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RECOVERY OF AN AMERICAN ROBIN POPULATION AFTER EARLIER DDT USE

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INTRODUCTION

In a series of papers by Wallace and his students the effects of DDT on the American Robin (*Turdus migratorius*) on the campus of Michigan State Univeristy (MSU) and surrounding East Lansing area were documented over a 15-year period (Wallace, 1958, 1959, 1960, 1962; Mehner and Wallace, 1959; Kettunen, 1961; Wallace et al. 1961, 1964; Bernard, 1962, 1963; Boykins, 1964; Tweist, 1965; Wallace and Boykins, 1965). DDT spraying on the MSU campus began in 1955 and ended in the fall of 1962. After a year of no spraying, DDT was replaced by methoxychlor in 1964 but residues of DDT and its breakdown products (DDE, DDD) remained high, especially in earthworms. As a result, die-offs continued for three years (Bradfield, 1972). Robins began to show signs of lessened mortality by 1967 in probable response to decreasing levels of DDT in earthworms and soil (Bradfield, 1972). Success of reproduction was monitored for only one season in 1962 (Tweist, 1965). McWhirter and Beaver (1977) noted some successful hatching of robins' eggs on the campus, but no formal study has been conducted in the intervening 10 years since the last study by Bradfield (1972). The purpose of this paper is to report on the condition of the robin population at MSU 17 years after the last use of DDT to control Dutch Elm disease.

METHODS

This study was conducted from 2 April to 29 June 1979. The area censused was the MSU campus north of the Red Cedar River from Bogue Street west to the Beal Entrance (north campus). A complete description of the area is presented by Wallace (1959). Total area was 177.5 acres (71.8 ha), less than the 185 acres given in Wallace (1959) and later papers apparently because of a more precise estimate provided in 1979 by the MSU Campus Parks and Planning Department. Excluding the buildings, roadways and parking lots of these 177.5 acres, 121 acres were available as nesting habitat for robins. Only minor changes in the north campus have occurred since 1955, such as parking lot construction, the destruction of some old buildings, and construction of new ones. The net change in lawn area has been a reduction of about five acres. Censuses were conducted in the early morning every other day (except during bad weather) by a single observer on bicycle. Census times ranged from 50 to 70 min. Following Wallace's (Wallace et al., 1961; Wallace, 1962) procedure, birds were counted and their locations plotted on a scale map of the area. As the nesting season progressed, nests were located (not done by Wallace and his coworkers except in 1962) and checked at intervals of every 3 or 4 days using a telescoping pole with a mirror mounted on it. Nests above 10 m could not be ex-

amined by this technique. The number of nests located was used in conjunction with census data to determine population size. Birds were not marked so renesting could not be ascertained with certainty. Based on data presented by Mehner (1958) nests found with eggs after the end of May were considered to be renests.

RESULTS

Population Trends

The typical pattern of robin arrival and nesting on the MSU campus is as follows. Birds first appear in late March and early April. Their numbers increase to a peak by the end of April, depending on weather. Nests are initiated by the first week of May and nesting continues through June.

For comparative purposes, the late April population is designated as the "prenesting" population and the May population as the "nesting" population. Below it will be shown that these two aspects of the robin population were affected differently by DDT.

Past records of robin population obtained by Wallace and his coworkers show clearly that from 1959 through 1966 nesting populations were significantly depressed compared to the prenesting population in the same year (Fig. 1). Nesting populations are not statistically different from the late April peak from 1967 through 1969 and 1979 (Fig. 1). Levels of DDT in earthworms on the north campus were high from 1963 through 1965 (Fig. 1) and probably earlier as well, although no systematic sampling was done. Levels of DDT then drop to a low of 4.9 ppm in 1968, the last year of sampling (Bradfield, 1972). A regression of robin nesting population size on ppm of DDT in earthworms (logarithm transformed to linear model) was highly significant (population size = 37.38 ppm $DDT^{-0.36}$, $r^2 = .86$, $F = 24.1$, $P < .01$) suggesting an inverse relationship between DDT levels and population size. Thus, the return of the robin population size to "normal" levels is accompanied by greatly reduced levels of DDT in earthworms.

Prenesting populations in late April do not show the pattern of nesting populations (Fig. 1). A significant difference was found between years (Analysis of Variance, $F = 3.15$, $P < .01$) but the highest years occurred in 1963 and 1964 while DDT residues were still high and in 1979 when residues were assumed to be very low. This variation in prenesting populations is interpreted as normal yearly variation unrelated to DDT levels on the north campus. The conclusion is strengthened by the pattern of robin mortality from April and May on the north campus for the years 1960–1966. Mortality is low up to the last of April (2 birds/week) by which time most of the prenesting population has arrived. High mortality (6 birds/week) then reduces the nesting population. Robins appear to require one to three weeks of feeding to accumulate lethal levels of DDT, a pattern noted by Bradfield (1972) and Knupp et al. (1976).

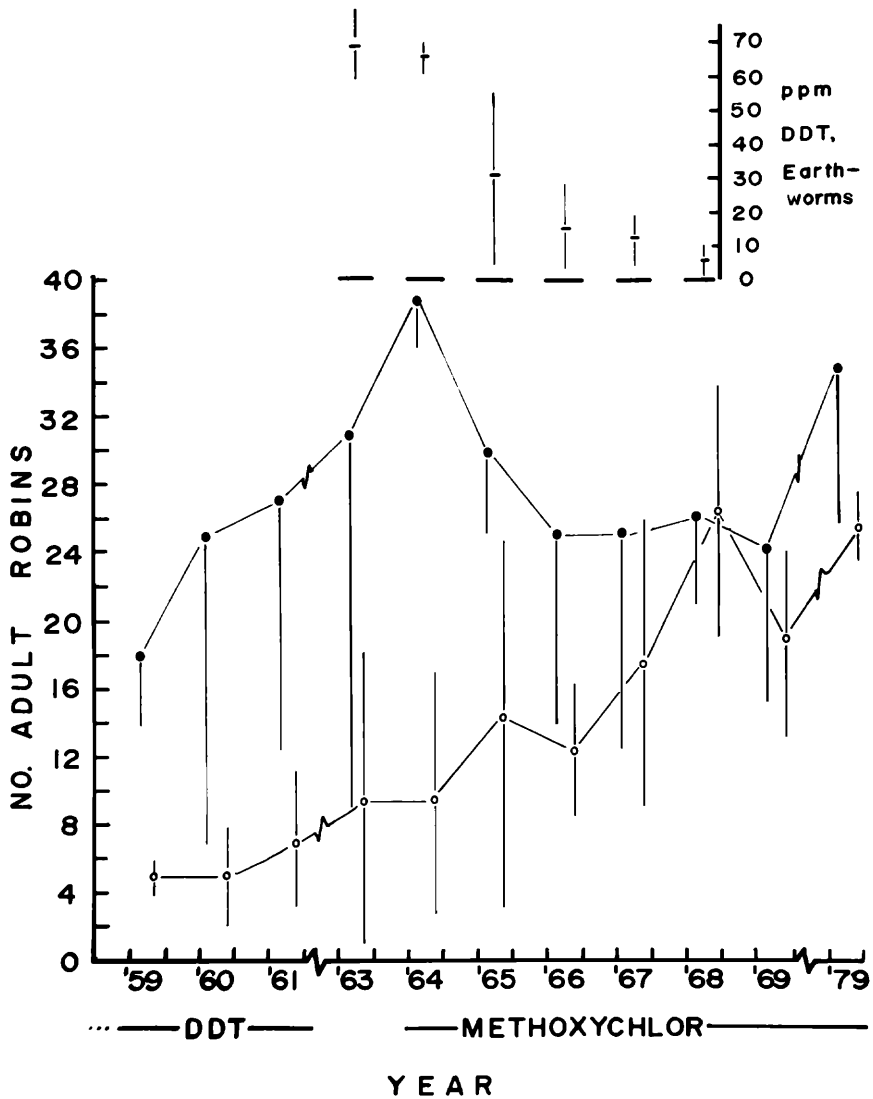

FIGURE 1. Prenesting (•) and nesting (○) populations ($\bar{x} \pm 95\%$ CL) for American Robins on the north campus of Michigan State University. Data for 1959 are from Kettunen (1961), 1960–1969 from Bradfield (1972), and 1979 the present study. Inset is the ppm of DDT ($\bar{x} \pm 95\%$ CL) for 1963–1968, the only years with data (Boykins, 1964; Bradfield, 1972).

Another feature of the mortality pattern of robins noted by Wallace and his coworkers was that the number dying in 1960, 1961 and 1963 exceeded the prenesting peak by as much as two-fold, about equalled

TABLE 1.

Reproductive statistics for American Robins between 42° and 45°N latitude for which variance statistics were available or could be calculated.

Year	Nest	Clutch size $\bar{x} \pm SE$	No. fledged/ nest $\bar{x} \pm SE$	Location	Source
1932–1942	83	—	2.9 ± 0.12	Groton, MA	Mason (1943)
1937	60	3.4 ± 0.07	—	Ithaca, NY	Howell (1942)
1938	67	3.6 ± 0.08	—	Ithaca, NY	Howell (1942)
1947	30	3.5 ± 0.10	—	Madison, WI	Young (1955)
1948	70	3.6 ± 0.07	—	Madison, WI	Young (1955)
1949	46	3.3 ± 0.09	—	Madison, WI	Young (1955)
1954–1956	42	3.4 ± 0.11	—	Pittsburgh, PA	Mehner (1958)
1954–1957	13	3.5 ± 0.18	—	East Lansing, MI	Mehner (1958)
1962	13	2.8 ± 2.6	1.0 ± 0.33	North Campus, MSU,	Tweist (1965)
1974	42	—	2.2 ± 0.16	East Lansing, MI	Champagne (1975)
1975	68	—	3.1 ± 0.08	East Lansing, MI	Champagne (1975)
1979	14	3.2 ± 0.19	3.1 ± 0.29 (n = 12)	North Campus, MSU, MI	Present study

it in 1964 through 1966, and then declined to one bird in 1969. Apparently, as resident birds died they were replaced. This process was most evident in the first part of May. The replacement reservoir must have been depleted because the nesting population declines to low levels by June in the years with high mortality. These data are particularly relevant to the question of whether the north campus robin population has returned to pre-DDT levels.

Mehner and Wallace (1959) estimated the pre-DDT (1955) population on the north campus to be 336 birds (168 pairs). The population in 1959 (prenesting) was about 18 birds (9 pairs) or about 19 times smaller. The 1967 through 1979 prenesting population is fairly stable (Fig. 1) and is about 25 birds, still about 13 times lower than pre-DDT estimates, even though nesting populations were by then equivalent to prenesting ones and DDT mortality was essentially zero. These data suggest the population is still severely depressed. I will argue in the discussion that this conclusion is not warranted.

Clutch Size

Data on clutch size for pre-DDT, DDT, and post-DDT populations on the north campus and other areas of similar latitude are shown in Table 1. No clear effect of DDT on clutch size can be seen. An analysis of variance with the appropriate *a priori* tests confirms this impression (Table 2). No effect due to location of the sample or exposure to DDT was found. Clutch size does not appear to be affected by DDT, probably because most birds were able to produce the clutch prior to significant

TABLE 2.

Analysis of variance with a *a priori* tests for reproductive statistics for American Robins on the north campus of MSU and other comparable areas. Data are from Table 1.

A. Clutch size

Source	df	MS	*F*	*P*
Groups	5	1.455	0.88	NS
Area effect within pre-DDT studies	3	0.098	0.60	NS
DDT vs. pre- and post-DDT	1	5.471	3.32	NS, <.1
Pre- vs. post-DDT	1	1.157	0.70	NS
Within	349	1.648		

B. Fledging success

Source	df	MS	*F*	*P*
Groups	3	14.224	7.25	>.001
DDT vs. pre- and post-DDT	1	38.746	19.74	>.001
Pre- vs. post-DDT	1	0.442	0.22	NS
Post-DDT, E. Lansing vs. post-DDT, MSU	1	1.278	0.65	NS
Within	217	1.963		

DDT accumulation, a pattern documented for robins elsewhere (Hunt and Sacho, 1969; Knupp et al., 1976).

Fledging Success

After eggs are laid, however, the full effects of DDT on adults and directly or indirectly on the dependent offspring are very pronounced. An analysis of variance on these data shows highly significant effects of DDT on fledging success (Table 2). Most of this effect is attributable to direct mortality of adults (Tweist, 1965; Hunt and Sacho, 1969). No effects were found for the geographic location of samples or pre- versus post-DDT exposed populations. Therefore, the fledging success of robin populations in East Lansing and on the north campus appears to have returned to levels equivalent to times preceding the use of DDT.

Further evidence of the recovery of the north campus population is that in June and July 1979 populations continued to increase and late nestings were common, a condition typical of pre-DDT populations studied by Howell (1942), Young (1955), and Mehner (1958). A census conducted on 9 June revealed a total of 48 birds, 13 of which were juveniles. On 29 June, 75 birds were counted, 35 of which were juveniles. Three nests were active on 29 June and another fledged four young three days earlier.

DISCUSSION

The data show that mortality due to DDT was essentially zero by 1969, and that reproduction returned to pre-DDT levels by 1979, if not

earlier. Yet population size is still far below the estimated pre-DDT population of 336 birds (Mehner and Wallace, 1959). However, the pre-DDT figure was probably an overestimate because of the manner in which it was derived. The 1955 figure was extrapolated from data based on 5 pairs of robins nesting in the MSU horticulture gardens, an area of only 5.5 acres. In 1979, 2.5 pairs of robins nested in the horticulture gardens which since 1955 have been reduced in lawn area by planting and tree growth (comparison of present conditions with photos in Mehner, 1958). The 1979 value extrapolates to 168 birds on north campus. Actually only about 25 birds comprised the nesting population. Thus, in 1979, the horticulture gardens yielded an excessively high estimate of the robin population for the whole of north campus. This was also probably the case in 1955. Doubtless, the north campus is not uniformly as high quality robin habitat as are the horticulture gardens.

Another line of reasoning leads to a similar conclusion regarding the pre-DDT population estimate, but in addition allows a realistic estimate of what the pre-DDT population was. First, the prenesting population (Fig. 1) varies from a low of 18 birds to a high of 39 from 1959 to 1979 but shows no apparent relation to the years of DDT spray or residues. That is, increases occur during DDT years or in non-DDT years (1979) and declines occur during years of high DDT residues (1965–1966). Yet nesting populations show a pronounced response to high levels of DDT and to its residues. This strongly suggests that the number of territories established by robins in the prenesting period was not influenced by DDT effects. Therefore, the size of the prenesting population was probably determined by the number of territories as set by habitat quality at that time (abundance of food, weather). The mortality pattern further supports this hypothesis. The years 1959 and 1964 had the highest and lowest prenesting populations, respectively, even though mortality was consistently high in both years and equalled or exceeded the entire counted population. In subsequent years, mortality was reduced to zero, yet prenesting populations were not statistically different from most of the preceding years (1964 was higher). If territorial behavior is setting the size of the prenesting population through all of the years from 1959 to the present, then it clearly must have also set population size prior to DDT use. The best estimate of pre-DDT populations would then be the mean of prenesting populations from 1959 through 1979, or 29.9 $\pm$ 1.8 birds. Thus, the north campus can be expected to have 15 nesting pairs of robins in most years. In 1979 (first nesting), 14 pairs nested there (as determined from nests found), 12 of which were successful. (The counts for 1979 yielded an estimated 13 nesting pairs, or about 90% of actual nests located.)

A similar pattern was found by Wuster et al. (1965) in two adjacent communities, one, Hanover, NH, which had been sprayed with DDT for many years up through 1963 and one, Norwich, VT, which had never been sprayed. In both communities, similar numbers of robins started to breed in 1963 and 1964. Mortality caused by DDT at MSU

and in New Hampshire and Vermont probably did not influence subsequent years' breeding populations because of a large and always available pool of birds in nearby areas that settled in empty territories. This pattern may not, however, be universal. Weller (1971) studying robins on the Iowa State University campus in Ames, Iowa, found the entire population declined during the use of DDT from 47 to 18 nesting pairs in four years. When DDT was replaced by methoxychlor in 1976, the nesting population rapidly increased to about 30 in just three years. The number of young birds seen on campus also increased from just one in 1967 to 37 in 1970, indicating some recovery of reproduction. The more isolated nature of this agricultural Great Plains city in terms of nearby robin habitat may account for the observed reduction because of fewer robins available to repopulate DDT sprayed areas.

Clutch Size

The data suggest that DDT has no detectable effect on clutch size in robins. The birds must be able to mobilize the required reserves to lay their normal clutch before mortality occurs and, furthermore, that accumulated DDT does not produce a graded response. That is, the laying process is normal up to the levels that cause the death of the female. Knupp et al. (1976) have shown that robins in DDT sprayed forests in Maine with sublethal brain concentrations of the pesticide showed no reduction in clutch size or fledging success and survival of offspring compared to nearby unsprayed habitat, even though the DDT levels increased significantly in adult and young birds by the end of the nesting season. Clutch size is, therefore, not a very useful indicator of population response to DDT unless we consider the number of adults that die before producing a clutch. No data on female mortality prior to producing a clutch could be found.

Fledging Success

The effect of DDT on the incubation of eggs and care of the nestlings appears to be primarily mediated through the death of the parents (Tweist, 1965; Hunt and Sacho, 1969). Tweist (1965) found high levels of DDT in dead embryos in eggs and young of campus robins but could not directly determine if DDT caused their death. In any case, a mean of one young per active nest fledged in 1962 indicated a significant impairment of reproduction. The levels of fledging success noted in 1979 are equivalent to pre-DDT levels found in other studies and for post-DDT (1974 and 1975) in the East Lansing Area.

Robins and Grackles

During the maximum depression of the robin population on the north campus (1957–1966), several workers noticed a significant increase in the Common Grackle (*Quiscalus quiscula*) (Hamel, unpubl. Ms; Wallace et al., 1964). Wallace et al. (1964) reported that grackles for the most

part were not affected by DDT, except perhaps during 1963, when 16 dead or dying birds were picked up. DDT levels were all sublethal in these birds suggesting some other cause of death. Grackles may occasionally compete with robins for nesting sites (Bouvier, 1974), and perhaps also for food (pers. obser.). It was suggested by Bradfield (1972) that the increase in the grackle population during the die-off of robins may cause a continued reduction in the robin population when DDT poisoning is eventually reduced on the MSU campus. Interaction of robins and grackles were noted casually in 1979 and were primarily chases with both species being the chaser with about equal frequency and one case of a grackle robbing a worm from an adult male robin. No evidence of grackle-induced robin mortality was noted. One pair of robins successfully fledged three young from a nest only about 2 m from two active (egg stage) grackle nests in an isolated conifer. Most grackles on campus nested in a parking structure (Harper, unpubl. data and pers. obser.) in small groups. Only a few robin pairs were near enough to these structures to interact regularly with large numbers of grackles. In any case, the analysis presented above on population levels of robins does not support any dramatic post-DDT effect of grackles on robins.

SUMMARY

Reproduction in the nesting population of the American Robin on the north campus of Michigan State University 17 years after the last spraying of DDT and 10 years since the last mortality due to DDT was noted appears to have recovered to pre-DDT levels. Clutch size was normal compared to pre-DDT studies. No significant reduction of clutch size was found for DDT-sprayed years. Fledging success was equal to pre-DDT years. Fledging success was significantly depressed during DDT-sprayed years.

Prenesting population size was not depressed by DDT spray or its residues but appeared to fluctuate according to other factors (such as food abundance and/or weather). No increasing or decreasing trend in prenesting populations occurred from 1959 through 1979, suggesting that the robin population is relatively stable. Furthermore, no evidence could be found for the suggested 16- to 19-fold population reduction of robins from pre-DDT years as suggested by Wallace and his coworkers. The nesting population is now equivalent to prenesting population size and has probably been so since 1967.

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