10.345, P<0.001; overall: χ_1^2=13.720, P<0.001).

Movement Rates

Cottontails moved an average distance of 84.9 m (SE=18.0) from immediately before to immediately after the burn was completed, with 9 of 10 marked cottontails emigrating from the burned fields. The single cottontail remaining within the field on the day of the burn moved to a moist site within a trumpet creeper *(Campsis radicans)* thicket. Post-burn sample sizes of focal runs for BURN were overall (N=104; i.e., 104 individual cottontail focal runs), diurnal (N=39), crepuscular (N=38), and nocturnal focal runs (N=27); whereas, sample sizes of focal runs for UNBURN cottontails were overall (N=152), diurnal (N=55), crepuscular (N=58), and nocturnal focal runs (N=39). These samples size differences were once again attributed to a greater mortality rate for BURN cottontails post-burn.

Overall movement rates from the date of the burns to the end of the breeding season did not differ between treatments (BURN: 23.8 m/hour, SE=3.2; UNBURN: 19.5 m/hour, SE=2.2; χ_1^2 =2.063, P=0.151). Diurnal (BURN: 8.2 m/hour, SE=2.3; UNBURN: 6.0 m/hour, SE=0.8χ_1^2=0.498, P=0.480) and crepuscular (BURN: 26.5 m/hour, SE=3.1; UNBURN: 24.3 m/hour, SE=2.5; χ_1^2=0.242 P=0.623) movement

rates also did not differ between BURN and UNBURN treatments. However, nocturnal movement rates were greater (χ_1^2=12.017, *P*<0.001) in the BURN (58.1 m/hour, SE=6.7) than UNBURN(28.8 m/hour, SE=2.9) treatment.

Survival and Cause-specific Mortality Rates

We observed no direct mortality of cottontails from the burns. Survival rates (BURN: 0.200, SE=0.127; UNBURN: 0.480, SE=0.164; χ_1^2=1.841, *P*=0.175) did not differ between treatments.

We observed 3 causes of mortality (mammalian [3 BURN, 2 UNBURN] avian [5 BURN, 1 UNBURN], and unknown predator [0 BURN, 2 UNBURN]). One cottontail was censored due to radio-transmitter failure, and 6 cottontails (2 BURN, 4 UNBURN) survived past 30 September 1998. Cause-specific mortality rates for mammalian (BURN: 0.296, SE=0.142; UNBURN: 0.206, SE=0.129; χ_1^2=0.219, P = 0.640) and unknown predator (BURN: 0.000, SE =0.000; UNBURN: 0.206, SE = 0.129; χ_1^2 = 2.596, *P*=0.111) did not differ between treatments. However, avian predation (BURN: 0.493, SE=0.153; UNBURN: 0.103, SE=0.097; χ_1^2=4.613, *P*=0.032) was greater in the BURN treatment.

Discussion

In our study, cottontails exhibited an immediate response to prescribed burning by moving an average of 85 m to avoid the fire. Most rabbits (9 of the 10) emigrated from the burn unit, although 1 sought refuge in an unburned patch within the burned unit. Prior to the prescribed fire, CA and HR size of cottontails in the BURN and UN-BURN treatments were similar in space use and cottontails in the BURN treatment extensively used fields scheduled for a prescribed burn. However, the burns altered space use. Cottontails in the BURN treatment dramatically reduced use of burned fields immediately post-burn and exhibited greater nocturnal movements and vulnerability to avian predation. We observed numerous nocturnal avian predators (e.g., barred owl [*Strix varia*], great horned owl [*Bubo virginianus*], and barn owl [*Tyto alba*]) on BPWMA. Additionally, fire may have influenced home range size and survival. Even though we did not observe any differences at the *P*<0.05 level, our small sample sizes may have influenced the inability to detect a difference. We previously reported that mortality of cottontails was positively associated with CA size and movement rates (Bond et al. 2001*b*). Increased avian mortality for rabbits in the BURN treatment may have resulted from the cumulative effects of increased movements and reduced cover. With the decrease in escape cover the BURN cottontails exhibited greater nocturnal movements and greater space use than the UNBURN cottontails. As a result, the BURN cottontails may have been more exposed and vulnerable to avian predation which is in agreement with Hill (1981) that because cottontails have small home ranges the destruction of late winter cover through prescribed burning could bring heavy predation pressures on a population.

Although prescribed burning may create short-term negative consequences for cottontails, fire produces long-term habitat enhancement by improving land species

composition and forage quality for ≥2 growing seasons after burning (Hill 1981, King et al. 1991). Numerous researchers have reported beneficial effects of burning, such as increased plant diversity, abundance of herbaceous forbs and legumes, and increased nutritional value of forage (Stoddard 1931, Dewitt and Derby 1955, Hodgkins 1958, Hill 1981, Wade and Lungsford 1988, King et al. 1991).

Fire characteristics can greatly influence the magnitude of direct effects on cottontails. Intensely hot fires are more destructive than cool fires typically associated with winter prescribed burns (Hill 1981). Fires with intense heat can cause direct mortality by heat prostration, asphyxiation, or incineration (Howard et al. 1959). Researchers have reported a range in number of direct rabbit mortalities from fire from several carcasses following a 405-ha August burn (Horn 1938) to no direct deaths of cottontails during winter (Komarek 1969, Erwin et al. 1979, King et al. 1991, and our study). Burns conducted during our study were cool, slow-burning dormant season fires, in late winter, on relatively small areas (20.5 ha and 25.7 ha) that allowed rabbits to obtain cover in adjacent unburned vegetation.

Fire also reduces woody cover and shifts the plant community to favor grasses and forbs. Lochmiller et al. (1991) and King et al. (1991) observed that brush management had a positive influence on cottontail rabbits. Densities of cottontails were greater on areas treated with herbicide and fire 1 year after treatment (Lochmiller et al. 1991). King et al. (1991) reported greater number of cottontail pellets on burned areas than unburned areas 1–2 years after treatment. Although neither of these studies measured predation or survival rates, Lochmiller et al. (1991) frequently observed predator scats and cottontail-kill sites in areas during 2 years following treatment. Other investigators have also reported an increase in lagomorph populations following burning or site preparation (Keith and Surrendi 1971, McKee 1972).

Although we observed some detrimental short-term effects of prescribed burning on cottontails, the long-term benefits of prescribed burning likely outweigh the short-term impacts. These short-term impacts, however, should be offset through increased reproduction or survival because cottontails are so prolific. Prescribed burning is one of the most economical tools for wildlife managers, and we recommend the continuation of its use. Because cottontails occur in a range of early to mid-successional vegetation, it is imperative to periodically disrupt or inhibit natural succession. Under conditions of no management, cottontail abundance will eventually decline to low levels as succession advances (Chapman et al. 1982). The basis of cottontail management is habitat management, with the key element being vegetation that provides abundant quality forage and good escape cover. Habitat diversity and interspersion are important in cottontail management and can be improved by using prescribed fire. With a paucity of research into long-term effects of prescribed burning on cottontails, we agree with Hill (1981) that the short- and long-term benefits of improved forage conditions following fire are believed to surpass any immediate detrimental effects.

Management Implications

Rotational prescribed burning is a practical method to manage succession and maintain a mosaic of early to mid-successinoal seral stages (Hill 1981). Annual fires would likely maximize forbs and legume production and provide the most summer foods. However, consideration must be given to a burn frequency that provides a balance of summer and winter foods (Hill 1981), as well as adequate escape cover. Burn intervals and the size of the areas to be burned are important for managing areas of abundant quality forage close to areas of abundant quality cover especially considering the small home ranges of cottontails. We agree with Hill (1981) that small burn management units are most beneficial to cottontails because they facilitate some annual burning during alternate years. This approach also benefits many other game and non-game wildlife species. The mean HR size for cottontails on BPWMA was 4.3 ha (SE=0.32; Bond et al. 2001*a*), so burn units that are approximately 5 ha in size may reduce short-term impacts on cottontails. Additional management practices that can be used to provide patchy mosaics of food and cover in and around burned areas for cottontails include maintenance of hedgerows, protection of coverts (i.e., shrubby habitat patches within fields), areas along streams, and waterways, and creation of brush piles. Although, the prescribed burning interval best suited for cottontails remains unknown and is likely site-specific, we suggest that efforts be made to periodically burn areas managed for rabbits. We acknowledge that some sites cannot be burned, and in these special circumstance other tools of succession manipulation (herbicides, roller chopping, disking, mowing, etc.) should be considered.

Numerous research questions remain regarding the impacts of prescribed burns on cottontails. Examples include the following: 1) What is the best burn interval to meet the needs of cottontails (annually, every other year, 3–5 year interval, or the combination of these)? 2) What time of year is best for burning to provide maximal benefits and minimal detrimental impacts on cottontails? 3) What differences exist between dormant and growing season burns and their benefits and impacts on cottontails? 4) What are the long-term impacts and benefits of prescribed burns compared to no burning regime? 5) Do cottontail populations, within burned areas differ in density, reproductive output, size of home range, core area, movements, and survival from areas with longer burning regimes or no burning regime?

Our observations provide new information on the responses of cottontails to the first year after prescribed burning. We hope that this study will spur other researchers to investigate long-term responses of cottontails and other species that depend on early successional habitats to this useful management tool.

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