riculture relevant to wildlife management on private lands. Pages 11–16 *in* R. T. Dumke, G. V. Burger, and J. R. March, eds. Proc. of symp.: Wildl. manage. on private lands. La Crosse Printing Co., La Crosse, Wis.
ROGERS, J. G., JR. 1974. Responses of caged red-winged blackbirds to two types of repellents. J. Wildl. Manage. 38:418–423.
———. 1978. Repellents to protect crops from vertebrate pests: Some considerations for their use and development. Pages 150–165 *in* R. W. Bullard, ed. Am. Chem. Soc. Symp. Ser. No. 67, Flavor Chem. of Anim. Foods.
STEEL, R. G. D. AND J. H. TORRIE. 1980. Principles and procedures of statistics, second ed. McGraw-Hill Book Co., New York. 633pp.
TEVIS, L., JR. 1956. Behavior of a population of forest-mice when subjected to poison. J. Mammal. 37:358–370.
ZURCHER, N. J., R. J. JOHNSON, AND R. M. TIMM. 1983. Methiocarb and thiram as corn seed repellents for thirteen-lined ground squirrels. Wildl. Soc. Bull. 11:38–42.

Received 21 February 1984.
Accepted 13 November 1984.

***Wildl. Soc. Bull.* 13:324–327, 1985**

EFFICACY OF AERIAL APPLICATION OF A 2% ZINC PHOSPHIDE BAIT ON ROOF RATS IN SUGARCANE

LYNN W. LEFEBVRE, *Denver Wildlife Research Center, U.S. Fish and Wildlife Service, 2820 E. University Ave., Gainesville, FL 32601*

NICHOLAS R. HOLLER, *Denver Wildlife Research Center, U.S. Fish and Wildlife Service, 2820 E. University Ave., Gainesville, FL 32601*

DAVID G. DECKER, *Denver Wildlife Research Center, U.S. Fish and Wildlife Service, 2820 E. University Ave., Gainesville, FL 32601*

Several species of rodents, including the roof rat (*Rattus rattus*), cause substantial damage to sugarcane (*Saccharum officinarum*) in south Florida. One grower/processor's economic loss, based on a 1975 assessment, was estimated at $235/ha (Lefebvre et al. 1978). Only ZP® Rodent Bait AG[1] (Bell Laboratories, Inc., Madison, Wis.) is registered for infield use in Florida sugarcane. ZP® Rodent Bait AG is a pelleted 2% zinc phosphide bait. This study was a preliminary determination of the effectiveness of ZP® Rodent Bait AG prior to more extensive testing of a control program including several successive treatment applications in numerous fields. This study also demonstrates the inadequacy of trapping data to establish efficacy of a rodenticide for a trap-shy species.

METHODS

Four 7.3-ha sugarcane fields (366 × 183 m) in the Western Division of U.S. Sugar Corporation (Clewiston, Fla.) were selected for study in January 1983. Selection was made after trapping the edges of each of 15 fields with 24 Haguruma (Japanese) wire mesh live traps for 1 night. Selected fields had the greatest number of roof rat captures: 4–8/field. Two of the 4 fields were randomly designated for treatment with the zinc phosphide bait and 2 for use as controls.

This field trial determined efficacy based upon rodent mortality and population reduction data. Earlier work (Walsh et al. 1976) indicated that roof rats seldom are recaptured after initial capture and marking, thus, we could not rely on trapping data alone to establish efficacy. During livetrapping of a Florida sugarcane field 8 nights/month from April 1974–January

[1] Mention of trade names does not imply U.S. Government endorsement of products.

1976, 171 roof rats were captured a total of 246 times (Holler and Lefebvre, unpubl. data), an average of 1.44 captures/individual. Captures of cotton rats (*Sigmodon hispidus*) averaged 5.72/ individual in the same field. In another study, capture-recapture was conducted for 6 days in 4 fields in which roof rats were the only or predominant species captured. Of 72 animals eartagged and released, none was recaptured during the 6-day livetrapping period, and 7 were snaptrapped during the following 3-day period (Lefebvre and Holler, in press). This poor roof rat recapture success may be specific to the south Florida sugarcane habitat. Stroud (1982) reported an average of 3.9 captures/individual in a riparian habitat in California, with 65% recapture success. However, Clark (1980) cited several studies in which *R. rattus* recapture success was about 50%; and Worth (1950), trapping monthly for a year in a vacant building, recaptured only 24% of roof rats he marked.

Four 366-m transects, 37 m apart, were established across each field; a path was cut to form each transect and 22 livetrapping stations were located on each transect (88/field) at 15-m intervals. All fields were livetrapped 18–20 and 22 January 1983. Both treatment fields were trapped on 2 additional nights to obtain more rats for radio-tracking; the first 4 nights' trapping data only were used for comparisons of captures of individuals among fields. Twenty adult roof rats/field were equipped with 164.425–164.700 MHz radio collars (MPM 1038, Wildlife Materials, Inc., Carbondale, Ill.). Radio-collared rats were released at capture sites within 10 min. In 3 fields, radio-collared rats were distributed 5/transect; but in 1 treatment field radio-collared animals were distributed less evenly (2, 2, 7, and 9 on the transects, respectively) because of uneven distribution of rat captures. All other roof rats captured were individually marked with numbered metal ear tags and released.

Radio-collared rats were relocated remotely from field edges using LA-12 receivers (AVM Instrument Co., Dublin, Calif.) and 2, 4-element Yagi antennas mounted on 2 vehicles in null-peak configurations. Radio-collared rats were located from field edges on 2 evenings following the trapping period before treatment, and on 6 evenings following treatment. On the sixth day post-treatment, exact locations were determined for all surviving radio-collared rats to ascertain their fate.

Rat activity was evident from fluctuations in signal strength, and most of the radio-collared rats were active just before or after sunset. Individuals from which radio signals were not received or were not fluctuating during the evening were located the following morning using 3-element handheld Yagi antennas or antenna leads to determine if rats were alive or dead.

The zinc phosphide bait was applied aerially on 26 January 1983 to the 2 treatment fields and buffer zones. The buffer zone (other sugarcane fields) around each treated field was 190 m wide on sides that were not bordered by barriers to rat dispersal. A large canal bordered 1 side of both of the treated fields, and railroad tracks bordered 1 side of one treated field; these 3 borders did not receive a buffer treatment. The application rate (approximately 3.2 kg/ha) exceeded the recommended rate of 2.3 kg/ha application because bait flow from an aircraft hopper is difficult to control with such a large pellet size (1 × 1.3 cm).

All 4 fields were snaptrapped 2–5 February 1983, with 44 traps/transect (176/field) at 7.6-m intervals. In both live- and snaptrapping, fresh apple chunks were used as bait. Differences in pre- and post-treatment captures and between control and treated field captures were tested by analysis of variance.

A rain gauge and a wire mesh cage containing 6 bait pellets were placed at each of 2 stations/treated field, 30 m from the edge, to check the bait's weather resistance. In addition, 10 unprotected pellets were placed at 4 sites on the edge of a field >1 km from the nearest study field and were monitored daily through 30 January 1983 to determine how quickly exposed bait might disappear.

RESULTS

Radio-tracking

Eighteen rats were tracked over the 7-day post-treatment period in 1 control field (1 radio malfunctioned and 1 radio-collared rat died prior to treatment). Twenty radio-collared rats were alive before treatment in each of the other 3 fields, and were successfully tracked throughout the period. Seven (18%) of the 40 radio-collared rats in the treatment fields died, 3 in 1 field and 4 in the other. One of the 7 was badly decomposed 2 days after treatment, and may have died before treatment. All radio-collared rats in control fields survived the post-treatment period.

Trapping

Differences in numbers of individuals captured pre- and post-treatment were independent of treatment ($P = 0.59$). Fewer rats ($P = 0.16$) were captured during the post- than pre-treatment trapping in all fields, despite the greater post-treatment snaptrapping effort (Table 1). Observed differences were relatively small in 1 treatment and 1 control field, whereas <50% as many individuals were captured post-treatment in the other treatment and control fields. Considerable varia-

Table 1. Number of roof rats captured in 4 days (18–20, 22 January 1983) of pre-treatment livetrapping with 88 traps/field and 4 days (2–5 February 1983) of post-treatment snaptrapping with 176 traps/field in 4 sugarcane fields.

Field	Roof rats captured		
	Pre-treatment	Post-treatment	Difference (%)
Treatment 1	22	18	4 (18)
2	94	37	57 (61)
Control 1	93	45	48 (52)
2	49	38	11 (36)
Totals	258	138	120 (48)

tion in daily trap success was also noted in pre-treatment livetrapping. Roof rat captures declined from 28, 30, 23, and 13 on the first 4 nights to 6 several days later in 1 field. Treatment × time interaction was insignificant ($P = 0.90$), as trap success declined in both treatment and control fields. Only 4% (10/232) of rats marked in all fields (including those radio-collared) on days 1, 2, or 3 were recaptured on days 2, 3, or 4 of the 4-day pre-treatment trapping period. In only 1 field was a substantial proportion (38%; 22/57) recaptured in the post-treatment snaptrapping, with recapture success in other fields ranging from 10 to 22% (Table 2). Radio-collared rats may have been more difficult to recapture in post-treatment snaptrapping than rats with ear-tags only.

Bait Weather Resistance and Acceptance

From 2 to 4 mm of rain fell the second night after treatment. Pellets appeared to swell slightly but were still fairly firm and did not become soft until 28 January. Some pellets started to crumble by 31 January. We are unsure how moisture affected bait acceptance by rats or ingredient activity on each successive day.

Most pellets at the exposed bait sites disappeared within 3 days. Rat feces were found at 3 sites and rabbit droppings at 2 of the 4 sites. No sick or dead nontarget animals were observed in or near the treated fields.

Table 2. Percentage roof rats recaptured in post-treatment sugarcane fields, 2–5 February 1983. Rats that were known to have died (live trap or treatment mortalities) were not included.

Field	Percentage recaptured (no. marked)	
	Ear-tagged only	Radio-collared
Treatment 1	20 (5)	9 (16)
2	13 (74)	0 (17)
Control 1	25 (73)	15 (20)
2	46 (39)	22 (18)

DISCUSSION AND CONCLUSIONS

Biotelemetry has been used successfully in other efficacy evaluation studies and is particularly useful when a trapping bias is suspected (Dodge 1967). The radio-tracking results indicated that only 18% of roof rats were killed by the rodenticide treatment. Given the resilience of rodent populations and the cost of application, we believe that a rodenticide should kill >50% of the animals in a small field trial to merit more extensive testing. Radio-collared rats were not recaptured as frequently as uninstrumented rats, indicating that radio-collared rats might have been more bait-shy. Pre- and post-treatment captures were similar between treatment and control fields, however, also indicating that the rodenticide was not effective.

Once captured and tagged, a roof rat apparently became trap-shy even to a different type of trap, thus causing trap success to decline with time as the proportion of individuals already captured increased. Our use of snaptraps in post-treatment trapping did not solve the problem of trap avoidance. Captures possibly varied over time with some climatic factor. Using a different bait might have improved the snaptrap success; however, fire ants (*Solenopsis* spp.) took most of the peanut butter and oats mixture that we tried in earlier studies.

ZP® Rodent Bait AG contains no moisture-proofing ingredients, and a more moisture-resistant formulation may have performed better. Rain occurred the second night after treatment, which should have been adequate time to permit substantial mortality.

Tietjen and Matschke (1982) reported that prebaiting with untreated bait carrier (steam-rolled oats) before treatment of black-tailed prairie dog (*Cynomys ludovicianus*) colonies with 2% zinc phosphide greatly improved the bait's effectiveness. Lefebvre et al. (1978) noted that laboratory bait acceptance by roof rats of 1.88% zinc phosphide/oat groats was increased by prebaiting, as was mortality. The added expense of prebaiting, which would require special formation of pellets without toxicant, may make it an impractical solution to bait-shyness with a pelleted bait. There is no evidence that prebaiting with oats or another grain before use of a pelleted bait would increase bait acceptance.

SUMMARY

The efficacy of aerially applied ZP® Rodent Bait AG on roof rats was tested in Florida sugarcane fields. Only 7 of 40 radio-collared roof rats died following treatment application to 2 fields, while none of 38 radio-collared roof rats died in 2 control fields during a 7-day post-treatment period. We found no significant difference between treatment and control fields in numbers of individuals captured pre- and post-treatment, and recommend further development of the ZP® Rodent Bait AG formulation to improve acceptance by roof rats.

Acknowledgments.—The study was supported by the Florida Sugar Cane League. We thank J. R. Orsenigo, M. Dyal, and J. W. Beardsley for assistance in coordinating the study, and R. Mulholland and C. D. Hillman for their field assistance. Bait was provided by Bell Laboratories, Inc. D. A. Wade and R. J. Johnson critically reviewed an earlier draft of the manuscript.

LITERATURE CITED

CLARK, D. B. 1980. Population ecology of *Rattus rattus* across a desert-montane forest gradient in the Galapagos Islands. Ecology 61:1422–1433.

DODGE, W. E. 1967. Biotelemetry—its use in vertebrate control studies. Proc. Vertebr. Pest Conf. 3: 126–127.

LEFEBVRE, L. W., C. R. INGRAM, AND MARK C. YANG. 1978. Assessment of rat damage to Florida sugarcane in 1975. Proc. Am. Soc. Sugar Cane Technol. 7:75–80.

———, N. R. HOLLER, AND D. G. DECKER. 1985. Comparative effectiveness of full-field and field-edge bait application in delivering bait to roof rats in Florida sugarcane fields. Proc. Am. Soc. Sugar Cane Technol. (In press.)

———, ———, ———, AND N. J. SHAFER. 1978. Assessment of zinc phosphide-treated-bait acceptance by cotton, black, and Florida water rats and determination of acute oral toxicity of zinc phosphide to these species. Proc. Am. Soc. Sugar Cane Technol. 7:81–85.

STROUD, D. C. 1982. Population dynamics of *Rattus rattus* and *R. norvegicus* in a riparian habitat. J. Mammal. 63:151–154.

TIETJEN, H. P. AND G. H. MATSCHKE. 1982. Aerial prebaiting for management of prairie dogs with zinc phosphide. J. Wildl. Manage. 46:1108–1112.

WALSH, L. E., N. R. HOLLER, D. G. DECKER, AND C. R. INGRAM. 1976. Studies of rodent damage and rodent population dynamics in Florida sugarcane. Proc. Am. Soc. Sugar Cane Technol. 5:227–230.

WORTH, C. B. 1950. Field and laboratory observations of roof rats, *Rattus rattus* (Linnaeus), in Florida. J. Mammal. 31:292–304.

Received 30 May 1984.
Accepted 2 October 1984.