THE EFFECTS OF ORCHARD PESTICIDE APPLICATIONS ON BREEDING ROBINS

ERIC V. JOHNSON, GUILFORD L. MACK, AND DANIEL Q. THOMPSON

In June 1965, the senior author visited a commercial fruit farm in New York's Hudson River Valley and discovered that American Robins (*Turdus migratorius*) were nesting in the orchards despite the fact that DDT and other toxic chemicals were applied regularly to the apple trees as part of a pest control program. At that time most DDT-robin studies had dealt with Dutch elm disease control programs on university campuses (e.g., Wallace 1962) or in residential communities (e.g., Wurster et al. 1965); no studies had concerned DDT-songbird relationships in agricultural areas with a long history of heavy organochlorine insecticide applications.

The results reported here are the culmination of a 3-year field and laboratory investigation of robin-pesticide ecology on this farm. The objectives were to examine robin productivity and behavior patterns in the orchards, as well as organochlorine insecticide content of the birds and their food items.

STUDY AREA AND METHODS

Study area.—This study was conducted on a commercial apple, cherry, and peach farm located near the village of New Paltz in New York's central Hudson Valley. The farm (Fig. 1) comprised a total of about 138 ha, with 97 ha in mature fruit trees on a northwest-facing slope. The orchards were bordered on the northwest, south, and northeast by woodlots of 36.4, 26.3, and 10.1 ha respectively; in addition a brushy edge of 26.3 ha formed the eastern boundary. The ground cover beneath mature apple and cherry trees, along the spray paths, and around the irrigation ponds was poison ivy (*Rhus toxicodendron*) and orchard grass (*Dactylis glomerata*), as well as many "volunteer" perennial grasses and legumes (including red clover, *Trifolium pratense*, and vetch, *Vicia americana*). Orchards of peach trees and newly planted apple trees were customarily cultivated throughout the growing season with a rotary disc.

The woodlots were fairly mature second-growth mixed hardwoods composed of elm (*Ulmus americana*), hickory (*Carya* sp.), beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), and hemlock (*Tsuga canadensis*), with hornbeam (*Carpinus caroliniana*) and yellow birch (*Betula lutea*) the major understory species, and with little ground cover. Other unplanted areas were all poorly drained marginal habitat with a scrubby growth of forbs and shrubs (*Cornus* sp. and *Salix* sp.).

The major reason for working on this study area was the long history of pesticide application. The land had been planted in fruit trees since the mid-1920's, and had received DDT since 1947. Application rates of DDT in the late 1940's were 45 kg or more of pure compound per ha/year; organophosphates were replacing most organochlorines while this study was in progress.

Spray schedules followed very closely the general recommendations for fruit crops issued by the New York State College of Agriculture and Life Sciences at Cornell Uni-
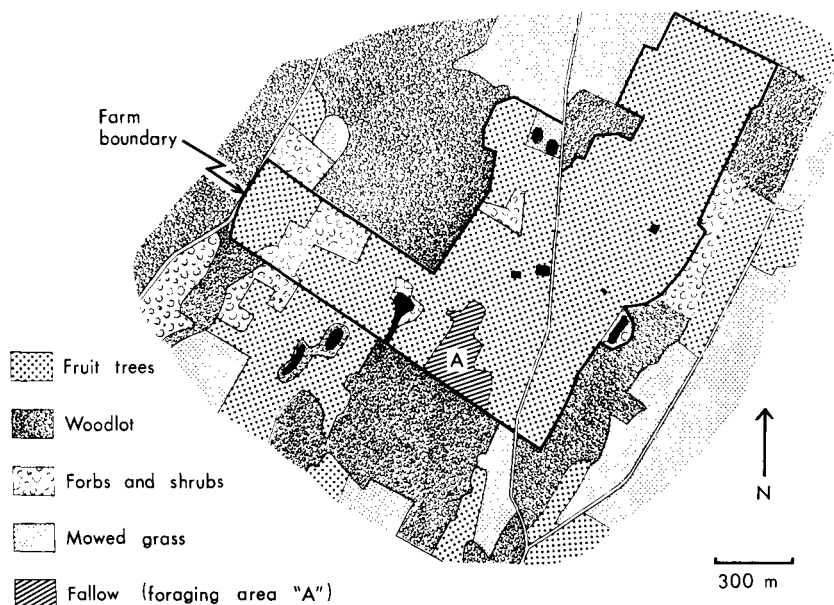
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FIG. 1. The New Paltz, New York, study area.

versity. A detailed account of all sprays applied to the farm would be extremely complex, since each orchard was individually treated according to apple variety and insect damage. A summary of the major insecticides applied to the apple trees during this investigation, and the application rates, are listed in Table 1. The grower was generally careful to avoid spraying during windy periods, but sometimes this was unavoidable. Under windy conditions (velocities of 25 to 40 km/hr) the spray could be seen to drift at least 30 m downwind.

Methods.—During each of the 3 summers of field work, the entire farm (29 orchards) was systematically searched at least twice, once in early May and again in mid-June, to locate robin nests. Subsequent searches in early winter, after the leaves had fallen, were made to obtain estimates of the number of nests not located each summer. Nearly all robin fledglings produced in the orchards were banded with U.S. Fish and Wildlife Service bands and, in addition, with colored bands to facilitate sight identification of individuals after they had left the nest.

Movement patterns of robins to and from their foraging areas were followed by a 2-man team using walkie-talkies. Despite the fact that individual adults were not marked, we are certain that birds so followed were correctly identified as to nest occupancy. The time, if any, between loss of sight of a bird by one observer and acquisition by the other was usually less than 10 sec. Furthermore the birds were distributed rather sparsely throughout the orchards so that it was highly probable that a bird seen carrying food into a particular orchard was returning to the nest known to be active in that area.

Food item determinations were made from gizzard contents of all robins collected for residue analysis. The sample consisted of 20 adults shot in April and 10 shot in June

<center>TABLE 1</center>

<center>MAJOR INSECTICIDES APPLIED TO THE STUDY ORCHARDS</center>

Compound	% active ingredient	Kg actual per ha per application	No. of applications each year
DDT	50	5.61	2
Dieldrin	50	1.40	2
Guthion and	25	1.40	7 to 10 in various
Carbaryl	50	5.61	combinations
Lead arsenate	98	22.45	2 or 3

and July, in both 1966 and 1967 (a total of 60 birds), as well as 33 nestlings (1 to 14 days old) removed from nests in 1967. Additional birds were obtained in 1968. Food items brought to nestlings by adults were identified as completely as possible by watching nests with binoculars and a 30× telescope.

An indoor experiment was conducted during the winter of 1967–68 to determine if earthworms could survive in the orchard soil. As controls, five 0.028-m³ boxes were filled with soil from unsprayed areas of the farm where worms were living in good numbers. Twenty 0.028-m³ boxes were divided into 4 sub-groups. Each sub-group received soil from one apple orchard on the farm where robins nested successfully each year. Soil was taken in October when, it was thought, it would contain a maximum load of chemicals. Efforts were made to take all soil in such a manner that the resulting hole measured 0.3 m × 0.3 m × 0.3 m; that is, soil was taken down to the 0.3 m level rather than scraped from the surface where most chemicals are likely to be concentrated (Chisholm et al. 1950). All soil was examined prior to the introduction of worms. Worms present in the control soil were removed; none were found in orchard samples. Into each box we put 25 worms collected from an unsprayed area of soil type similar to that of orchard soil. *Lumbricus terrestris*, *L. rubellus*, and *Octolasium lacteum* were the worm species represented, and individuals were randomly assigned to the boxes. Boxes were kept moist and sod was maintained. Worms were periodically removed by hand from all boxes, weighed, counted, and returned. The experiment was terminated at the end of 90 days.

From April to June, 1968, 45 traps for invertebrates were placed in the apple orchard of highest robin nesting density, and 45 in an adjacent, heavily used foraging area of approximately equal size. The traps were empty, unused paint cans, 10.2 cm deep and 8.6 cm in diameter, with an overhanging lip; they were sunk into the ground so their tops were flush with the ground surface. All traps were opened for 2-day periods, then emptied, contents counted and identified, and traps closed until the next sampling period. There were 7 such sampling periods, covering the time from mid-April until mid-June, roughly the peak of robin breeding activity.

No sampling of caterpillars was conducted, nor were there any experiments concerning them, since, unlike ground beetles and worms, they were "target organisms" of the spray program and were extremely scarce on orchard trees.

Soils throughout the study area were sampled for DDT and dieldrin analyses in April, 1966, before spraying of chlorinated hydrocarbons began, and again in early October after all such spraying had ceased. Five cores 4.13 cm in diameter and 7.62 cm deep

were collected from under the "drip zone" of each of 10 trees in 4 separate orchards. Fifty cores were also collected from each of 2 areas of non-orchard habitat where robins foraged.

Invertebrates, principally earthworms (Lumbricidae) and caterpillars (mostly Tortricidae), were collected by hand both before and during the robin breeding season from the major foraging areas. Commercial cherries were analyzed as a composite sample of ripe fruit removed at random from 20 trees. Wild cherries (*Prunus serotina*) were likewise analyzed as one sample of fruit removed from bushes at 2 different locations on the farm periphery.

Each year, in late April, 10 robins were collected from the orchards, and 10 were obtained at the same time from adjacent unsprayed areas within 300 m of the sprayed orchards. Ten additional robins were collected from the orchards each year in the period from late May to mid-July.

Our original intention was to collect 10 unincubated eggs for analysis in 1967. Only 3 fresh eggs were obtained because of the difficulty in locating nests while the clutches were incomplete.

Seventeen live and apparently healthy nestlings of known age were collected in 1967 from 10 orchard nests, and 15 additional nestlings from 9 nests were collected when discovered dead in or near their nests. Two additional robins raised on the study area were captured as independent juveniles in the cherry orchard in 1967, and these were also collected for analysis.

Extraction procedure for robin tissue analysis was essentially that of Hamence et al. (1965), involving extraction with acetone and hexane, with an acetonitrile cleanup. Birds were plucked rather than skinned, and brain, liver, and muscular tissue ("remainders") of the adult birds were analyzed separately. Eggs were extracted according to a method provided by W. L. Reichel, Patuxent Wildlife Research Center, which involved drying the sample with sodium sulfate and extracting with petroleum ether or acetone for 15 hr. All extracts were eluted through a florisil column (Mills et al. 1963) to separate DDE and dieldrin; the column was standardized according to the lauric acid method of Mills (1968).

All analyses were conducted by gas chromatography using an electron affinity detector. Temperature at injection port was 225°C; temperature of the column and detector was 195°C. The carrier gas was nitrogen. Six different columns were used, either 0.92 m $\times$ 0.32 cm or 1.78 m $\times$ 0.32 cm, packed with varying combinations of Dow 11, QF-1, DC 200, and XE-60 on Gas-chrom Q 60/80 mesh, Gas-chrom Q 80/100 mesh, or Chromsorb W 60/80 mesh. Certain identifications were confirmed by thin-layer chromatography.

RESULTS

Nesting activity.—To construct nesting-activity curves (Fig. 2), we back-dated nests found active during the breeding season by allowing 1 day for each egg, 12 days for incubation (including the day the last egg was laid), and 14 days for fledging. As determined from these nest-activity curves, there were at least 22, 22, and 13 breeding pairs of robins present in 1966, 1967, and 1968 respectively.

The nesting season began each year about 20 April, and extended at least until 10 July, with the peak of nesting occurring between 25 May and 1 June
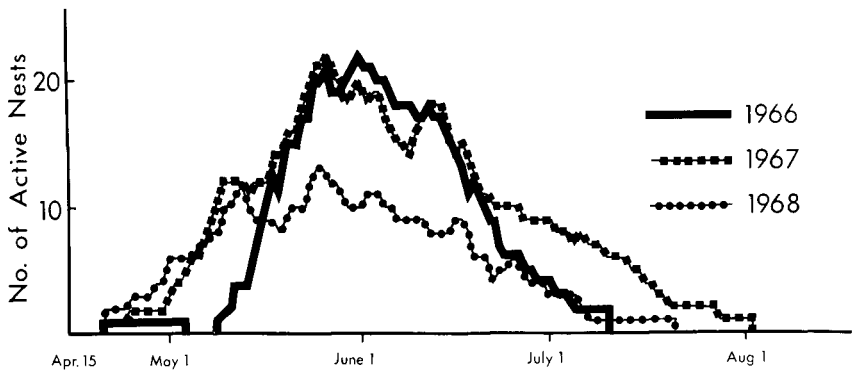
FIG. 2. Robin nesting activity in the study area for 3 years. The peak of each curve denotes the minimum number of breeding pairs present for that year.

(Fig. 2). This period of breeding activity agrees closely with that reported by several authors for this latitude (Howell 1942, Eaton 1914, Young 1955). While the length of the nesting season allows time for at least 2 successful broods per female, the unimodal shape of the nesting-activity curves are probably the result of late successful first nestings of birds whose first attempts failed.

Clutch size.—Frequencies of clutch sizes in this study were compared by chi-square analysis with pooled data obtained in 3 other robin studies (Table 2). Results indicated a highly significant difference, $p < .005$, with a higher frequency of 1-egg clutches and a lower frequency of 4-egg clutches in the present study.

Egg and nestling mortality.—A mortality curve for 294 eggs (Fig. 3) shows that mortality was fairly evenly distributed over the first 20 days, from day of laying until nestlings were 7 days old. Beyond that point nestling mortality was negligible. All eggs were assumed present on the first day of laying to avoid masking mortality during clutch completion. In many cases, the exact day of death or predation was known. In instances where eggs or chicks were alive at one visit but dead on the next, we have taken the median day as the date of death. The sharp decline between day 1 and 2 of the nestling period is an artifact of the way we have chosen to treat unhatched eggs. In this period, we counted as dead all eggs which failed to hatch, regardless of whether they were infertile or contained dead embryos.

Causes of mortality were diverse. Predation was generally attributable to House Wrens (*Troglodytes aedon*), Blue Jays (*Cyanocitta cristata*), or Common Grackles (*Quiscalus quiscula*), though red and gray squirrels (*Tami-*

TABLE 2

COMPARISON OF FREQUENCIES OF ROBIN CLUTCH SIZES FROM NEW PALTZ STUDY AREA
WITH POOLED FREQUENCIES OF 3 EARLIER ROBIN STUDIES[1]

No. of eggs	Other studies		This study	
	No.	Percent	No.	Percent
1	3	0.3	2	2.5
2	64	5.4	7	8.6
3	520	44.0	43	53.1
4	576	48.8	29	35.8
5	18	1.5	0	0.0

[1] Howell 1942, Young 1955, Howard (For Mass. and N.Y.) 1967.

asciurus hudsonicus and *Sciurus carolinensis*) also occurred in the area. We have no adequate data on post-fledging mortality, but house cats (*Felis domestica*) were present and caught some poorly flying young robins.

Inclement weather was also a mortality factor, possibly involved in the death of embryos and certainly in that of young nestlings. In 1967, 6 nestlings
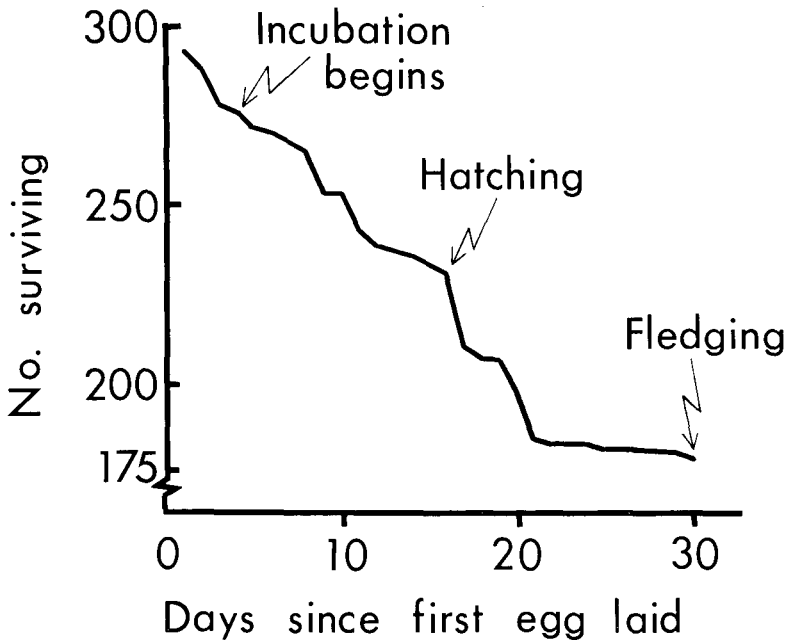

FIG. 3.   Robin egg and nestling mortality pooled for 1966, 1967, and 1968.

TABLE 3
ROBIN REPRODUCTIVE SUCCESS

	1966		1967		1968	
	Orchards	Northeast[1]	Orchards	Northeast	Orchards	Northeast
Mean clutch size (n)	3.4 ± 0.1[2](30)	3.7(271)	3.0 ± 0.1(34)	3.5(116)	3.3 ± 0.1(20)	3.4(92)
% hatching success (n)	70(111)	no data	74(108)	no data	68(76)	no data
% egg-to-fledgling success (n)	64(111)	53(829)	59(108)	52(400)	51(76)	59(278)
Mean no. young produced per successful nest (n)	3.1 ± 0.2(23)	3.3(135)	2.2 ± 0.2(29)	3.0(68)	2.4 ± 0.2(18)	3.0(55)
Mean no. young produced per active nest (n)	1.9 ± 0.3(37)	2.0(222)	1.6 ± 0.2(39)	1.3(115)	1.5 ± 0.3(26)	1.8(83)
% nest success based on active nests (n)	62(37)	64(222)	74(39)	59(115)	62(26)	66(83)

[1] From North American Nest Record Cards for New York, New Jersey, Pennsylvania, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.
[2] Standard error.

TABLE 4

COMPARATIVE REPRODUCTIVE DATA

Species	This study (1966–68) Robin	Howard (1967) Robin	Young (1955) Robin	Howell (1942) Robin	Nolan (1963) Several[1]	Nice (1957) Several[2]
Mean clutch size	3.2	3.5	3.4	3.4	–	–
% hatching success	71.2	–	58	–	38.6	59.8
% egg-to-fledgling success	60.9	–	45	–	17.6	45.9
Mean number of young produced per successful nest	2.6	–	2.9	2.4	–	–
% nest success[3]	66.7	–	49	65.0 and 49.3	21	49.3

[1] Birds with elevated open nests in scrub habitat.
[2] Altricial birds with open nests.
[3] Based on all nests with at least one egg; a successful nest produced at least one successful fledgling.

(2 different nests) were found dead following 2 days of constant rain; in 1968, 4 nestlings in one nest were discovered dead after an 11 cm rainfall. Presumably the female left the nest to forage, thus exposing the young to the elements. Male robins sometimes sat on the nest rim, but we never saw one incubate or brood.

Nesting success.—Robin reproductive data obtained in this study were compared with similar data from 9 northeastern states collected through the North American Nest Record Card Program (Table 3). Only those cards based on several visits to the nest and with incubation and nestling periods agreeing with those reported in other studies were included. Certain other qualifications were also applied to make the data as nearly comparable as possible.

Despite a lack of statistical treatment, certain trends are clear. Orchard robins in this study consistently produced fewer eggs per clutch, though differences were not extreme. They also produced fewer fledglings per successful nest than nests reported on the nest record cards, a reflection of the reduced clutch size. Hatchability and egg-to-fledging success were in close agreement, with orchard birds faring better in many instances.

Table 4 compares the robin reproductive data obtained in this study with similar information presented in 3 other major robin studies. as well as with reproductive information presented in 2 studies of birds which build open nests and have altricial young. Again, orchard robins fared as well as or better than the birds reported in these investigations in all categories except clutch size.

Nest searches in late November, after the leaves had fallen, allowed a

TABLE 5

SPRING NEST-FINDING SUCCESS AND ESTIMATES OF ROBIN PRODUCTIVITY

Year	% of robin nests found in spring	Estimate of total no. of robin nests built in study orchards	Estimate of total robin fledglings produced
1966	51	90	135
1967	82	78	66
1968	83	47	43

measure of the efficiency of nest-finding during the breeding season and estimation of total robin productivity in the orchards. They also provided a basis for estimating the total number of nests on the study area by the application of the formula:

$$\text{Total nests} = \frac{\text{number of nests found in spring} \times \text{number of nests found in fall}}{\text{number of spring nests found in fall}}$$

Furthermore, we could determine whether nests not found until fall had contained at least one successful fledgling on the basis of the presence of feather sheath fragments (Johnson 1967). Spring nest-finding success rates and estimates of total numbers of young robins produced in the orchards are presented in Table 5. We attribute the low rate of spring nest discovery in 1966 to the fact that EVJ was not living on the study area that season, whereas he was present during the entire breeding seasons of 1967 and 1968.

Fledgling survival.—Young robins disappeared from the vicinity of their nests within 2 days of fledging, and were subsequently difficult to identify by means of color bands because they remained high in trees. Mist-netting was carried out from the last week in June to 10 July each year in a cherry orchard where large numbers of birds were attracted by ripening fruit. The aim of this effort was to determine post-fledging survival of robins and to detect the presence of birds banded as nestlings in previous years.

In 1966, we recaptured 17 of 61 birds previously banded the same season as nestlings in orchard nests. The mean age of these birds was 35 days, or 21 days post-fledging. They all had full tails, and were apparently independent. Our relative recapture efficiency was estimated at 28%. In 1967, only 2 banded orchard-reared robins (6%) were recaptured as independent juveniles; in 1968, no banded orchard-reared juveniles were recaptured.

We attribute the yearly differences in recapture rates to differences among seasons and cherry crops. The year 1966 was dry, and the crop (with irrigation) was excellent. In 1967, a cold spring significantly reduced the crop
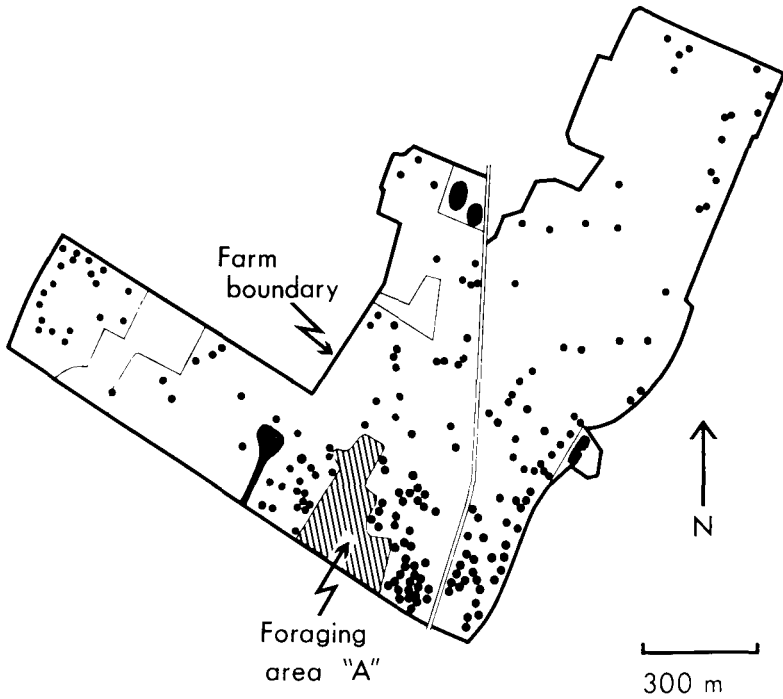
Fig. 4. Robin nest distribution on the farm for the years 1966, 1967, and 1968.

compared with 1966, and consequently there were fewer birds (Austin-Smith, pers. comm.). The crop was good in 1968 but extensive rains during picking-time ruined about 80% of the cherries. In addition, this rain made mist-netting virtually impossible throughout most of the period of peak bird abundance.

In 1966 the results of netting indicated that post-fledging survival of young robins raised in orchard nests was good. There was apparently no drastic mortality when young were between the ages of 14 and 35 days. We suspect that this was also the case in 1967 and 1968, but low bird numbers and poor netting conditions adversely affected our captures. In 1967 and 1968, we did not recapture any birds banded as orchard nestlings in previous years. This is perhaps not surprising in view of the overall 50% mortality rate for robins suggested by Farner (1945), and the very low return (4 of 250) of banded nestling robins to a Massachusetts suburb in the following year (Howard, pers. comm.).

Adult mortality.—In 2 cases, the male partner of a pair disappeared while their nest was active. The female successfully raised the young to fledging in

TABLE 6

RESULTS OF FORCING EARTHWORMS (LUMBRICIDAE) TO LIVE IN SPRAYED ORCHARD SOIL FOR 90 DAYS[1]

| Group | No. Worms[2] | | Wt. Loss(%) | DDT Plus Degradation Products (ppm, wet wt.) |
	Begin	End		
Control	125	221[3]	31.0[3]	3.0
I	125	28	85.5	47.3
II	125	58	77.5	21.8
III	125	42	82.6	22.1
IV	125	68	71.5	11.9

[1] Totals of 5 replications in each group.
[2] Groups I through IV were in sprayed soil from mature apple orchards.
[3] Significantly different from all other groups, $p < .025$.

both instances. Two females incapable of flight were discovered near nests containing young. One had mechanical injuries but the other was "in tremors." In the latter case, the young were dead and were collected along with the female for residue analyses. We can find no published information on the frequency of disappearance of one member of a pair of nesting robins, but 4 individuals lost in 3 years from 57 pairs does not seem excessive.

Nest distribution and density.—Robin nest density in the orchards was never high. The mean distances between active nests (including only those simultaneously active on the day or days of maximum nest activity) were 102, 159, and 232 m in 1966, 1967, and 1968 respectively. Nests tended to be clumped about the major foraging area of recently cleared land (Fig. 4). Of the estimated total number of nests built in the study orchards each season, at least 30, 26, and 38% (1966, 1967, and 1968) were constructed within 153 m of this area. Other nests were scattered over the rest of the farm, often with over 300 m separating neighbors.

Foraging areas.—In all years of the study, robins were seen foraging under orchard trees in early April. These birds were in migrating flocks composed principally of males. From late April until July, there were very few observations of robins on the ground under orchard trees, despite the fact that observers on foot were present in the study area up to 10 hours a day. Following preliminary observations in 1966, observers equipped with walkie-talkies followed birds from 29 nests in 161 foraging trips in 1967; in no case were birds observed foraging directly under sprayed orchard trees. Instead, they used woodlots, marginal areas, and especially the large section (5.1 ha) of recently cleared land adjacent to the south woodlot ("A" in Fig. 1). The same was true in 1968. Mean distance from nests to foraging areas was 122 m in 1967 (29 nests), and 103 m in 1968 (19 nests), with extremes of 30 and 300 m.

TABLE 7

PESTICIDE RESIDUE LEVELS IN SOILS OF THE STUDY AREA IN 1966

Source of Soil	DDT + DDE Range of Levels (ppm, wet wt.)
Young apple orchard	90 – 150
Semi-abandoned apple orchard	106 – 180
Mature apple orchard	127 – 391
Mature apple orchard	427 – 441
Robin foraging area ("A")	2 – 11
Northwest edge of study area	<1 – <1

Food items.—Observations made in late March and early April showed that migrating flocks fed extensively on rotten apples left on the ground from the previous autumn's crop. The gizzard contents of 5 birds collected during this period were 97% apple by volume. At commencement of the breeding season, earthworms were the most important item, followed by lepidopterous larvae and beetles. By late June, however, the adult birds' diets consisted of 70% fruit, principally commercial varieties of sweet cherries which were grown on the study area. Worms and caterpillars assumed a secondary importance. Gizzards of nestlings contained, in order of importance: earthworms, lepidopterous larvae (chiefly Tortricidae: *Archips argyrospila*), and cherries. These results agree generally with those of Beal (1915).

Invertebrate populations.—Trapping by pitfall trap-cans in 1968 resulted in a good representation of the animal component of robins' diets: worms, carabid beetles, spiders, snails, and some lepidopterous larvae. Under orchard trees, nearly 30,000 trap-hours resulted in 0.7 captures per 100 trap-hours, with 11% of 315 traps making captures. In the foraging area, the same number of trap-hours produced 4.5 captures per 100 trap-hours, involving 57% of 315 traps. Ground-dwelling invertebrates were apparently 5 or 6 times more abundant in the unsprayed area than in the orchard. This factor may actually be even larger since most of the items captured in the orchard were trapped under trees adjacent to unsprayed areas.

The earthworms forced to live in orchard soil had high mortality and weight loss compared with those living in unsprayed control soil. Pooled totals of the 5 replicates in each group are shown in Table 6. A Kruskal-Wallis rank test (Steel and Torrie 1960) showed that, at the end of 90 days, experimentals had significantly fewer numbers of worms and significantly more overall weight loss than controls (p < .025). The presence of more than the original number of worms in the control group at the end of 90 days was

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TABLE 8

INVERTEBRATE PESTICIDE RESIDUE LEVELS

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Source of Sample	Composition of Sample	Date	DDT and Related Compounds	Dieldrin
Foraging Area "A"				
	Worms	4/19	0.8[1]	0[1]
	Worms	4/25	0.6	0
	Composite[2]	5/23	0.2	0
	Worms	6/1	2.1	0.2
	Worms	7/21	1.4	0.1
New Orchard Planting				
	Worms	4/13	3.7	trace
	Worms	7/21	7.7	0.5
Brushy Edge				
	Worms	4/19	0.6	0
Woodlot				
	Worms	6/1	2.9	0.2
	Caterpillars[3]	6/20	1.0	0.6
	Worms	7/25	1.4	0.2
Mature Orchard				
	Composite[2]	5/23	0.6	0

[1] All values ppm, fresh weight basis.
[2] Worms + beetles (Carabidae) + caterpillars.
[3] Principally *Archips argyrospila*.

probably due to overlooked eggs in the soil at the beginning of the experiment, and/or reproduction by the control worms.

Pesticide levels.—Soils within the study area exhibited a wide range of pesticide levels. Results of analyses of soil samples are shown in Table 7. It should be understood that the values of Table 7 are maximal because the cores were taken directly under the crown periphery (drip zone) where highest residue levels in soil are expected. Dieldrin was detected in measurable amounts only in fall samples and did not exceed 2.6 ppm.

While residue levels would be expected to be higher in the fall, immediately following spraying, than in the spring, this was not always the case. Sampling error may be partially responsible for this apparent inconsistency, but other factors such as runoff of residues, delayed decomposition of vegetation containing residues, and protection of the soil by leaves may have been important. Most levels in orchard soils agree with those reported by Chisholm et al. (1950). The values in excess of 300 ppm are higher than any published data, but the study area has a 20-year history of DDT application. In addition, samples in this investigation were taken only from the drip zone; other studies

TABLE 9

MEAN PESTICIDE RESIDUE LEVELS IN ADULT ROBINS[1]

	1966			1967		
	Spring orchard	Spring reference	Summer orchard	Spring orchard	Spring reference	Summer orchard
Brain						
DDE	0.9(0.30)[2]	1.2(0.31)	2.6*(0.62)	0.9(0.33)	0.8(0.19)	2.2**(0.39)
DDT	2.1(0.22)	2.1(0.21)	1.0(0.39)	1.1(0.13)	1.1(0.33)	1.8(0.46)
Dieldrin				0.2(0.09)	0.2(0.05)	0.6*(0.15)
Liver						
DDE	1.5(0.32)	2.9(1.08)	10.1**(2.69)	1.3(0.36)	1.4(0.35)	3.8**(0.74)
Dieldrin				0.7(0.27)	0.4(0.11)	1.0(0.16)
Remainder						
DDE	3.1(0.55)	2.8(0.67)	6.5*(0.98)	3.0(0.76)	3.8(1.58)	8.6**(1.61)
DDE-fat basis				84.9(66.46)	113.2(52.10)	169.0*(17.03)
DDT	9.8(2.03)	7.1(1.99)	6.7(2.35)	6.7(4.50)	2.9(1.32)	7.3(1.68)
DDT-fat basis				191.2(131.00)	79.9(34.25)	139.0(32.19)

[1] All values ppm, wet weight basis, unless otherwise indicated. Sample sizes range from 8 to 11. All tests were Kruskal-Wallis rank.
[2] Standard error.
* Significantly different from other 2 categories in group, $p < .05$.
** Significantly different from other 2 categories in group, $p < .01$.

report that samples were taken from under trees, but do not specify any particular site. DDT is one of the most persistent of the chlorinated hydrocarbons and has been shown to last longest in heavy clay soils with high organic content (Edwards 1966). The study area soil matched this description well. It is difficult to explain the absence of dieldrin in spring soil samples since this compound is also highly persistent (Edwards 1966). It was sprayed at far lower rates than DDT, however, and had not been used for as many years.

Results of pesticide residue determinations for invertebrates were based on pooled extractions (up to 25 g) of several individuals of different species (Table 8). Data from a single mature orchard indicated that total residue levels were low; however, a seasonal trend was apparent in that residue levels in invertebrates peaked at about 1 June, shortly after DDT and dieldrin application, and dieldrin was not detected in any sample collected before that season's dieldrin application. Analysis of live worms raised for 90 days in pesticide-treated and untreated soil showed that the treated worms had much higher DDT residue levels than either the controls or field-collected samples (Table 6).

Commercial cherries from the study area showed no measurable residues; wild cherries from woodlot margins contained less than 0.2 ppm total residues.

The results of the analyses of adult robins are presented in Table 9. All DDT values are for the p-p′ isomer; no o-p′ isomer was encountered though it occurs as about 20% of commercial DDT preparations. Each year there was a seasonal increase in DDE levels in all tissues examined with no corresponding increase or decrease in DDT. In 1967, the fat content of "remainders" was determined, and the expression of ppm on a fat basis shows that the increase was not simply a reflection of an increase in fat. We have not included DDD in the table because of its highly irregular occurrence. When present, it was usually in the livers where it is probably formed (Wurster et al. 1965). Dieldrin values are shown only for 1967 birds; analytical problems in 1966 led us to exclude that year's data. Remainders were not extracted for this compound unless there was evidence of its presence in excess of 1 ppm.

The one adult female found in tremors in 1967 contained 15 ppm DDT plus degradation products (wet weight basis) as well as 2.6 ppm dieldrin in the brain, and 7.4 ppm dieldrin in the liver. These are the highest levels found in any adults examined and suggest pesticide poisoning. Jefferies and Davis (1968), in their study of Song Thrushes (*Turdus ericetorum*), suggest that these dieldrin levels should at least be considered dangerous.

The 3 fresh eggs examined contained an average of 12.2 µg of DDT and related compounds per ml of egg, while 7 eggs that did not hatch averaged 13.4 µg per ml. A 2-sample rank test leads to acceptance of the null hypothesis of no difference between samples. Levels are not expressed as ppm since an egg loses weight during development and thus ppm of pesticides would appear to increase with age of the egg. The maximum level encountered was 35.2 µg/ml in an unhatched egg. Interpretation of these data is difficult. There is no guarantee that the fresh eggs would have hatched; thus, one cannot say for certain that they were "normal." Many factors can result in an egg's failure to hatch. From these data, and from the high rate of hatching success (Table 4), it seems probable that pesticides did not play a significant role in reducing hatchability of robin eggs in the study orchards.

Nestlings were analyzed on a whole-bird basis. Four live birds aged 1 to 5 days averaged 4.7 ppm DDT and related compounds (wet weight basis); 7 live birds aged 6 to 10 days, 4.2 ppm; and 6 live birds aged 11 to 15 days, 6.1 ppm. Six young found dead (3 each from 2 nests) aged 2 and 4 days averaged 16.9 ppm; 5 nestlings found dead, aged 6, 7, and 9 days, averaged 3.0 ppm; and 2 young found dead, aged 11 and 14 days, averaged 4.4 ppm. Two juveniles which were recaptured in the cherry orchard at the ages of 34 and 45 days contained residue levels which agreed closely with those found in

summer orchard adults. In all young examined, dieldrin levels (whole bird) never exceeded 2 ppm.

<div align="center">DISCUSSION</div>

The most important observation explaining good robin reproductive success in this polluted environment was that birds did not forage in areas which received direct spray. The reasons for this are readily apparent. We noted previously that worms were not present in sprayed soil and, in fact, showed high mortality when forced to live in it (Table 6). It is not possible at this time to pinpoint any one chemical or combination of chemicals responsible for this. There is published information, however, which suggests that at least 4 chemicals applied to the study orchards may be deleterious to worm survival. Baker (1946) reported that earthworm populations decreased markedly after an elm grove was sprayed heavily with DDT. Slater (undated) reported that lead arsenate is effective as a vermicide when applied at the rate of 2.27 kg per 93 m². Orchard applications did not approach these levels, but the compound had been applied continually for 20 years in many sections. Slater also mentioned that DDT will kill earthworms. Edwards (1969) reported that carbaryl "seriously decreased populations of earthworms" (p 92), and in addition stated that, in poor orchard soil, "earthworms . . . were killed by copper residues from spraying" (p 91). Copper was not sprayed in our study area during the years of this investigation, but Bordeaux mixture (copper sulfate) was used extensively before the advent of modern organic insecticides. Thus it seems likely that worms had been absent from the study orchards for over 20 years and will probably not reappear until spraying of such compounds ceases and residues degrade. These observations do not agree with those of Menhinick (1962), who compared soil and litter invertebrate populations in sprayed orchards with those in an unsprayed habitat. He found good numbers of lumbricids in both sprayed and unsprayed areas. However, lead arsenate was applied to his sprayed area at the rate of only 6.7 kg/ha/yr (compared with 45 kg/ha/yr in this study); he did not mention the use of carbaryl.

Our reason for sampling orchard soil for residue analysis was to examine pesticide levels in the robins' food chain from the source (presumably orchard soil) to the birds. When it became evident that orchard soil residues played only a prohibitive role, if any, in regard to invertebrates, the soils pertinent to our original purpose were those of the unsprayed foraging areas. The last 2 values in Table 7 are for soils from such areas, and are quite low. These results indicate that pesticide application by speed sprayer was remarkably efficient in confining the pesticides to the intended target area. Soil collected at foraging area "A" contained less than ⅒ the residues of adjacent sprayed

orchards bordering it on 3 sides. Soil from a site about 60 m from the nearest sprayed orchard contained less than 1 ppm total DDT residues.

Invertebrates living in these soils contained residue levels (Table 8) which reflected soil levels. Values are very similar to those reported by Davis and Harrison (1966) for worms, beetles, and slugs living in soils containing low levels of chlorinated hydrocarbons (0.03 to 0.7 ppm). Wheatley and Hardman (1968) found little concentration of dieldrin and DDT-complex compounds in *Lumbricus terrestris* when soil levels were below 1 ppm for each compound; DDE and dieldrin were concentrated 2.9 and 2.5 times respectively. When these observations are applied to the data of Tables 7 and 8, it is evident that the same was probably true for the worms of robin foraging areas in this study. There was no detectable "biological magnification," and residue levels in food items which the birds actually used were low.

Robin eggs contained levels of DDT and DDE which probably reflect the lipophilic nature of the compounds. Results of other studies on possible effects of various pesticides on hatchability are somewhat contradictory. Genelly and Rudd (1956) found no decrease in hatchability of pheasant eggs containing more than 150 ppm DDT, but more recent work suggests that DDT or one of its metabolites is responsible for a decrease in eggshell thickness in some raptorial and piscivorous birds (Ratcliffe 1967, Hickey and Anderson 1968, Porter and Wiemeyer 1969). No cracking of eggshells was observed in the present study, and egg breakage was extremely uncommon.

Low concentrations of pesticides in adults were consistent with the levels in the food items. Small but significant increases through the season were predictable since the diet was somewhat contaminated. If robins carried low "background" concentrations of pesticides when they arrived in the spring, these levels could be expected to show an increase through the season. Of the DDT-complex compounds, only the metabolite DDE showed a detectable increase in robin tissues. There was no increase in DDT as such. In addition, the presence of DDE in a robin is not necessarily proof of DDT ingestion; DDE may be ingested as such. Dieldrin showed a slight increase in brains, but not livers (Table 9), and this is consistent with the increases noted in the soils and invertebrates.

No adult robins examined in this study contained brain residue levels in excess of 30 ppm DDT plus DDD, a minimum value suggested by Stickel et al. (1966) to indicate pesticide poisoning. Wurster et al. (1965) considered 50 ppm total brain residues as indicative of pesticide poisoning in robins. The one adult in tremors discovered in the study area perhaps died from dieldrin poisoning, but no deaths can be directly attributed to DDT. An additional point for consideration is the fact that the cherries which comprised nearly 70% of the diets of robins in late June and July contained little or no

pesticides. Harvey (1967) has shown that surviving Starlings (*Sturnus vulgaris*) placed on a clean diet after receiving high doses of DDT were able to excrete more than 90% of the amount ingested within 10 days after poison in the diet was eliminated. If the same is true for robins, then the high percentage of clean fruit in the orchard robins' diets in summer may have provided them with an opportunity to excrete excess pesticides.

In conclusion, there was no undue mortality of robins in the study area nor would any be anticipated in light of what is known of the birds' foraging habits and the pesticide content of their foods. The conditions which favored the presence of robins on the farm were probably the park-like nature of the orchards in spring and the abundance of suitable nest sites. The birds' ability to forage in areas quite far removed from their nests was perhaps the major factor contributing to their success. The situation was in large measure a fortuitous one, in that future changes in spray program, mulch, or cover management practices might increase the numbers or availability of invertebrates under orchard trees. A situation comparable with what has occurred on college campuses and in residential communities would then exist with the very real possibility of direct mortality from poison ingested with the robins' food and/or reduced natality through disturbance to reproductive physiology.

SUMMARY

From 1966 through 1968, robins reproduced successfully in commercial apple orchards which were periodically sprayed with DDT, dieldrin, and other pesticides. Observations by a 2-man team using walkie-talkies revealed that breeding robins obtained essentially all food for themselves and nestlings from unsprayed areas adjacent to the orchards. Invertebrate trapping in sprayed and unsprayed areas showed that these food items were 5 or 6 times more abundant in unsprayed habitat. Worms forced to live in sprayed orchard soil displayed significantly greater mortality than controls. Mean robin clutch sizes in the study orchards were lower than those reported for robins in other studies, perhaps because of food shortage and/or increased foraging distances. Levels of DDT and its analogs in food items from robin foraging areas did not exceed 8 ppm wet weight basis. From late April to July, adult robins showed small but significant increases in DDE levels in all tissues examined, as well as an increase in dieldrin in brains. Pesticides sprayed on the farm had no direct demonstrable adverse effects on the robins; productivity was high and adult mortality low. The situation was in large measure fortuitous, since any changes in orchard management practices which resulted in the presence or availability of invertebrates under orchard trees would be expected to result in robin mortality and/or reduced breeding success.

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NEW YORK COOPERATIVE WILDLIFE RESEARCH UNIT, CORNELL UNIV., ITHACA 14853 (PRESENT ADDRESSES: BIOLOGICAL SCIENCES DEPT., CALIFORNIA POLYTECHNIC STATE UNIV., SAN LUIS OBISPO 93407; NEW YORK AGRICULTURAL EXPERIMENT STATION, GENEVA 14456; U.S. FISH AND WILDLIFE SERVICE EDITORIAL OFFICE, AYLESWORTH HALL, COLORADO STATE UNIV., FORT COLLINS 80521). ACCEPTED 12 FEB. 1975.

REQUESTS FOR ASSISTANCE

Great Gray Owl.—A study is currently in progress to determine the historical and present status of the Great Gray Owl (*Strix nebulosa*) in North America. Any information regarding sight records or possible breeding occurrences of the Great Gray Owl is needed. Your cooperation will be gratefully acknowledged. Send information to: M. Collins, Department of Zoology, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

Red-cockaded Woodpecker.—The Red-cockaded Woodpecker Endangered Species Recovery Team is trying to develop a recovery plan for this species. In order to quantify its present and recent past status I am cataloging active or recently active Red-cockaded Woodpecker colonies. Please send as much of the following information as possible on known active colonies: (1) specific location—a map if possible, (2) dates and numbers of birds seen, (3) records of active nests, (4) land ownership if known. For colonies that are known to have become inactive in recent years, please send as much of the above information as possible and indicate specific or probable cause of the colony loss. Any documentation would be of great help. Send information to: Jerome A. Jackson, Leader, Red-cockaded Woodpecker Endangered Species Recovery Team, P. O. Box Z, Mississippi State, MS 39762.