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ABSTRACT: A 2.2 ha-cedar and mixed deciduous tree woodlot in Crawford, Mississippi, harboring 330,000 blackbirds (Icterinae) and European starlings (Sturnus vulgaris) was aerially sprayed by helicopter the night of 1 March 1989 with 1050 1 of a CPT-avicide formulation at a rate of 49 kg CPT/ha. Most mortality occurred within 36 h of treatment. Mortality in the roost was 3% of the pretreatment population. No reliable technique to estimate out-of-roost mortality was identified. Pilot misapplication and probable CPT volatilization of the spray formulation contributed to the low mortality. Only 1 of 37 radio-tagged blackbirds using the roost the night of the spray was verified as a CPT-related mortality. Pre- and posttreatment numbers of hawks and owls in and near the roost did not differ ($P > 0.05$). Dead nontarget animals found in and near the roost included 10 cardinals (Richmondena cardinalis), 1 robin (Turdus migratorius), and 1 least shrew (Cryptotis parva). Additional research is needed to develop methodologies for evaluating the efficacy of slow-acting toxicants.

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INTRODUCTION

Large roosts of blackbirds and European starlings often establish in areas where they are objectionable for agricultural, health, aesthetic, and nuisance reasons. The surfactant, PA-14, has been successfully used in spraying operations to lethally control roosting blackbirds and starlings (Heisterberg et al. 1987). The success of this technique depends upon delivery of large amounts of water synchronized with low temperatures (< 7°C). However, such requirements often cannot be met at a roosting location (Heisterberg et al. 1987). Therefore, a safe effective toxicant that can be used with less-restrictive requirements is needed.

One candidate contact toxicant is CPT (3-chloro-4-methylbenzenamine, DRC-1347), the basic compound used to make Starlicide® (DRC-1339) (Schafer et al. 1969). CPT is thought to decompose rapidly in the environment and has low toxicity to nontarget bird and mammal scavengers (Schafer et al. 1969). CPT aerial application tests in the U. S. and France showed potential field efficacy, but also identified problems related to formulations, delivery systems, and techniques of evaluating efficacy and environmental impact (Douville de Franssu et al. 1988, Linz et al. 1988, Cummings and Schafer 1989). Estimating the efficacy and environmental impact of CPT spray applications is difficult because mortality can take many hours to days to occur (Schafer, pers. comm.).

Therefore, as a first step in development of a roost toxicant for Environmental Protection Agency (EPA) registration, our objectives in conducting a field study were to evaluate methodologies used to determine the efficacy of CPT-Avicide spray applications and to evaluate any associated hazards to nontarget wildlife. Permission to conduct this study was given by EPA in January 1989.

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STUDY AREA AND METHODS

The test roost was located near Crawford, Lowndes County, Mississippi. Blackbirds and starlings were roosting in approximately 2.2 ha of a 12-ha cedar (Juniperus virginiana) and mixed deciduous tree woodlot (Fig. 1). Maximum tree height was 12 m. Nine 1.8-m wide transects were established in the roost to estimate spray deposits and bird mortality. The transects were evenly spaced and covered 880 m^2 or about 4% of the 2.2-ha roost area.

Daily temperatures averaged from 3° to 11°C, respectively, during the week before and after treatment. The only precipitation recorded during the study was 39 mm, on Days 3 and 4 posttreatment.

Chemical Formulation

The product tested was CPT-Avicide 16% glycol/alcohol concentrate which contains 16% (v/v) CPT, 36% (v/v) propylene glycol, and 48% (v/v) isopropyl alcohol. One hour before application 675 1 of CPT/glycol/alcohol concentrate, 375 1 of tap water and 10 kg of a water-soluble fluorescent dye marker (fluorescein) were mixed in a nurse tank. The 1050 1 of diluted product was transferred to the aircraft spray tanks where it was continuously agitated until application. The final product contained 10% (v/v) CPT, 23% (v/v) propylene glycol, 31% (v/v) isopropyl alcohol, and 36% (v/v) water. The dye concentration in the final spray product was approximately 1% (w/w).

Chemical Application

On the evening of 1 March 1989 weather conditions were ideal for aerial spraying (i.e., overcast sky, light east-southeast wind [2-6 km/h], 74% relative humidity, and 9°C). The roost area, marked with 4 barge lights in each corner, was treated at a rate of 477 1/ha (approximately 49 kg CPT/ha based on bioassays of the final spray formulation) using a Bell 47 Soloy helicopter. Four loads of approximately 260 1 each were applied from 2014 to 2044 h (2.5-3 h after sunset). The 10.4 m Warnell boom system (Ward Helicopter, Inc., Vivian,

Louisiana) covered a 15-m swath on the ground from a 46-m altitude.

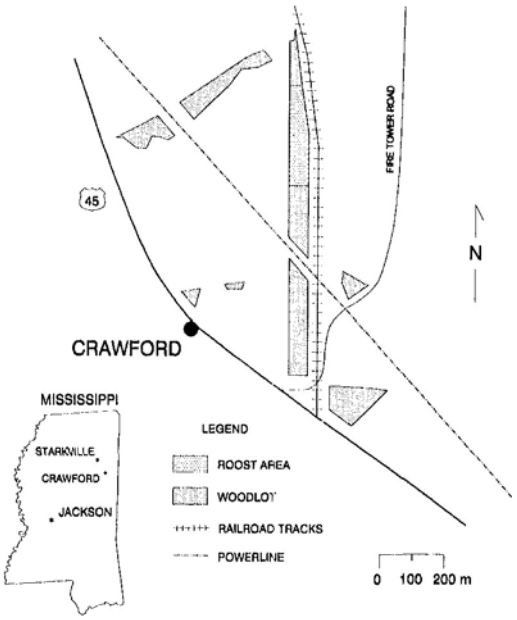

Figure 1. Location of study area, Crawford, Mississippi.

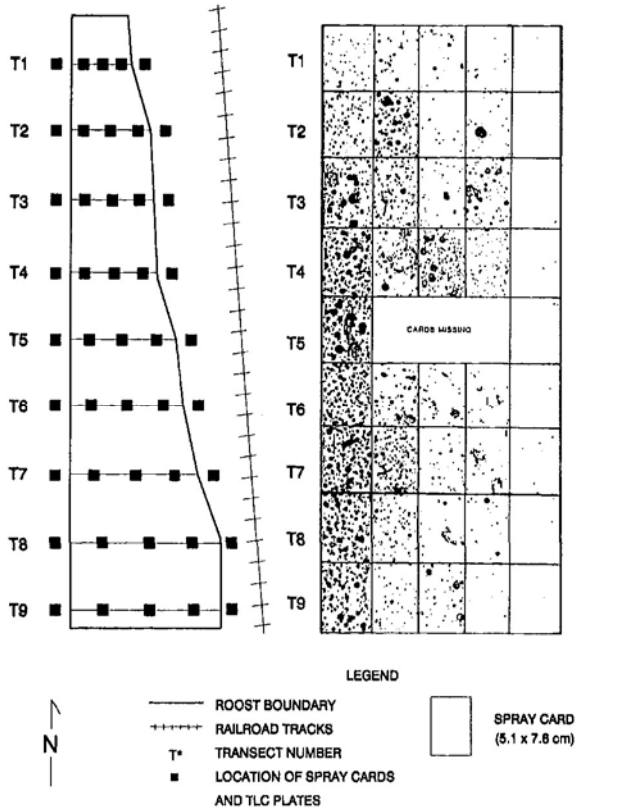

Figure 2. Location of roost transects (T), spray cards, and thin-layer chromatography (TLC) plates used to determine spray coverage, Crawford, Mississippi. Black marks on the photo mosaic on the right show where spray droplets impinged upon the spray cards. Spray cards on the right were located in the roost at the corresponding map location on the left.

Spray Deposition Evaluation

On the day of treatment, 45, 5.1 x 5.1-cm thin-layer chromatography (TLC) plates and 45, 5.1 x 7.6-cm oil-sensitive spray cards were placed on 1-m-high platforms along transects within the roost and around the perimeter of the roost to estimate spray volume and particle size of CPT applied (Fig. 2). Thirty-three TLC plates were also positioned north, south, east, and west of the roost at 100-m intervals up to 400 m from the roost boundary. TLC plates and spray cards located in the roost were collected 13 to 15 h posttreatment and TLC plates located outside the roost were collected 4 to 6 h posttreatment. TLC plates were immediately frozen and shipped to Denver Wildlife Research Center, Denver, Colorado (DWRC) for CPT assay using high-performance liquid chromatography with ultraviolet detection. From these data, the volume of liquid and amount of CPT deposited on the roost and surrounding area were determined.

Roost Population Estimates

Roost population estimates were made to assist in evaluating changes in the population related to CPT treatment. Daily counts of birds entering or leaving the treated roost were made by 2 to 4 observers (Meanley 1965). Species composition of the roosting population was estimated on 7 evenings pre- and posttreatment by haphazardly selecting and identifying 200 to 300 birds as they entered the roost (Dolbeer et al. 1978). Bird species recorded were common grackles (Quiscalus quiscula), starlings, and other blackbirds.

Mortality Estimates

Nine observers counted all dead birds in the roost 6 days posttreatment. Losses to scavengers were estimated by placing 90 marked blackbirds and starling carcasses on the transects the morning following treatment and following their fate through the 6-day posttreatment period. On Days 2 to 6 posttreatment the disposition of marked bird carcasses were recorded as either carcass intact, carcass missing, or carcass partially consumed. The number of carcasses remaining on Day 6 was used to adjust the total kill in the roost

The transects were searched for dead animals at 15, 36, 60, and 84 h posttreatment. The number and species of target birds and nontarget animals found dead on the transects were recorded but not removed. Additionally, 8 to 20 target species found dead near the transect lines were haphazardly collected during Days 1, 2, 3, and 4 posttreatment. These were examined for presence or absence of dye, and examined for pathological abnormalities (i.e., presence of white uric acid deposits on the heart) of CPT poisoning. All nontarget animals found dead were collected for pathological examination.

In addition, a 200-m long fence, located 0.5 km from the roost, was searched for dead birds 42, 67, and 91 h posttreatment. During each search, dead birds were collected, identified by species, and randomly sampled for presence of the dye marker.

Caged Birds

Captive birds were used to determine the fate of birds unable to escape during treatment. Five days before treatment grackles and red-winged blackbirds (Agelaius phoeniceus) were trapped in the foraging area around the roost and maintained in holding pens. Just prior to treatment

8 grackles and redwings were haphazardly assigned to each of 13 test cages. Each bird was confined to a 20 x 20-cm compartment. Nine of the cages were placed at the level of the tree canopy (5.5 m) midway along each transect in the roost. To estimate the amount of spray reaching the cages, a 5.1 x 5.1-cm TLC plate was placed on top of each cage. The other 4 cages of birds served as controls and were suspended in a nearby woodlot.

The morning after treatment birds were removed from the test cages, examined for dye marker, and placed in holding pens for observation for up to 6 days posttreatment. All test birds found dead were examined for pathological abnormalities. Test birds surviving the 6-day observation period were sacrificed and examined for pathological abnormalities. Percent mortality of each species in the captive bird population was determined.

Posttreatment Bird Collections

The morning after treatment blackbirds and starlings were followed as they exited the roost and collected by live-trapping and shooting. Live-trapped birds were captured in cannon nets at 3 prebaited sites 1 to 7 km away from the treated roost. Captured birds were placed in holding pens and inspected daily for 6 days posttreatment. Dead birds were removed and examined for the dye marker and examined for pathological signs of CPT poisoning. Birds surviving the 6-day observation period were sacrificed and similarly assessed. Data from these birds were used to support mortality estimates obtained by other means.

Those birds shot leaving the roost were examined for dye marker to help estimate the percentage of birds that came in contact with the spray formulation. Birds collected with and without evidence of the dye marker were randomly selected and examined for pathological signs of CPT poisoning.

Radio-tagged Birds

On 25-28 February, 28 male and female grackles and 29 male redwings were captured near the target roost, fitted with radio transmitters (Rt), and released to provide information on their movements and posttreatment fate. Movements of Rt birds were monitored daily and nightly until the night of treatment. Thereafter, only Rt birds in the target roost during the spray were monitored. We attempted to relocate each Rt bird at least two times during the day for a maximum of 6 days posttreatment. Any Rt birds found immobile were immediately recovered and examined for signs of CPT poisoning.

Birdshed Survey

A 16 to 19 km roadside survey route was established in the four cardinal directions from the roost to obtain an index of blackbird, starling, and hawk numbers in the foraging range (birdshed) of the roost birds before and after treatment. Permanent survey stops were established at 0.8-km intervals on each route. Routes were driven daily from 1200 to 1630 from 4 days pretreatment to 6 days posttreatment. At each stop the observer surveyed the countryside with binoculars for 1 minute and recorded the species and number of birds observed.

To assess changes in the bird populations in the birdshed, the number of census stops with birds in various numerical categories (0, 1-100, 101-1000, > 1000) were compared 4 days pre- and 6 days posttreatment by Chi-square analysis. Blackbirds and starlings were analyzed together. Red-tailed hawks (Buteo jamaicensis), American kestrels (Falco sparverius), and turkey vultures (Cathartes aura) were analyzed separately using rank sum analysis.

Impact on Nontarget Species

Nontarget bird and selected mammal species were censused in the roost and its immediate environs. A 2-km route around the roost periphery was walked by two observers daily over a 2-h period starting between 0730 and 1000 h from 3 days pretreatment to 5 days posttreatment. The number of animals in various categories observed per route per day for the 3-day pretreatment period was compared with Days 1 to 5 posttreatment using a 2-sample rank sum test.

The presence of barred owls (Strix varia), great horned owls (Bubo virginanus) and screech owls (Otus asio) was monitored at the roost pre- and posttreatment by broadcasting 30-min tape-recorded owl calls from two stations at the roost edge on Nights 1 and 3 pretreatment and Nights 1, 3, 5, and 7 posttreatment. Number of owls responding was compared pre- and posttreatment.

Two other methods of monitoring nontarget species were used. Daily counts of hawks (Buteo spp.) using the immediate roost area were recorded in 5-min intervals over a 1-h period beginning at sunrise for 3 days pre- and 6 days posttreatment. Finally, all nontarget birds and mammals observed during the posttreatment roost searches were recorded by species.

RESULTS

Chemical Application and Spray Deposition

Observers with night vision goggles reported minimal bird flushing during the spray. An estimated 5,000 to 6,000 birds (< 2% of roost populations) abandoned the roost area during the spray. We observed most birds departing during the first application.

An average 4.6 kg CPT/ha (SD = 6.7, range 0.01-26.0 kg/ha) was recovered from the 45 TLC plates positioned in and along the edge of the roost. This is 91% less than the expected 49 kg CPT/ha application rate. All 45 TLC plates assayed positive for CPT. However, spray coverage was extremely uneven. Levels of spray coverage increased from east to west suggesting that the west portion of the roost was sprayed more than once. For example, the 9 TLC plates located along the east boundary of the roost averaged 0.01 kg an CPT/ha (SD = 0.002, range 0-0.02 kg CPT/ha) compared with average 14.1 kg CPT/ha (SD = 8.1, range 0.8 -26.0 kg CPT/ha) for the 9 TLC plates along the west boundary.

Spray cards also indicated uneven coverage (Fig. 2). Two spray cards within the roost showing the highest and lowest spray volumes were examined for droplet size and volume. The cards showed a volume median diameter of 53 (range 16-818) and 50 (range 16-152) microns, respectively. Spray density estimates based on these cards were 25.0 and 0.4 kg CPT/ha, respectively.

The 33 TLC plates positioned 100 to 400 m outside the roost site received very little spray drift. No CPT was recovered from the 12 TLC plates located 100 to 400 m north, south, and east of the roost site. The 21 TLC plates located 100 to 400 m west, northwest, and southwest of the roost site received an average 0.5 kg CPT/ha (SD = 1.5, range 0-5.3 kg CPT/ha) with most of that (92%) being recovered from 2 TLC plates located 100 m directly west of the roost. These 2 plates were located in an open field which

the pilot inadvertently sprayed while attempting to unclog his spray nozzles.

Assays of TLC plates positioned on top of the 9 cages suspended in the roost canopy showed an average 6.0 kg CPT/ha (SD = 6.4, range 0.2-17.8 kg CPT/ha) hitting the cages. This is 88% less than the expected 49 kg CPT/ha application rate.

Roosting Bird Populations

Blackbirds and starlings were first reported using portions of the 12-ha woodlot in December 1988. Roost counts before the spray varied between a low of 165,000 birds on 23 February and a high of 537,000 birds on 28 February (Fig. 3). An estimated 330,000 birds used the roost the night of treatment. The population decreased to 70,000 5 days posttreatment and the roost was abandoned 13 days posttreatment (14 March).

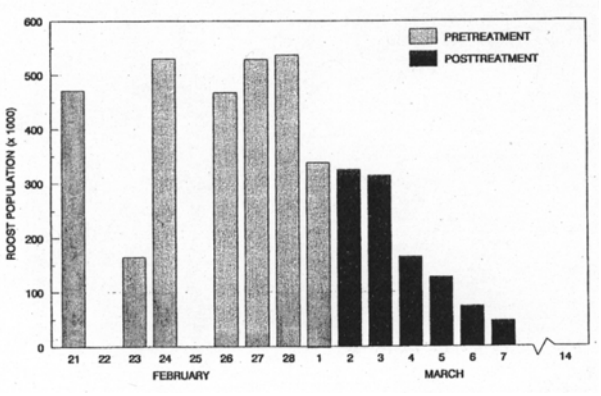

Figure 3. Population estimates of birds using the Crawford, Mississippi roost during February and March 1989.

Species composition estimates of the roost pre- and posttreatment averaged 37 and 25% grackles, 50 and 58% other blackbirds (redwings, brown-headed cowbirds [Molothrus ater]. rusty blackbirds [Euphagus carolinus]) 11 and 14% starlings, and 2 and 3% robins, respectively.

Three days posttreatment birds were first noted using a cedar woodlot 1.6 km south-southwest of the spray roost. On 7 March we estimated that 50,000 birds used this roost which was comprised of 40% robins and 60% blackbirds and starlings (n = 70). This satellite roost probably formed in response to the treatment. We checked the satellite roost 6 days posttreatment and found no dead birds on the ground and very few droppings indicating no treatment- related mortality and only recent occupancy by birds.

Target Bird Mortality

On Day 1 posttreatment, target birds did not immediately depart the roost as on previous mornings. Departures were staggered over a 2-h period compared to an average 8-min departure time for the pretreatment mornings. Thousands of obviously sick birds flew < 3 km from the roost to nearby woodlots where they were eventually found dead. Many of these birds were observed drinking water, a behavior often associated with birds experiencing uremic poisoning. Six days posttreatment (7 March), we counted 7,545 dead target birds in the entire roost which represented 54% starlings, 24% grackles, 18% cowbirds, 4% redwings, and <1% rusty blackbirds. Scavengers removed 31% of the carcasses during the 6-day posttreatment evaluation period. Thus, the mortality in the roost may have been as high as 10,950 (7,545 ÷ 62/90) or about 3% of the roosting population.

Counts of dead birds on the transects indicated that 16% of the mortality occurred within 15 h of treatment and the remaining 84% occurred during the subsequent 21 h (Table 1). Although starlings made up only 11% of the pretreatment roosting population, they made up 54% of the total kill. Total numbers of dead birds decreased after 36 h posttreatment because of scavenging and heavy rains that washed some birds off the transects.

Of 49 dead blackbirds and starlings randomly collected from the transects 15 to 84 h posttreatment, 36 had dye marker on their plumage. Of these, 80% showed pathological abnormalities associated with CPT poisoning. The other 13 birds showed no evidence of dye marker; however, 11 had internal abnormalities due to CPT poisoning. Only 2 birds had no indications of coming in contact with the spray.

Table 1. CPT posttreatment in-roost mortality by species found on 9, 1.8-m wide transects in Crawford, Mississippi[a]

Hours post-treatment	Species composition					
	Starling	Cowbird	Grackle	Redwing	Rusty blackbird	Cumulative total
15	1 (2%)	31 (67%)	11 (24%)	2 (4%)	1 (2%)	46
36	151 (54%)	62 (22%)	58 (21%)	8 (3%)	2 (1%)	281
60	139 (54%)	58 (23%)	50 (20%)	8 (3%)	1 (1%)	256
84	134 (55%)	57 (23%)	43 (18%)	10 (4%)	1 (1%)	245

[a]Birds counted during each posttreatment search include those counted during previous searches less those removed by scavengers or washed off transects by heavy rains.

The species composition of the dead birds in the roost indicated that 50% of the cowbirds succumbed within 15 h posttreatment, whereas most grackles, redwings, and starlings died between 15 and 36 h.

Dead birds were collected from the 200-m fence row during 3 posttreatment searches. Of 1084 birds collected, 1073 (99%) died within 42 h posttreatment. Species composition of the birds collected were 63% cowbirds, 15% grackles, 15% starlings, 5% redwings, and 2% rusty blackbirds.

Exposure of Caged Birds to Spray Application

Of the 50 grackles and 22 redwings suspended in cages in the roost canopy, 13% (7 grackles, 2 redwings) died within 12 h posttreatment, 51% (27 grackles, 10 redwings) died within 36 h posttreatment, and 61% (34 grackles, 10 redwings) died within the 6-day observation period. All 72 birds showed signs of the dye marker at 12 h posttreatment. However, at the time of death only 29% of the 72 were externally marked, indicating that the water-soluble dye had washed from their feathers. Of the 72 birds, 54 showed pathological abnormalities of CPT poisoning. Of those birds, 44 died during the 6-day observation period. All 32 reference birds survived the 6-day observation period.

Posttreatment Bird Collections

Blackbirds (116 redwings, 92 grackles, and 30 cowbirds) were cannon netted 10 to 13 h posttreatment. Of these 238 birds, 64 (27%) were marked with dye. The marked birds and 57 of the 174 unmarked birds were placed in holding pens for observation. Of the 64 marked birds, 18 (28%) died within 36 h and 27 (42%) died within 6 days. Of the 27 dead birds, 13 showed signs of CPT poisoning. None of the 57 unmarked birds died during the 6-day posttreatment observation period. All marked and unmarked birds surviving the 6-day observation period showed no signs of either the dye marker or CPT poisoning.

The morning after treatment (10 to 14 h posttreatment) 157 cowbirds, 141 redwings, 60 grackles, and 6 starlings were shot 2 to 11 km away from the roost. Of these 364 birds, 99 (27%) had dye marker on their plumage. Pathological examinations of 61 randomly selected birds (23 marked with dye, 38 unmarked) showed only 1 bird (marked with dye) with signs of CPT poisoning.

Radio-tagged Birds

Of the 57 Rt birds, 37 (19 grackles and 18 redwings) were in the roost the night of treatment. During the application period, triangulation coordinates of Rt birds indicated bird movement within the sprayed area and at least 6 of the 37 Rt birds may have moved to unsprayed habitat bordering the main roost. Of 37 monitored Rt birds, 25 (68%) were alive and moving normally 6 days posttreatment. The majority of these foraged within 12 km of the spray roost and returned to either the spray or satellite roost during the evening. Three redwings moved 19 to 58 km north of the spray roost by the end of the 6-day tracking period. The only confirmed CPT mortality was 1 grackle found dead in the roost 60 h posttreatment. Of the remaining 11 Rt birds, 3 lost their radios, 1 was apparently killed by a raptor and had no evidence of CPT poisoning, 1 was shot and had no evidence of CPT poisoning, and 6 could not be found.

Impact on Nontarget Populations

Ten cardinals, 1 robin, and 1 least shrew were found dead in the roost during the 6-day posttreatment search. Nine of the 11 birds showed signs of CPT poisoning; the shrew was not analyzed. No dead nontargets were found on transects or observed away from the roost.

The number of nontarget species noted in and around the roost did not differ ($P > 0.05$ $\bar{x} = 19.4$, SD = 5.8) between pre- and postspray. No nontarget animals were found dead along the survey route. Cardinals were the most abundant nontarget bird observed at the roost site. Cardinal numbers in and within 100 m of the roost did not differ ($P > 0.05$, $\bar{x} = 24.0$, SD = 4.8) pre- and postspray. Hawk numbers also did not differ ($P > 0.05$, $\bar{x} = 7.5$, SD = 3.5) along the nontarget survey route pre- and posttreatment.

The number of buteos observed for approximately 1 h after sunrise did not differ ($P > 0.05$, $\bar{x} = 3.4$, SD = 1.3) between pre- and posttreatment. However, the behavior of the hawks and numbers seen were notably different during the first 2 days posttreatment. This change probably reflected the satiated state of the hawks from feeding on sick or dead birds.

Screech, barred, and great horned owl populations around the roost did not change between pre- and postspray. Five calls (3 great horned, 1 screech, 1 barred) were recorded during the two pretreatment surveys and 7 calls (4 screech, 3 great horned) were recorded during the four posttreatment surveys. No dead owls were found in or near the roost.

Birdshed Survey

Numbers of stops with blackbird and starling flocks seen did not differ ($P > 0.05$) pre- and posttreatment. Numbers of red-tailed hawks, kestrels and turkey vultures observed also did not differ ($P > 0.05$) pre- and posttreatment. Thus, there was no evidence that the CPT spray impacted the numbers of blackbirds and starlings or the birds of prey.

DISCUSSION

Chemical Application and Spray Deposition

Massive flushing reported by Lefebvre et al. (1979,1980) during previous experimental toxicant sprays was avoided in this experiment by spraying after sunset under overcast skies and by the helicopter staying > 33 m above the vegetation (Mott 1983). These conditions minimized bird flushing to < 2%. However, dark overcast spray conditions made it difficult for the spray pilot to discern the roost boundary, attributing to uneven spray coverage of the roost. Additional lights designating a predetermined flight path and/or night flying devices may reduce the chance of misapplication.

The amount of CPT recovered from TLC plates positioned on the transects in the roost averaged 91% less than the expected 49 kg CPT/ha application rate. Intercept by roosting vegetation and pilot spray misapplication undoubtedly contributed to this discrepancy. Interestingly, however, the 9 TLC plates positioned along the west perimeter of the roost which received the heaviest spray application were in the open about 2 to 3 m from any roosting vegetation. An average 14.1 kg CPT/ha was recovered from these TLC plates which is still 71% less than the expected application rate. Possible explanations for this discrepancy are volatilization of the CPT before and after reaching the TLC plates, inadequate sampling points, and

inefficient recovery of CPT by the TLC plates. Lab studies subsequent to our study showed a 17% decrease in CPT from TLC plates after 12 h exposure in open air space (Mishalanie, unpubl. data). The apparent high volatility of CPT is desirable from the standpoint of rapid degradation in the environment. This advantage, however, may be offset by the possible loss of CPT in the air after it leaves the spray aircraft.

Target Bird Mortality

We found about 3% of the pretreatment roosting population dead in the roost. In comparison, Douville de Franssu et al. (1988) applied 100 kg CPT/ha on European starling roosts in France and estimated in-roost mortality to be about 22% of the roosting population. Lefebvre et al. (1979, 1980) applied 22.4 kg CAT/ha (CAT is a compound similar to CPT) on two blackbird roosts in Arkansas and found an average of 0.6% of the roosting population dead in the roost and nearby areas. We agreed with their conclusion that the in-roost kills probably represented only a small portion of the overall kill.

Most in-roost mortality occurred within 36 h after treatment. Cowbirds appeared to die faster than the other target species, indicating that cowbirds were either more sensitive to CPT or were in areas of the most heavily treated roosting vegetation. Species composition of the in-roost kill did not agree with pretreatment estimates. Notably, starlings accounted for 54% of the in-roost kill but made up only 11% of the pretreatment population. Lab studies show that starlings are more resistant than blackbirds to CPT (Schafer, unpubl. data). The reason for this discrepancy is unknown.

The morning after treatment thousands of birds exiting the roost flew only short distances to nearby woodlots and watering areas where they eventually died. The 1,084 dead birds that we found along a fence row 0.5 km from the roost indicated that considerable mortality occurred nearby. Future evaluations of slow-acting toxicants should include intensive carcass surveys of woodlot areas near the roost.

We found no changes in the numbers of flocks of blackbirds and starlings observed in the birdshed pre- and posttreatment. This is not surprising given the probable low roost kill and extreme daily fluctuations in roosting bird numbers which were unrelated to the spray operation.

The fluorescein dye marker used in the spray formulation was a useful indicator of spray coverage of roosting birds. The water soluble nature of fluorescein, however, makes it easily washed off birds and an unreliable marker after a day or two. Fluorescein was a poor indicator of bird mortality as we could find no consistent relationship between birds marked and CPT-verified mortality. Fluorescein can, however, be accurately quantified from TLC plates, and its stable nature may make it a more reliable indicator of spray formulation applied (Mishalanie, pers. comm.).

Both the shotgun and cannon net samples of birds leaving the roost the morning after treatment showed 27% of the birds with dye marker. Since these collections occurred within 14 h after treatment, the dye probably did not have a chance to wash off the birds. If the shotgun collections can be considered a random sampling of birds leaving the roost, then 27% of the roosting population came in contact, at least to some degree, with the spray formulation.

We found no reliable technique for estimating bird mortality occurring away from the roost site. Pretreatment roost counts fluctuated widely making any mortality estimates based on changes in bird numbers of dubious value. Such drastic changes in bird numbers using a roost are not uncommon. Heisterberg et al. (1984) found an average 32% daily turnover of blackbird and starling populations. The advent of spring migration may also have contributed to these fluctuations. Posttreatment roost counts can also be confounded by surviving birds abandoning a roost site in response to spray activities (Heisterberg et al. 1987).

Live-trapping birds leaving the roost the morning after treatment and holding them for observation to determine their fate gave some indication of percent mortality occurring away from the roost. Of the 238 birds that were live-trapped, 27 (11%) eventually died and 13 (5%) showed internal signs of CPT poisoning. This technique, however, assumes that both affected and unaffected birds are equally attracted to bait sites. This may not be the case as thousands of sick birds observed exiting the roost flew < 3 km to woodlots and watering areas where they eventually died. One way to overcome this possible sampling bias would be to mist net birds in and around the perimeter of the roost as they leave the morning after the spray.

Monitoring the posttreatment fate of the 37 Rt birds using the roost the night of treatment confirmed only 1 CPT mortality, giving a 3% (1 ÷ 37) mortality estimate. The fate of 9 of the 37 birds could not be determined because of lost radio contact or detached radios. The relatively high percentage (24%) of birds that could not be accounted for suggests an underestimate of roost mortality. Also, the extremely small sample size of Rt birds made the usefulness of radio telemetry doubtful as a mortality-estimation technique. Lefebvre et al. (1979, 1980) also found Rt birds of little use in evaluating the efficacy of slow-acting toxicants. We feel that radio telemetry as an efficacy evaluation technique has been adequately investigated and recommend that it not be used in future efficacy evaluations.

Suspending birds in cages in the roost the night of treatment and subsequently holding them for observation to determine percent mortality gave some indication of the fate of birds unable to escape the spray application. The location of the caged birds in the center of the roost (midway along each transect) probably accounted for the relatively high percent (61%) mortality compared to the other efficacy evaluation methods. These cages received an average 6.0 kg CPT/ha, which was 30% more spray formulation than was recovered from the TLC plates positioned throughout the roost. We suggest that the placing of cages throughout the tree canopy at levels where the birds are roosting may be useful in estimating the percent kill of a spray operation.

Impact on Nontarget Animals

We did not identify any changes in nontarget bird or mammal numbers during the pre- and posttreatment walking censuses, buteo and owl surveys, and birdshed surveys. The only dead nontargets we found were 10 cardinals, 1 robin, and 1 least shrew. Nine of the 11 birds showed external signs of the dye marker, indicating that they were directly sprayed during treatment. No other dead nontargets were found either in or away from the roost. However, the high percentage (31%) of carcasses removed from the roost transects indicates that a large number of scavengers were utilizing the roost. We observed foxes (Vulpes fulva), domestic cats (Felis domesticus) and dogs (Canus familiarus) foraging in the roost area. Additionally, we saw opossum (Didelphis marsupialis) and raccoon (Procyon lotor) tracks in

the roost. Although we found no indications of secondary poisoning to scavengers or predators, future studies involving more sophisticated hazard assessment techniques will be necessary to address this issue.

RESEARCH STATUS

Development of effective delivery systems for aerially applied avicides involves complex spray technologies. Recent developments in avicide delivery systems such as ultra low-volume (ULV) spraying of quelea (Quelea quelea) in Africa (Manikowski 1988) may have some utility in bird control in the United States. The DWRC is tentatively planning to investigate the use of ULV and other spray application techniques.

Initial probes conducted at the DWRC subsequent to this study have shown the CPT formulation to be markedly more lethal to starlings when applied as an inhalant mist than when applied dermally (Thompson, pers. comm.). These findings suggest that spray applications using ULV application methods may be developed that not only require less chemical but are more efficacious. This research project is also designed to gather comparative toxicity data on CPT and DRC-1339. If no differences in the properties of these two related compounds can be identified, it may be cost effective to consider use of DRC-1339 in future roost toxicant development. The advantage is that DRC-1339 is currently under going reregistration by EPA, and some of the data that will be generated in support of this registration could also be used to support development of DRC-1339 as a roost toxicant. Another study at DWRC is examining changes in blood chemistry of birds exposed to CPT treatment. This study is designed to develop predictive mortality models based on levels of uric acid or other parameters in the blood after treatment (Thompson, pers. comm.). Pending results of these studies, additional testing will be conducted to refine field application and evaluation techniques.

Future field testing of CPT will require an Environmental Use Permit (EUP) from EPA. Before EPA will consider issuing an EUP, several environmental fate and toxicology laboratory studies will be required. Because some of these studies require up to 18 months to complete, further field testing will be delayed until at least 1992.

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