Hazards to Birds and Mammals Following Nifluridide Baiting for Controlling Fire Ants

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Abstract: Hazards to birds and mammals were evaluated following the aerial application of 0.75% nifluridide (EL-468) bait for controlling imported red fire ants (*Solenopsis invicta*). Birds were recorded on 12 transects (6 treated and 6 control) pre- and posttreatment. Small mammal abundance was estimated by live trapping 6 plots (3 treated and 3 control) pre- and posttreatment. Bait disappearance rates were measured for 3 different densities of red fire ant mounds. Overall, more birds and small mammals were counted posttreatment than pretreatment. Posttreatment ingress by northern cardinals (*Cardinalis cardinalis*), dickcissels (*Spiza americana*), and indigo buntings (*Passerina cyanea*) accounted for most of the increase. Conversely, 10 bird species with recognizable territories showed a population decline posttreatment on the treatment area, but the reductions were not statistically different from the control area ($P > 0.20$). However, of these 10, the disappearance of well-documented territories of 3 low-foraging insectivorous species (white-eyed vireo [*Vireo griseus*], Swainson's warbler [*Limnothlypsis swainsonii*], and common yellowthroat [*Geothlypis trichas*]) occurred at, or shortly after, treatment. The number of small mammals increased on 5 of the 6 plots posttreatment. During the posttreatment searching period, no carcasses were found that were attributed to treatment. These data suggest that no significant primary poisoning occurred to passerine birds or small mammals after the aerial application of nifluridide bait. However, in future applications of nifluridide bait to brushy or wooded habitats, its potential effects on low-foraging insectivorous birds should be further investigated.

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In the 1950s, the U.S. Department of Agriculture began a red fire ant eradication program calling for treatment with 2.25kg/ha of technical heptachlor in the southeastern United States. Serious wildlife and domestic animal losses occurred (Lay 1958, Rosene 1958, Newsom 1958, Glasgow 1958, Cottam 1958, Baker 1958), and the program was cancelled until a new insecticide, Mirex,[1] became available in the early 1960s. But Mirex persisted in the environment, and the Environmental Protection Agency cancelled its registration in 1971. Limited use of Mirex in Federal and state programs was permitted until 1978.

Eli Lilly and Co. have tested a new insecticide, nifluridide (EL-468),[1] N-[2-Amino-3-nitro-5-(trifluoromethyl) phenyl] -2,2,3,3-tetrafluoropropanamide, for controlling red fire ants. Nifluridide is thought to impair microsomal oxidative function after the molecule cyclizes, with the elimination of water, to a benzimidazole. Preliminary field tests showed red fire ant control of 85% to 90% following broadcast application of a 0.75% active bait at 9.9–19.7 g/ha. Treated colonies did not repopulate, indicating queen ant mortality.

Concerns over potential hazards of EL-468 to wildlife were raised because of its high order of toxicity to laboratory rodents (white rat LD_{50} is 48 mg/kg and mice LD_{50} is 172 mg/kg), bobwhites (*Colinus virginianus*) (LD_{50} is 25.2 mg/kg), and mallards (*Anas platyrhynchos*) (LC_{50} for juvenile mallards is 0.005%) (Eli Lilly, unpubl. data). Concerns were also raised because the physical appearance of the bait may duplicate that of a natural food item to wildlife and the proposed method of application would make it readily available to birds and mammals. After cycling to a benzimidazole, toxicity of nifluridide baits to wildlife increases 4 to 5 times, therefore increasing its potential hazards. This field study, conducted by the Denver Wildlife Research Center, U.S. Department of the Interior, Fish and Wildlife Service, was designed to evaluate the effects of an aerial application of a 0.75% active nifluridide bait at a rate of 1.9 kg/ha on birds and mammals.

Study Area

The site for the evaluation of nifluridide was in southeastern Texas, near Navasota. Treatment and control areas (1 each) of 233.5 and 297.6 ha, re-

[1] Reference to trade names does not imply endorsement by the U.S. Government.

spectively, were located in southwest Grimes and eastern Washington counties. Both areas were of similar habitat type and separated only by the Brazos River. Each area consisted of primary flood plain covered with hardwoods and extensive understory and secondary flood plain of pastures interspersed with hardwoods and sparse understory. Two habitat types were identified: pasture (including mowed, unmowed, and pastured oats) and woodland.

Methods

Hazard Assessment

Birds.—Bird species were estimated pre- and posttreatment on treatment and control areas by counting in 6 500-m strip transects randomly placed on each study area (3 each in pasture and woodland habitats). Observation points along the transects were identified with numbered plastic flags placed at 20-m intervals. Transects and flags were put in place 2 weeks before censusing to allow birds to acclimate to the flagging material.

Beginning on 17 April 1982, 2 observers censused the treatment and control areas 6 times before the application of nifluridide bait on 28 April. Then, beginning on 29 April, both areas were censused daily for 6 consecutive days. Observers rotated every other day between the treated and control plots, and the sequence of running the transects was reversed every other day. Each observer, wearing camouflage clothing and moving at about 1 km/hr, censused birds between daylight and 1000. Because of inclement weather, the treated area was not censused on 21, 22, or 24 April, and the control area was not censused on 22 or 24 April.

Bird species were divided into 2 categories: (1) singing—those most likely to be heard and less likely to be observed and (2) sighted and/or singing—those more likely to be observed. Each singing or sighted bird was recorded in relation to its position along the transect, along with the estimated perpendicular distance (up to 100 m) from the bird to the transect. All observations were recorded on portable tape recorders and data were later plotted on transect maps.

Nesting territories were tracked for species with recognizable territories. At least 2 song registrations constituted a territory (Robbins 1970). Territories were considered to have survived nifluridide treatment if they were recorded at least once 3 days posttreatment (few territories were consistently recorded every day, or even every 2 days). Territories not recorded until after nifluridide treatment were not included for this analysis. Pre- and posttreatment ratios of territories from the treated and control groups were compared using Fisher's exact probability test (Conover 1971).

Mammals (Live Trapping).—Small mammal abundance was estimated by live-trapping the treated and control areas for 5 days pre- and posttreatment. Three trapping plots were established on each area, 2 in the pasture (except the pastured oats) and 1 in the woodland habitats. Each plot consisted of grids with 4 parallel lines 300 m long, with 15 m between lines. A trapping station was established at the starting point of each line and every 15 m thereafter. A steam-cleaned 7.2 × 7.6 × 25.2 cm Sherman live trap was placed at each trapping station. Each trap was set and baited with peanut butter and rolled oats at 1600 hours each day, examined at 2100 hours, and examined and closed at 0600 hours. Pretreatment trapping was conducted on the nights from 19 to 26 April. Severe thundershowers prevented trapping on 20, 22, and 24 April. Posttreatment trapping was conducted from 29 April to 3 May.

Each trapped rodent was identified as to species and was sexed and sequentially toe clipped (Baumgartner 1940). During the 2100-hour check, each trap with a catch was moved to another predetermined point within a 5-m radius around its trapping station. At 1600 hours, when traps were reset, all relocated traps were returned to their original point. Pre- and posttreatment population indices for each plot were the total number of rodents trapped.

Differences between the number of rodents trapped pre- and posttreatment for both control and treated plots were tested by a repeated measures analysis of variance:

Source	*df*
Treatment	1
Plots in treatment	4
Time	1
Time × treatment	1
Time × plot × treatment	4

A comparison of proportions (normal Z statistic) was used to analyze differences between number of animals marked pretreatment and retrapped posttreatment on the treatment and control plots.

Mammals (Snap Trapping).—On 4 May, immediately after the posttreatment live-trapping period, all plots were snap-trapped for 1 night. The objective was to establish a secondary basis for estimating treatment effect by determining (1) the number of animals marked pretreatment but not recaptured posttreatment and (2) the number of unmarked animals. Starting at 1700 hours, 1 museum special trap baited with peanut butter and rolled oats was placed at each trapping station in the grid; i.e., 84 traps per plot. Traps were continually checked, rebaited, and set from 2100 hours until daylight except for a period of approximately 2 hours from 0300–0500 hours. Each capture was identified by species and was sexed, weighed, and examined for clipped toes.

Bait Formulation

Nifluridide was dissolved in acetone and then mixed with a predetermined quantity of once-refined soybean oil (27% by weight). This mixture was then added to a bait carrier PDCG (pregelled, defatted corncob grits). The PDCG was agitated to distribute the nifluridide and oil mixture and to facilitate evaporation of the solvent. A sample of 3 bait preparations assayed at 0.75% ± SE 0.007. The control bait was PDCG and soybean oil (27% by weight).

Treatment

A commercial applicator aerially applied the treated and control baits to areas on 28 April. Before treatment, the translar spreader on the aircraft was calibrated to dispense bait at 1.9 kg (14.3 g technical nifluridide/swath ha), with 109 bait particles/m. The aircraft applied a blanket treatment by baiting in swaths 15 m wide at an altitude of 24 m and at a speed of 161 km/hour. Time of treatment on the control and treatment areas was 0900–1200 hours and 1200–1530 hours, respectively. Ground personnal (spotters) established each flight line with a flag pole, to aid the pilot in aligning the aircraft and to ensure accuracy of the blanket application.

Weather conditions during baiting included a clear sky from mid-morning to dark, a noon ambient temperature of 28° C, and a 13 to 16 km/hour wind in an east to west direction. Heavy dews occurred every morning posttreatment, but no rain fell until 7 days posttreatment.

Bait Disappearance

Bait disappearance for the treatment area was measured along 3 transects, laid according to habitat type and density of fire ant mounds: TB_1 in the unmowed pasture (with 1112 mounds/ha), TB_2 in the oat pasture (with 161 mounds/ha), and TB_3 in the woodland (with 70 mounds/ha). Five sample sites were randomly established on each of 3 300-m transects (not to be confused with bird transects). Each site consisted of 8 adhesive collectors (0.0811 m^2) to catch fallen bait particles and 4 counting quadrant frames (0.25 m^2) to measure the rate of bait particle disappearance. Counting quadrants were placed in a square pattern with 1 m between quadrants. Adhesive collectors were placed along 2 outer edges of each of the 4 counting quadrants to obtain an estimate of the number of bait particles deposited during treatment.

One person counted bait particles at each sampling site. Immediately before treatment, the adhesive side of each collector was exposed to catch fallen bait particles, and immediately posttreatment they were covered with a sheet of plastic for counting at a later date. Bait particles in each counting quadrant were tallied immediately after application and at either 1- or 2-hour intervals until light conditions prevented counting (at approximately 1900 hours). On Day 2, counts were made at 0800 hours, 1200 hours, and 1600 hours. On Days 3 to 5, counts were made once in the morning and once in the afternoon. On Days 6 and 7, counts were made once a day between 1000 hours and 1200 hours.

The 3 transects were analyzed by regression techniques. Data from the 5 sampling sites were combined into 1 value per time period. Time periods varied for each transect: TB_1: 0, 1, 2, 3, 4, 5, and 6 hours; TB_2: 0, 2, 4, 18, and 22 hours; TB_3: 4, 18, 22, 26, 41.5, and 50 hours following treatment. Counting intervals was stopped because the bait was no longer disappearing.

Carcass Searching

Searches for non-target wildlife mortality were conducted pre- and post-treatment. All habitat types were sampled with emphasis on searching the edges of each type. Pre-planned routes were established for the line of searchers. All dead animals, time, and manpower spent in searching were recorded. After the searches, routes were plotted on a map overlay; distances traveled were measured, and area (ha) covered was estimated based on the width of the search line.

Results

Pretreatment Census Period, Birds

Forty resident species were recorded on the strip transects (Table 1). On the treatment area, 453 registrations comprising 29 species were recorded. The woodland habitat supported more birds (281) than the pasture habitat (172). On the control area, 433 registrations comprising 31 species were heard or seen (Table 2). These registrations were equally divided between pasture (217) and woodland habitat (216).

Cardinals were by far the predominant singers on the treatment and control areas (2 to 3 times more abundant than the next most common bird). In the sighted and/or singing category, the most abundant birds on the treatment and control areas were red-bellied woodpeckers (*Melanerpes carolinus*), followed by American crows (*Corvus brachyrhynchos*), blue jays (*Cyanocitta cristata*), eastern kingbirds (*Tyrannus tyrannus*), and black vultures (*Coragyps atratus*).

Table 1. Nesting birds recorded in the 1982 nifluridide-Texas red fire ant study areas.

Singing category	Sighted-singing category
Northern bobwhite (*Collinus virginianus*)	Little blue heron (*Egretta caerulea*)
Mourning dove (*Zenaida macroura*)	Black vulture (*Coragyps atratus*)
Yellow-billed cuckoo (*Coccyzus americanus*)	Red-shouldered hawk (*Buteo lineatus*)
Eastern wood pewee (*Contopus virens*)	Broad-winged hawk (*Buteo platypterus*)
Great-crested flycatcher (*Myiarchus crinitus*)	Red-tailed hawk (*Buteo jamaicensis*)
Blue jay (*Cyanocitta cristata*)	Barred owl (*Strix varia*)
American crow (*Corvus brachyrhynchos*)	Ruby-throated hummingbird (*Archilochus colubris*)

Singing category	Sighted-singing category
Carolina chickadee (*Parus carolinensis*)	Red-headed woodpecker (*Melanerpes erythrocephalus*)
Tufted titmouse (*Parus bicolor*)	Red-bellied woodpecker (*Melanerpes carolinus*)
Carolina wren (*Thryothorus ludovicianus*)	Downy woodpecker (*Picoides pubescens*)
Eastern bluebird (*Sialia sialis*)	Pileated woodpecker (*Dryocopus pileatus*)
Wood thrush (*Hylocichla mustelina*)	Eastern kingbird (*Tryrannus tyrannus*)
Gray catbird (*Dumetella carolinensis*)	Scissor-tailed flycatcher (*Tyrannus forficatus*)
Northern mockingbird (*Mimus polyglottos*)	Northern rough-winged swallow (*Stelgidopteryx serripennis*)
Brown thrasher (*Toxostoma rufum*)	Loggerhead shrike (*Lanius ludovicianus*)
White-eyed vireo (*Vireo griseus*)	Eastern meadowlark (*Sturnella magna*)
Red-eyed vireo (*Vireo olivaceus*)	Brown-headed cowbird (*Molothrus ater*)
Northern parula (*Parula americana*)	
Swainson's warbler (*Limnothlypis swainsonii*)	
Kentucky warbler (*Oporornis formosus*)	
Common yellowthroat (*Geothylpis trichas*)	
Hooded warbler (*Wilsonia citrina*)	
Yellow-breasted chat (*Icteria virens*)	
Summer tanager (*Piranga rubra*)	
Northern cardinal (*Cardinalis cardinalis*)	
Indigo bunting (*Passerina cyanea*)	
Painted bunting (*Passerina ciris*)	
Dickcissel (*Spiza americana*)	
Northern oriole (*Icterus galbula*)	

Posttreatment Census Period, Birds

The number of bird registrations was higher during the posttreatment census period than during the pretreatment period. Registrations increased on the treatment area posttreatment by 33% (453 to 604) (Table 2) and on the control area by 31% (433 to 566) (Table 2). The number of species on the treatment area remained the same, but increased on the control area from 31 to 33 species. On both treatment and control areas, registrations were greater

Table 2. Pre- and posttreatment counts of birds recorded during the 1982 nifluridide Texas-red fire ant study.

Transect	Singing birds		Singing and/or sighted	
	N species	Individuals	*N* species	Individuals
Control area—*pretreatment*				
C_1 woods	9	63	8	17
C_2 woods	5	51	5	13
C_3 pasture	6	33	9	30
C_4 pasture	10	53	8	46
C_5 woods	8	61	4	11
C_6 pasture	6	37	5	18
Total		298		135
Control area—*posttreatment*				
C_1 woods	12	100	7	20
C_2 woods	9	82	5	13
C_3 pasture	7	45	10	32
C_4 pasture	10	68	9	39
C_5 woods	9	76	4	21
C_6 pasture	6	50	8	20
Total		421		145
Treated area—*pretreatment*				
T_1 woods	11	79	7	21
T_2 woods	12	73	4	11
T_3 pasture	9	53	6	19
T_4 woods	10	82	6	15
T_5 pasture	7	45	5	10
T_6 pasture	5	28	6	17
Total		360		93
Treated area—*posttreatment*				
T_1 woods	13	116	6	20
T_2 woods	8	104	7	22
T_3 pasture	10	67	4	17
T_4 woods	13	111	4	15
T_5 pasture	8	68	3	5
T_6 pasture	5	55	3	4
Total		521		83

in the woodland habitats (388 for treatment and 312 for control) than in the pasture (216 for treatment and 254 for control).

Cardinals were again the predominant bird in the singing category in both control and treatment areas (2 to 3 times more abundant than the next most common bird). Red-bellied woodpeckers were the most abundant bird in the sighted/singing category in both the treatment and control areas.

The increase in registrations in the posttreatment period was undoubtedly due to the continued arrival of breeding birds. Cardinals, dickcissels, and indigo buntings were primarily responsible for the increase in the posttreatment population. Cardinal registrations increased by 74% and 43% in woodland habitat on the treatment and control areas, respectively. Dickcissel registrations increased by 191% and 76% on the pasture treatment and control areas, respectively. Indigo bunting registrations on the treatment area increased by 65%; for unknown reasons this bird was practically nonexistent on the control area. The number of territories for these 3 species also increased dramatically, but those of cardinals and dickcissels were too numerous to map properly.

The breeding territories of 10 species that could be mapped readily and which had comparable populations on treatment and control areas (indigo bunting did not) were examined (Table 3). The number of territories for 5 of these species (mourning dove [*Zenaida macroura*], crested flycatcher [*Myiarchus crinitus*], tufted titmouse [*Parus bicolor*], Carolina wren [*Thryothrus ludovicianus*], and common yellowthroat), unlike cardinals, dickcissels, and indigo buntings, declined posttreatment on both the treatment and control areas. Perhaps this was due to a decrease in male singing as nesting progressed. Further, 4 species (white-eyed vireo, Kentucky warbler [*Oporornis formosus*], eastern meadowlark [*Sturnella magna*], and summer tanager [*Piranga rubra*]) showed at least some decline in the treatment area but not in the control. The difference in territory loss between the treatment and control areas for these 9 species was not significantly different ($P > 0.20$) even though a large numerical decline in mourning dove and white-eyed vireo territories occurred on the treatment area compared with the control.

The decline in mourning dove territories does not appear to be related to the treatment. Bait acceptance tests conducted at the Denver Wildlife Re-

Table 3. Comparison of numbers of pre- and posttreatment territories for 10 bird specie in the 1982 nifluridide-Texas red fire ant study.

Species	Foraging height[a]	Treatment Pre	Treatment Post[b]	% Pre	Control Pre	Control Post[b]	% Pre	Difference	P[c]
Mourning dove	Low	8	1	12.5	9	5	55.6	− 43.1	0.109 N
Crested flycatcher	High	8	3	37.5	11	5	45.4	− 7.9	0.590 N
Tufted titmouse	High	8	3	37.5	20	8	40.0	− 2.5	0.631 N
Carolina wren	Low	16	11	68.8	15	11	73.3	− 4.5	0.564 N
White-eyed vireo	Low	15	8	53.3	5	5	100.0	− 46.7	0.329 N
Red-eyed vireo	High	3	3	100.0	4	4	100.0	0	0.703 N
Kentucky warbler	Low	3	2	66.7	2	2	100.0	− 33.3	0.642 N
Common yellowthroat	Low	3	0	0	1	0	0	0	
Eastern meadowlark	Low	1	0	0	2	2	100.0	−100.0	0.600 N
Summer tanager	High	2	1	50.0	1	1	100.0	− 50.0	0.700 N
Totals		67	32	47.8	70	43	61.4	− 13.6	

[a] Low = <10 feet, High = >10 feet.
[b] Includes only territories in existence before spray application on 28 March 1982 and that were still foun to be in existence on 2, 3, or 4 April 1982.
[c] Fisher's Exact Probability Test (Conover 1971). NS = Not significant.

search Center provided evidence that mourning doves refuse nifluridide baits (Schafer et al. 1982). Further, mourning doves are granivorous and, therefore, would not likely feed upon insects that had taken nifluridide baits.

The decline in the number of white-eyed vireo territories on the treatment area may have been related to the treatment although there was no statistical difference between treatment and control areas. White-eyed vireos are insectivores that forage on or near the ground and are known to include ants in their diet (Martin et al. 1951).

If the decline in white-eyed vireo territories was related to treatment, then other birds whose foraging behavior and diet are similar to that of white-eyes may also have been affected. Common yellow-throats and Swainson's warblers (Table 3), which had 4 recognizable territories on the treatment area disappeared shortly after nifluridide application. Unfortunately, no Swainson's nested on the control area.

Pretreatment Census Period, Mammals

Abundance of small mammals was low on all 3 control plots and treatment plots 4 and 5 (trapping index of 0.7 to 5.0 animals trapped/100 trap nights); but on treatment plot 6, the trapping index was 21.4 animals/100 trap nights. Population estimates and corresponding confidence limits could not be calculated because of insufficient initial captures or recaptures on plots 1 through 6. Consequently, the total number of individuals of all species trapped on each plot served as the index to population size (Table 4).

Five species were trapped pretreatment on the control and treatment areas. Pygmy mice (*Baiomys taylori*) and white-footed mice (*Peromyscus leucopus*) were the most prevalent, 60.3 and 30.4%, respectively. Pygmy mice predominated in 2 plots: uncut pasture (plot 6—treatment area) and pasture (plot 3—control area). White-footed mice predominated in 4 plots: woodland in control and treatment areas (plots 1 and 4, respectively) and 1 pasture plot in each of the control and treatment areas (plots 2 and 5, respectively). Cotton rats (*Sigmodon hispidus*), fulvous harvest mice (*Reithrodontomys fulvescens*), and rice rats (*Oryzomys palustris*) accounted for only 9.3% of the total number of small mammals trapped.

Posttreatment Census Period, Mammals

Forty-two more rodents were trapped posttreatment than pretreatment (Table 4). However, 35 of these were trapped on treatment plot 6. On treatment plot 4, the numbers trapped increased by only 1 animal, whereas treatment plot 5 showed a decrease of 6 animals. On the control plots 1, 2, and 3, the increase in rodents captured was 3, 2, and 7 individuals, respectively. Despite the overall increase, the trapping index remained similar to the pretreatment values on plots 1 through 4; i.e., 1.2–5.7 animals/100 trap nights. The trapping index for plot 5 decreased from 3.1 to 1.7, but the trapping index showed the greatest increase on plot 6, going from 21.4 to 29.8 animals.

Table 4. Small mammal species trapped during the pre- and posttreatment live trapping periods in a 1982 nifluridide-Texas red fire ant study.

	Control plots							Treated plots						
	Pretreatment			Posttreatment			Absolute change from pre- to post-treatment	Pretreatment			Posttreatment			Absolute change from pre- to post-treatment
Plot no.	1 *N*	2 *N*	3 *N*	1 *N*	2 *N*	3 *N*		4 *N*	5 *N*	6 *N*	4 *N*	5 *N*	6 *N*	
White-footed mice	20	3	0	24	4	0	+ 5	13	10	0	12	2	0	− 9
Pygmy mice	0	0	10	0	0	16	+ 6	0	1	80	0	4	100	+23
Rice rats	1	0	0	0	0	0	− 1	0	0	0	0	0	0	0
Fulvous harvest mice	0	0	1	0	0	0	− 1	0	2	1	0	1	0	− 2
Least shrew	0	0	0	0	0	1	+ 1	0	0	0	0	0	1	+ 1
Hispid pocket mice	0	0	0	0	1	1	+ 2	0	0	0	0	0	0	0
Cotton rats	0	0	0	0	0	0	0	0	0	9	0	0	24	+15
Eastern wood rats (*Neotoma floridana*)	0	0	0	0	0	0	0	0	0	0	2	0	0	+ 2
Totals	21	3	11	24	5	18	+16	13	13	90	14	7	125	+30

Differences between numbers of rodents marked pretreatment and retrapped posttreatment on the treatment and control plots were not significant ($P = 0.5$). Only 27.5% (53 of 193) of the posttreatment population had been marked pretreatment and then recaptured: 40 (27.4%) of 146 on treatment plots and 13 of 47 (27.6%) on control plots. Pygmy and white-footed mice were the most common animals recaptured that were marked pretreatment, 32 (35.2%) and 19 (41.3%), respectively. Only 1 cotton rat and 1 fulvous harvest mouse that were marked pretreatment were recaptured posttreatment.

Snap-Trapping Census, Mammals

Seventy-seven rodents (5 species) were kill-trapped during the 1-night trapping period (Table 5). Numbers trapped varied considerably among the 6 plots, ranging from 60 on plot 6 to 0 on plot 5. The remaining 17 were trapped on plots 1 through 4. Pygmy mice accounted for 72.7% of the sample, followed by white-footed mice at 13.0%, and cotton rats at 9.1%. Least shrews at 3.9% and harvest mice at 1.3% were also taken.

Fifty-two (67.5%) of the rodents snap-trapped were marked. Twenty-eight had been marked pretreatment and 19 had been marked posttreatment. Of the 28 marked pretreatment, only 9 were live-trapped posttreatment. Five marked animals were partially eaten and it could not be determined if they had been marked either pre- or posttreatment. Two other animals were mutilated and marks could not be determined.

Carcass Searching

No mortality associated with treatment was observed during posttreatment carcass searching, bird censusing, or small mammal trapping. The only posttreatment mortality observed occurred on the treatment areas. After searching about 21.0 manhours and covering approximately 16.5 ha, 2 dead raccoons (*Procyon lotor*) were located. One was found dead at the same location where it had been observed behaving abnormally on the morning before treatment. The second was a decomposed individual. On the control areas, 13.6 manhours were spent posttreatment searching approximately 12.5 ha, but no carcasses were found.

Table 5. Small mammal species snap-trapped during the nifluridide-Texas red fire ant study, 1982.

		Control			Treated			
Species	Plot no.	1	2	3	4	5	6	Total
Pygmy mice		0	0	7	0	0	49	56
Deer mice		7	1	0	2	0	0	10
Least shrews		0	0	0	0	0	3	3
Cotton rats		0	0	0	0	0	7	7
Harvest mice		0	0	0	0	0	1	1
Totals		7	1	7	2	0	60	77

One decapitated and decomposed white-footed mouse was found pretreatment on the treatment plot after searching for 15.0 manhours and covering approximately 12.7 ha. After searching 13.6 manhours and covering approximately 13.5 ha on the control plot, no carcasses were found.

Nifluridide Bait Disappearance

Foraging by fire ants or red harvester ants (*Pogonomyrmex barbatus*), decomposition due to the environmental conditions at the soil surface, or a combination of these factors was responsible for the loss of bait particles from the sample sites (Table 6). The only non-target species that foraged the nifluridide bait was the red harvester ant, but the numbers of bait particles they removed were insignificant and confined to the oat pasture transect. Warm temperatures and lack of rain were ideal conditions for foraging by fire ants during the 7-day posttreatment period. A regression analysis using an exponential model and a linear model was done for each transect at 3 time intervals to help identify the primary cause in the loss of bait particles (Table 7). The results from the 2 models were similar; thus, only the exponential model will be discussed. The slope of the regression line was correlated to the density of fire ant colonies during the time that bait particles were actively foraged.

Transect TB_1 was located in an unmowed grass pasture and provided an ideal habitat for fire ants. Fire ants were observed removing the bait from sample sites as soon as it contacted the ground, and only 1 bait particle remained in a sample site 6 hours posttreatment. The speed with which the fire ants foraged the bait particles is represented by the slope of the regression line (Fig. 1). The bait was not in contact with the soil long enough for environmental factors to effect the rate of bait loss; thus, along transect TB_1, fire ants were responsible for the removal of all the bait particles in the sample sites.

The oat pasture (TB_2) contained populations of fire ants and red harvester ants. The soil was sandy and dry and received sunlight during most of the day. Fire ants and red harvester ants were observed removing bait from the sample sites, but all the bait was removed from only 1 of 5 sample sites. Comparison of the regression values of the time intervals for the initial 24 hours with the period after 24 hours indicates that a rapid removal of bait particles occurred during the first 24 hours, but the number of particles for the remainder of the posttreatment period remained relatively constant. The loss of bait particles during the initial 24 hours represents the active foraging by fire ants and red harvester ants. The constant count of bait particles after the initial 24 hours indicates a lack of foraging by ants and that the environmental conditions at the soil surface did not favor decomposition of the bait particle. Actual bait counts began increasing 93 hours posttreatment, but this was attributed to a change in the personnel that was counting the particles. The shallow slope of the regression line indicates the medium density of ant colonies in the oat pasture (Fig. 1).

Trees along the woodland transect (TB_3) intercepted the bait particles

Table 6. Means ± SD of adjusted[a] bait particle counts (M[b]) for each transect in the 1982 nifluridide-Texas red fire ant study.

Transect														
	Hours posttreatment													
TB1 hours					0	1	2	3	4	5	6			
TB1					269	110	69	44	26	16	1			
					±111	±80	±53	±42	±30	±26	±2.2			
	Hours posttreatment													
TB2 hours		0	2	4	19	23	26	42	50	66	73	93	112	136
TB2		228	202	194	148	133	134	132	135	130	133	159	174	159
		±91	±94	±121	±109	±99	±102	±98	±114	±122	±119	±128	±145	±132
	Hours posttreatment													
TB3 hours	0	2	4	18	22	26	42	50	66	74	92	100	116	114
TB3	252	234	241	226	220	205	162	163	131	110	96	86	78	73
		±99	±90	±109	±108	±101	±91	±93	±81	±57	±61	±48	±48	±39

[a] The number of bait particles at t_0 is the actual count of particles from the adhesive collectors and adjusted for size of the collector.
[b] $N = 5$ for each time interval.
[c] Increase of bait particles at 93 hours posttreatment can be attributed to a switch in personnel counting particles.
[d] Vegetation intercepted the bait particles and prevented accurate estimate of the number of t_0 from the adhesive collectors. The t_0 value is the 4 intercept of an exponential equation.
[e] Increase of bait particles at 4 hours posttreatment can be attributed to bait particles settling on the leaves during treatment and then, when winds blew, falling onto the sample sites.

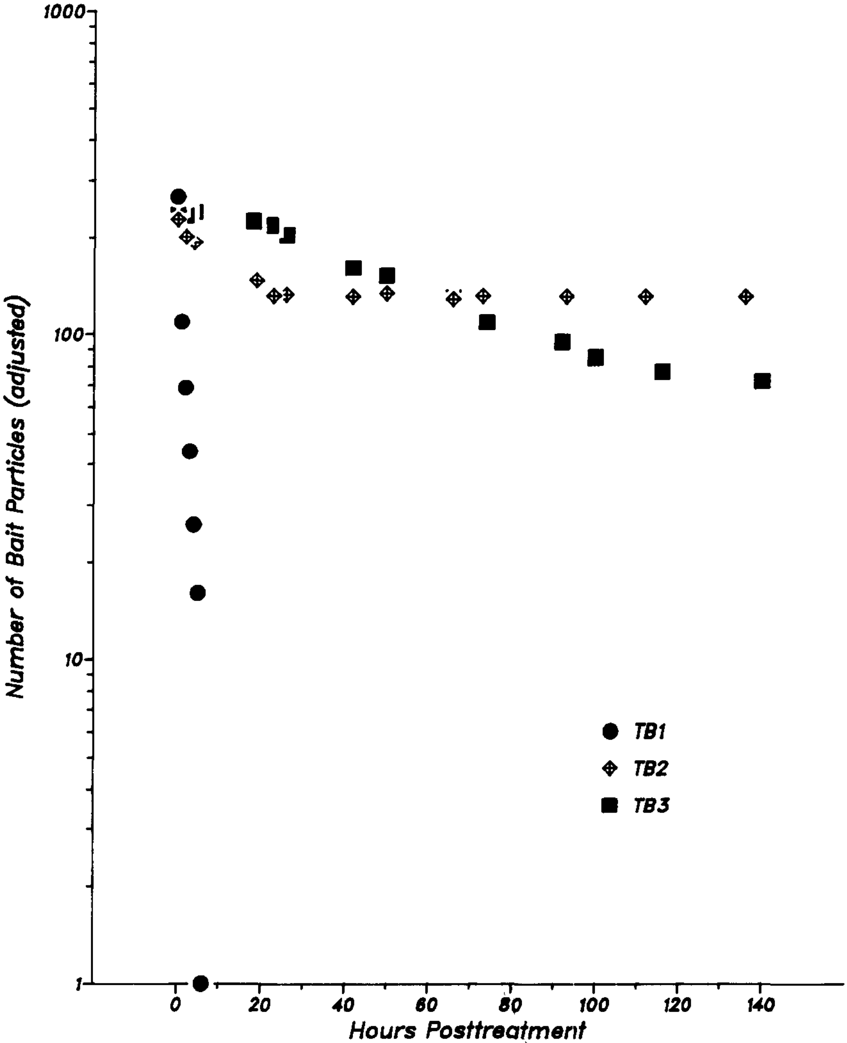

Figure 1. Plot of adjusted bait particle counts for each transect.

during treatment, and these particles continued to fall into sample sites when the wind moved the leaves. This caused higher counts of particles 4 hours post-treatment than the initial counts. Consequently, the number of bait particles immediately after treatment was estimated using the Y intercept of the exponential model. The pattern of bait loss is readily apparent when comparing regression values of the data for the time intervals <24 hours, >24 hours, and the entire 7-day posttreatment period. These values are equivalent and indicate a slow, constant loss of bait particles due to environmental conditions at

Table 7. Parameter values and correlation coefficients for exponential model[a] for disappearance of nifluridide bait on a Texas red fire ant study.

	Slope k	Intercept N_o	R
TB_1[b]	−0.772	328	0.93
TB_2[b]	−0.001	165	0.28
TB_2[c]	−0.021	217	0.99
TB_2[d]	−0.000	133	0.10
TB_3[b]	−0.010	252	0.99
TB_3[c]	−0.004	240	0.92
TB_3[d]	−0.009	242	0.98

[a] $N = N_oe^{-kt}$.
[b] Regression on all data.
[c] Regression on initial 24 hours posttreatment.
[d] Regression on all data except initial 24 hours.

the soil surface (cool, moist, and shaded), rather than active foraging by fire ants. Decomposition due to environmental conditions is supported by observations that the bait particles became lighter in color and appeared to be covered with a white or green tinted "mold" as the number of hours posttreatment increased.

Discussion and Conclusions

The apparent lack of primary poisoning hazards by nifluridide bait to birds and mammals could be related to several factors: (1) In areas of high red fire ant density, rapid removal of the bait reduced exposure to wildlife; (2) insectivorous birds may not have recognized the unfamiliar bait (PDCG) as food; (3) the bait carrier repelled passerine species (Schafer et al. 1982); (4) only 14.3 g/ha of technical nifluridide was applied.

During the posttreatment period, no bird or mammal remains were found that could be attributed to treatment. Height and density of vegetation hindered searching for carcasses; and the warm, humid conditions would have hastened carcass decomposition. However, had substantial bird or mammal mortality occurred within 6 days posttreatment, it would have been detected.

This study provided no evidence to suggest that nifluridide treatment caused immediate and significant mortality to birds and mammals. Small-mammal populations on 2 of the 3 plots were definitely not affected. These data suggest the decrease on the third plot was not treatment-related, because no mortality was detected, and nifluridide bait was not readily available to small mammals because red fire ants rapidly foraged the bait.

Bird populations did not appear to be grossly and immediately affected by nifluridide treatment because no carcasses were found. Although territories remained intact for the most part through the course of the study, it is not known to what extent, if any, territorial birds died or became sick and were rapidly replaced by others. Nevertheless, this phenomenon could not likely have been commonplace without carcasses being recovered.

The disappearance of well-documented white-eyed vireo territories following treatment may represent a treatment-related effect, and other insectivorous species with similar foraging habits such as common yellowthroats and Swainson's warblers also may have been affected. It is suggested that if there is further testing of nifluridide, the effects on insectivorous birds that forage on or close to the ground be closely watched.

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