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Abstract: During 1994, we tested the hypothesis that an energized, high-tensile wire fence prevents fox squirrels (*Sciurus niger*) from crossing into a pecan (*Carya illinoensis*) grove. When the fence was energized, we recorded fewer ($P = 0.03$) trips across the fence by squirrels ($n = 19$) and fewer ($P < 0.001$) telemetry fix-points in the pecan grove. Effective squirrel fencing may offer wildlife managers an alternative method of damage prevention. Ecological ramifications to target and non-target species are discussed.

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Key words: damage control, fencing, fox squirrel, Oklahoma, radio telemetry, *Sciurus niger.*

Damage prevention, in addition to utilization and conservation, is 1 category of squirrel management (Rowe 1983). When compared to the relative success of utilization tactics (e.g., hunting), damage prevention tactics such as shooting, trapping, snaring, poisoning, and spreading chemical repellents have not been as successful in accomplishing their goals (Fiske 1992, Rowe 1983). This failure is due, in part, to wildlife managers relying on standard utilization tactics (e.g., hunting) for damage prevention and resisting alternative, expensive control tactics such as tree protection and habitat modification (Rowe 1983).

Fox squirrel *(Scirius niger)* depredation of native pecan *(Carya illinoensis)* production is significant, exceeding harvested pecans in some groves (Huggins 1991). This study used home range patterns constructed from radio-tracking data and trap-recapture methods to test an electric fence that shows promise in reducing fox squirrel depredation of native pecans. Radio-tracking is a more accurate method of studying daily animal movements than trap-recapture techniques and can be used as a tool to better determine cost-effectiveness of fencing as a method for preventing pecan depredation (Harris et al. 1990).

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METHODS

Study Site

This study was conducted at the RRDRF in Love County, Oklahoma. The area of interest included the 143 ha of native pecan grove and 57.5 ha of woodland adjacent to the grove. The study site was measured in meters using large scale aerial photographs (2.54 cm = 30 m), and a grid pattern of 30.5-m squares was established covering the site. No squirrel hunting was allowed on the study site.

The woodland was divided into 3 approximately equal zones. Radio collared squirrels were selected from those squirrels trapped repeatedly in or near the middle zone of the woodland in an attempt to collar resident squirrels who were less likely to emigrate from the edge of the woodland.

Fence Control

In July 1992, 2 km of fence was erected within a 6.1 m wide dozed lane between the pecan grove and adjacent woodland. The fence design consisted of 81.3 cm high 10.2 x 2.5 cm welded wire mesh ringed to the center of a 30.5 cm wide 2.5 x 5.1 cm vinyl-coated welded wire mesh apron laid flat along the length of the fence. At heights of 5.1 cm and 35.6 cm, high-tensile electric wires were offset 5.1 cm from the upright mesh on the woodland side of the fence. Thus, only squirrels moving from the woodland to the pecan grove came into contact with the electric pulse, which averaged 6000 volts. During the summer and fall of 1994, additional high-tensile electric wires were installed 25.4 cm outward from the bottom of each side of the fence to reduce dig-unders by raccoons (*Procyon lotor*) and armadillos (*Dasypus novemcinctus*).

In 1994, the fence remained on continually except for 7-22 September. A telemetry session occurred from 15-22 September. Additional telemetry sessions occurred before and after the deactivation period.

Trapping

Sixty-five, 15 x 15 x 60 cm wire-mesh live traps (Tomahawk Live Trap Co., Tomahawk, Wis.) were baited with pecans and placed in 4 lines running east-west at 100-m intervals within the grid matrix described above. Two lines were on

each side of the fence. The first line was within 10 m of the fence, the second line approximately 100 m farther north or south, respectively. Thirty-four traps in the woodland and 31 traps in the grove were attached to L-shaped wooden platforms nailed to tree trunks (Huggins and Gee 1995).

Fox squirrels were transferred from live traps to a bag for data collection and attachment of collars using a modified version of the procedure illustrated by Adams (1990). Captured squirrels were ear-tagged and collared with uniquely numbered, colored, nylon collars (Campbell Enterprises, Brush Prairie, Wash.). Captured squirrels were sexed, aged by evaluation of genital and mammary development (Allen 1943, Larson and Taber 1980) and by use of tail pelage characteristics (Sharpe 1958), and weighed using a spring scale.

Initial trapping in 1994 was conducted for 5-6 day intervals every other week from 20 July to 31 August on both sides of the fence. During telemetry sessions, trapping occurred only on the grove side of the fence. There were 25 trapping days for traps on both sides of the fence and an additional 17 trapping days for traps in the grove during telemetry sessions.

Radiotelemetry

Radiotelemetry equipment consisted of an AVM receiver and 19, SM1-H, 150.069 MHZ transmitters powered by 3.6 v lithium thionyl chloride 1/2 AA batteries (AVM Instrument Company, Ltd., Livermore, Calif.). A collar, with transmitter attached, weighed 15 g (2.0% of mean body weight for an adult fox squirrel) and had an expected life of 15 months.

A handheld H-Adcock antenna was used to locate collared squirrels by triangulation from 11 telemetry stations distributed throughout the study area. Each location was plotted from sequential bearings taken from 2 stations, usually < 50 m from the animal. The error arc was $\pm 2.25^{\circ}$ and the average area of the error polygon was 112.9 m^2 (SD = 61 m) (White and Garrott 1990).

Three telemetry sessions occurred in the fall when pecans incur heavy depredation (Huggins 1991). Thirty fix-points per squirrel were obtained prior to (8 Aug - 2 Sep) and during (15 Sep - 22 Sep) deactivation of the fence; and, after (23 Sep - 13 Oct) reactivating the fence. Initial telemetry data were used to determine at what point home-range size reached an asymptote (Stickel 1954, Hawes 1977, Harris et al. 1990). The number of fix-points in subsequent telemetry sessions reflected these findings.

Data Retrieval And Analysis

Sequential bearings were initially recorded in field notes for each animal and subsequently transferred to an acetate-overlay grid matrix laying on top of a large-scale aerial photograph and converted to X-Y coordinates. During a telemetry cycle, all of the radio-collared squirrels were located no more than once per hr between sunrise and sunset.

Chi-square goodness-of-fit test was used to compare the following data to fence status: (1) number of trips across the fence, (2) number of squirrels captured in the grove, and (3) number of fix-points in the grove (Conover 1980). The program HOME RANGE was used to calculate home range estimates (Ackerman et al. 1990). The Jolly-Seber model (Jolly 1965, Seber 1965) was used to estimate early autumn population size based on accumulated captures and recaptures.

RESULTS

Crude density of squirrels at the RRDRF was 1.6 per ha during August and September 1994. Adults, subadults, and juveniles comprised 70%, 21%, and 9% of the sample population, respectively. Seventy-percent were males and 30% were females. The total number of squirrels captured in zone 1 (56) was significantly greater ($P = 0.05$) than captures in zones 2 (36) and 3 (37).

Telemetry revealed that 4 (21%) of 19 radio-collared squirrels crossed the energized fence. When the fence was not energized, 2 additional squirrels crossed into the pecan grove and more ($P = 0.03$) trips across the fence occurred. In addition, more ($P < 0.001$) fix-points occurred in the pecan grove when the fence was not energized. The number of squirrels crossing the fence did not differ significantly by fence status ($P = 0.49$).

Squirrel movement from the pecan grove to the woodland was detected twice by trap-recapture data. There was no evidence of movement from the woodland into the pecan grove from trap-recapture data.

DISCUSSION

Testing of fence effectiveness assumes that squirrel tendency to cross the fence during the study either remained constant or increased as pecans ripened. Therefore, any significant differences in squirrel movements can be attributed to fence status. We observed significantly more trips across the fence and more fix-points in the grove when the fence was off. However, future research must consider the influence of mast density in the woodland on squirrel movement into the pecan grove. Available woodland mast could decrease squirrels' trips across the fence for distant pecans.

Testing fence effectiveness also assumes that dig-unders and end-runs around the fence are not options for squirrels attempting to enter the pecan grove. Dig-unders were available and we observed squirrels using them. However, installation of ground-level, high-tensile electric wires should deter dig-unders and effectively remove them as options for squirrels crossing into the pecan grove. The use of end-runs by squirrels without radio-collars remains unquantified. Given that the fence in this study does not enclose the pecan grove, end-runs were conceivable options for entering the pecan grove. However, the radio-collared squirrels were selected, in part, for their distance from the ends of the fence and were not observed using end-runs.

An analysis of any damage reduction measure must consider ecological ramifications to target and non-target species. Since establishment of the fence in 1992, 6 fox squirrels have died from contact with the fence. In addition, several non-target species have either become trapped and/or electrocuted in the wire mesh: painted bunting (*Passerina ciris*), cotton rat (*Sigmodon hispidus*), wood rat (*Neotoma micropus*), bobwhite (*Colinus virginianus*), box turtle (*Terrapene carolina*), leopard frog (*Rana blairi*), timber rattlesnake

(*Crotalus horridus*), copperhead (*Agkistrodon contortrix*), black rat snake (*Elaphe obsoleta*), diamondback water snake (*Natrix rhombifera*), and rough green snake (*Opheodrys aestivus*). Further research should consider possible variations to fence design that reduce animal mortality.

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