WALLACE · NICKELL · BERNARD

BIRD MORTALITY

in the

DUTCH ELM DISEASE

PROGRAM

CRANBROOK INSTITUTE OF SCIENCE

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Dutch Elm Disease Program in Michigan

by

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Publisher's Preface

CRANBROOK INSTITUTE OF SCIENCE has for thirty years been concerned with research and education in the natural sciences. In this time it has always sought to keep abreast of problems of conservation of our biological resources and with the intelligent meeting of problems brought about by our impact on these, once-gone gone forever, resources. To this end we sponsored a part of the study here reported.

We have to thank not only the authors and the authorities of Michigan State University with which Dr. Wallace and Mr. Bernard are associated, but also Dr. George Miksch Sutton of the University of Oklahoma who contributed the drawing of a living robin reproduced on the cover and Dr. Dale Zimmerman, Silver City, New Mexico, who provided the drawing of a deceased robin used as a tailpiece*.

The design of the cover and layout of the forward matter was done by William Bostick of the Detroit Institute of Arts.

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R.T.H.

*This was based on a photograph of a robin killed by DDT in East Lansing.

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If we have misquoted, or misrepresented, any of these sources of information, it is unintended and regretted.

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Introduction

In 1930, *Ceratostomella ulmi*, the fungus which produces Dutch elm disease, was discovered in the United States, first near Cleveland, Ohio, then subsequently in New York and other eastern states (Whitten and Swingle, 1958). Since then the destructive disease has swept over or into more than 20 states, leaving in its wake millions of dead and dying elms. Millions of dollars have been spent in unsuccessful attempts to prevent continued spread of the disease and millions of birds have been destroyed. The discouraging prospects for the immediate future seem to be further losses of elms, dollars, and birds; but there is a glimmering of hope in some of the new control methods now under investigation.

This report, rather than describing the details of the disease and its consequences or cures, attempts to assess bird losses that have been observed in Michigan in connection with control programs.

Early History of the Disease

Dutch elm disease spread rapidly over the eastern states in the late 30's and 40's, before any effective means of control were known. Though a study of the natural spread of the disease (without artificial controls) in Essex County, New Jersey, in the mid-40's (Liming, Rex and Layton, 1951) seemed to indicate that the disease might die out in that locality, perhaps from natural control agencies, this did not seem to apply to communities with dense stands of elms where the disease became epidemic. Then came the miracle insecticide, DDT, which was being used with such outstanding success in insect control that its use was quickly visualized for the control of the bark beetles (*Scolytus multistriatus*, and *Hylurgapinus rufipes*) believed to be responsible for spreading Dutch elm disease. Some preliminary tests on the toxicity of DDT to wildlife by Fish and Wildlife Service biologists indicated that the dosages recommended for use on elms would be lethal to birds (Hotchkiss and Pough, 1946), but this fact seems to have been given little thought in the high hopes of finally finding an effective means of combating a truly devastating disease among the elms.

Early field tests on the use of DDT in Dutch elm disease control at Princeton, New Jersey, beginning in 1947, seemed to bear out the predictions of mortality to wildlife. Complaints of bird mortality followed both the spring and summer applications in 1948 (Benton, 1951), but such reports in general were discounted by operators and administrators of the program. To determine whether

or not the observed mortality was really attributable to DDT, Dr. Benton, in 1949, submitted 26 suspected victims to a laboratory for chemical tests. Fifteen of these were analyzed and all contained DDT. Since at least 10 of these were immature birds, including 6 nestlings, there seemed to be no question of the origin of the DDT in their tissues, a question now frequently raised wherever free-flying birds are involved.

The following year Blagbrough (1952) made a more comprehensive survey of mortality at Princeton. He found 122 dead and dying birds of 27 species following that year's operations. The chief victims were robins (35) and myrtle warblers (31). An additional 81 specimens reported by other observers brought to 203 the known avian victims. Blagbrough's estimate of dead birds for the whole borough was 546. From his study of the mortality at Princeton, Blagbrough made some recommendations for conducting operations in a way that would reduce hazards to wildlife, but where these recommendations have been heeded wildlife losses still occur, particularly in the Midwest.

Inexplicably, many New England villages have been conducting control programs for Dutch elm disease for ten years or more, apparently without the heavy mortality that has been observed in the Midwest. Why this is so is not clear, but probably is related to the distribution and density of both elms and robins. Many eastern towns have fewer elms per acre, often distributed in broken patterns, rather than in continuous stands as is the case in many midwestern communities. New England elms were originally thinned out by the early ravages of the disease, before effective control measures were known, and subsequently reduced further, along the coast at least, by hurricanes. It seems likely also that robins are not as abundant (senior author's personal observations) in the East as they are in favorable areas in the Midwest, but no comprehensive studies have been made in the East, so far as we know, on the distribution and density of elms in relation to robin numbers, nor have any follow-up studies on mortality been made. This situation merits further study.

Mortality and the Disease in the Detroit Area

The Control Programs

THE FIRST KNOWN occurrence of Dutch elm disease in Michigan was found in Detroit in the summer of 1950. Since that date it has spread rapidly into surrounding communities, so that by 1959 the disease was known in 77 cities and townships in the Detroit area, 30 in Wayne County, 40 in Oakland County, and 7 in Macomb County. (Michigan Department of Agriculture, Annual Report, 1959.)

Soon after the discovery of the disease several communities in the Detroit area, faced with the prospect of losing up to 90 per cent or more of their shade trees, took prompt steps to try to stamp out the disease and to prevent its further spread. Grosse Pointe, for instance, started a small-scale program to protect its elms in 1951. In general, however, public funds were not available until 1953 when the State Plant Industry Division was able to initiate a coordinated program of inspection, identification of the disease, and promotion of control measures in the infested areas. A number of communities started control programs in 1953 or 1954 and by 1959 at least 35 cities and townships within the three counties ringing the sprawling metropolis of Detroit had had control programs underway over a several-year period (Lovitt, letter).

Steps in the control program consisted of (1) surveys to look for signs of the disease, (2) submission of samples to the State Dutch Elm Disease Laboratory for accurate diagnosis, and (3) initiation of a control program consisting of (a) sanitation, or prompt removal and disposal of all dead and dying twigs, branches and trees, and (b) a spraying program with DDT to kill, control, or prevent the spread of the bark-beetle vectors of the disease. Most communities followed State and Federal recommendations (see Michigan State University Extension Folder, F-195, and U.S. Department of Agriculture Bulletin No. 193) in the matter of formulations, dosages and methods of application, but some private operators may have used their own formulations and techniques. In the earlier years of the programs both foliar and dormant sprays were used, with two or sometimes three applications annually, but the tendency in recent years has been to reduce the applications to one dormant treatment per year, either in the fall after leaf drop or in the early spring before the elm buds open. Hydraulic sprayers were used mainly at first, but there was a gradual conversion to mist blowers over the years, both to conserve on materials by applying

it more directly to the trees and to reduce some of the hazards to wildlife by decreasing run-off, puddling and drift.

Mortality to Birds

With the adoption of the full-scale spraying programs in 1953 and the years immediately following, residents in the heavily sprayed areas began to report considerable numbers of dead and dying birds, particularly robins, with the symptoms commonly associated with nerve poisons. The sequence of events, unnecessarily it now seems, followed the pattern established earlier at Princeton: complaints of residents about dead or sick birds, denials on the part of operators and administrators that any such losses were occurring, or, if they were, that they were in any way connected with the control program; and then often bitter controversies over the relative merits of robins and elms.

To try to assess to some degree how real the loss of birds might be, the Cranbrook Institute of Science, in 1956, asked that birds suspected of DDT poisoning be turned in or reported to the Institute. During April, May and June of that year, but mostly in May, more than 200 dead and dying birds were turned in to the Institute. This taxed their deep-freeze facilities to capacity, so that offers of other specimens had to be turned down, but calls regarding several hundred additional birds were received. By 1959 the number of specimens received had mounted to about 400, with an estimated 600 calls or reports regarding birds not turned in. One woman in Bloomfield Hills called to report that 12 robins were lying dead on her lawn as she called.

Nearly all of the specimens submitted to the Institute came from areas in the immediate vicinity of the Cranbrook grounds, Bloomfield Hills or Birmingham. Losses in other areas, such as in Grosse Pointe, were reported to be high; but the specimens were not saved, nor, so far as we know, any record kept of numbers of individuals or species involved. Nearly half of the retrieved specimens were still alive when found, exhibiting typical symptoms associated with DDT poisoning—i.e., tremoring of the wings and tail, convulsions, gaping and death. None of the afflicted birds recovered, even with confinement and care, but several persons in Illinois have reported some recovery, if the victims are not too far gone, by injecting them with nembutal.

Although the robin seems to be the chief victim in all the Dutch elm disease programs, often constituting up to nearly 100 per cent of the reported specimens, many other species are involved. By 1959, 63 different species had been identified among the specimens turned in at the Institute, a number that can be raised to 94 species if other areas in Michigan are included through 1960.

The birds received at the Institute are clearly divisible into about five categories on the basis of their feeding habits. Foremost among these are (1) the terrestrial feeders, which get much of their food on the ground by probing in the leaf litter or soil. The chief victim among these, the robin, has been reported apparently dying from the effects of elm spraying in about 60 different communities in the Midwest. Barker (1958) has described the leaf litter-earthworm cycle apparently so fatal to robins, but where foliar sprays are not used direct contamination of the soil appears to be just as lethal (Hickey and Hunt, 1960). Moreover, it is by no means certain that robins get their DDT only through earthworms. Other affected ground feeders, some of which rarely if ever feed on earthworms, include several species of thrushes, catbirds, brown thrashers, cardinals (primarily seed-eaters) and flickers (which feed on ants). Stomach examinations to date have failed to give any clue as to the sources of contamination for these species, because the digestive tracts of poisoned birds have nearly always been empty.

(2) A second group of victims is comprised of foliage gleaners, such as orioles, warblers and vireos. Ordinarily these might be expected to be affected chiefly, perhaps only, by foliar sprays, or by dormant sprays applied in late April or May after the leaves start to unfold. This was conspicuously evident in 1956 when a late cold spring held back migration and delayed spraying so that it coincided with one of the heaviest May flights of warblers that the central states have witnessed in many years (Gunderson, 1956). Nearly all species of warblers known to be present in the area at that time were represented in the heavy kill, as were orioles, vireos, and kinglets.

(3) Species that feed primarily by budding in elm trees in late April and May were also involved, though it is not clear, in all cases, whether the source of toxicity here is from eating buds on sprayed elms, or from feeding on insects among the terminal twigs. Potential budders, particularly in 1956 and 1959, included cedar waxwings, rose-breasted grosbeaks, indigo buntings, pine siskins and American goldfinches (see Table 3).

(4) Bark-foragers, such as black-capped chickadees, white-breasted nuthatches, brown creepers, and several species of woodpeckers, which commonly forage over the trunks, branches, and twigs of elms, have apparently suffered heavily. Only small numbers of these species have actually been retrieved and analyzed, but they have declined sharply in the heavily sprayed areas, not only in the Detroit region but in other areas in the Midwest. Some of the specimens have been picked up in the fall and winter, following dormant fall sprayings. Nearly all of these bark-foragers, which formerly were the most dependable patrons of winter feeding stands at Cranbrook, have virtually disappeared.

(5) It seems a little surprising to find predatory birds numbered among the victims turned in to the Institute. These included about 12 hawks of 9 different species, 5 screech owls, a great horned owl and several crows. Nearly all of these were found alive, with typical poisoning symptoms, but succumbed soon after capture. Though it was inferred at first that these were cases of secondary poisoning from eating infected robins or other songbirds, several of the screech owls were found in late winter when robins and most other songbirds were not available. Mortality, in these cases, could be due to (1) feeding on wintering vertebrates (sparrows, starlings and mice) that were carrying sublethal amounts of DDT, (2) delayed toxicity from utilizing stored fat and body lipids during the late winter period of food shortages, or (3) some other cause. Hickey (pers. comm.) reports that several dying screech owls in Wisconsin were picked up following heavy rains in spring. He speculated that they might have been feeding directly on toxic earthworms, like the robins. An East Lansing screech owl was seen dying with convulsions on June 16 (Reid, personal communication). Apparently toxicity in predatory birds can operate in different ways and be reflected at different seasons.

Mortality in the Birmingham-Bloomfield Hills area reached a peak in 1956, when a cold late spring delayed both spraying operations and the arrival of spring migrants, but the heavy die-off continued through the spring of 1957. Few specimens were received at the Institute in 1958, but by that time robins and many other songbirds had reached an all-time low. Some recovery in robin numbers in 1959 gave hopes that the depressed populations of 1957 and 1958 might be a temporary situation after all, but the unfortunate result was higher mortality, the highest since the 1956 peak. The 1959-60 wintering population at Cranbrook also reached an all-time low.

In both 1959 and 1960 breeding bird censuses were made over the 300-acre Cranbrook campus. The breeding bird population, estimated at about 250 pairs in pre-spraying years, was down to 25 pairs or less in 1959 and 1960, with no assurance of course that the nesting pairs would be successful. No successful nests of robins were found in either year. At one robin nest, located in a juniper under the outer branches of an elm sprayed the previous week, the female was found dead immediately below the nest, the male was lying on the ground about 25 feet away, and three of the four young were dead in the nest. The fourth nestling was removed and hand-reared successfully.

Hence, it is clear that avian mortality in the Birmingham-Cranbrook area has been high, at least from 1956 through 1960, as is demonstrated by records of approximately one thousand specimens, nearly half of them exhibiting apparent poisoning symptoms.

The 1960 Spring Die-off of Robins at East Lansing

PREVIOUS REPORTS (Mehner and Wallace, 1959; Wallace, 1959; Wallace, 1960) have documented robin losses on the Michigan State University Campus at East Lansing from 1955 through 1959, coincident with various spraying programs, particularly the one for the control of Dutch elm disease. Briefly, an estimated pre-spraying population of at least one pair per acre over our 185-acre study area dwindled to a few scattered adults and one young by the end of June 1957 (Mehner and Wallace, 1959). In 1958 several successive small waves of robins invaded the campus in April and May, but these died or disappeared before the end of June (Wallace, 1959). In 1959 about 10 pairs settled on the campus in mid-April; by the end of June we had at least 45 dead robins (specimens or unduplicated reports) from the area where the 10 pairs were resident in April (Wallace, 1960). This supplementary report describes in detail the 1960 spring robin losses and presents more complete data on spraying programs.

Spraying History

The campus program for the control of Dutch elm disease, which is felt to be primarily responsible for the near-annihilative spring robin losses although other programs are also involved, began with the experimental (protection) spraying of a few trees in 1954. The program was expanded in 1955 (when dying robins were first noted) and became a full scale treatment of all campus elms in subsequent years. Both foliar (summer) and dormant (fall or spring, usually spring) sprays were used in 1956, 1957 and 1958; since then (1959 and 1960) only the dormant sprays have been used. These data on past spraying history are from grounds maintenance officials who have charge of the on-campus elm tree care.

Unfavorable weather conditions in the fall of 1959 prevented much fall spraying and a late spring in 1960 postponed operations until April 13, close to the date usually recommended for the cessation of the spring treatment because of opening buds. Spraying for Dutch elm disease was completed in early May in 1960. Rotomist sprayers were employed, using a 12½ per cent solution of DDT (one part of a 25 per cent DDT emulsion to one part of water). These dosages are those recommended in the M.S.U. Cooperative Extension Folder on Dutch Elm Disease Control (F-195, Revised).

According to grounds maintenance men, some 2,300 elms on 880 acres of East Lansing campus come under their care; 565 of these are on our North Campus study area. An additional 142 large elms

along the boulevard forming the north boundary of the campus (US-16) come under the jurisdiction of the State Highway Department, but are also sprayed annually. This gives a North Campus density of 3.05 elms per acre, or higher if peripheral trees are included. Such a high density of elms (Hunt, 1960; Hickey and Hunt, 1960) might well be a factor in the high mortality observed.

Methods of Study

Weekly censuses of the North Campus were taken in the spring of 1960 from April 2 through June 26 to ascertain the original population of incoming robins and to try to measure the decline from week to week. Census takers were chiefly student volunteers, all with advanced ornithology training, and the method employed was to assign each counter a route to be traversed by walking slowly and counting all the robins seen or heard within the assigned area. Then the counters assembled at the ends of their routes and compared notes. Usually three census-takers were used, but on two occasions only two were available and in two other cases five counters participated. Some duplication of counts is probably inevitable by this method, as when a robin flies over or into another counter's area and gets listed twice, but we feel that this is more than offset by robins that were missed entirely, especially during late May and June when dense foliage may have concealed some non-singing birds. Incubating females might also be missed, but in most cases we knew the location of their nests, which were routinely checked on the censuses. All of the counts were taken in the morning, between 6:00 and 8:20 A.M., mainly before much campus activity, such as incoming 8:00 A.M. traffic, could cause disturbances. Singing male counts proved unreliable, as territories were so widely spaced that singing was minimized; often, by careful search, we could find upwards of a dozen or so robins, when perhaps only one or two would be heard singing during the counting period.

We are indebted to Ralph Moldenhauer and Willet Van Velzen, student volunteers, who usually helped with the censuses, and to Mrs. Wallace, who filled in on the post-Memorial Day count when students were not available. Gerald Kettunen and Ernst Lucas also participated in the censuses, but as a part of a research project financed by the Bureau of Sport Fisheries and Wildlife. Ten other persons, mostly students, were helpful in reporting or turning in dead or dying robins. Ira Glover, a grounds maintenance worker, was particularly faithful in reporting his finds.

Results

Robins were unusually late in arriving in numbers in East Lansing in the spring of 1960, due in part to a delayed spring,

and in part to the fact that few if any territory-holding males (or females) survived the 1959 die-off (Wallace, 1960). The first migrant robins usually show up in early March (sometimes late February), then arrive in numbers with the first thaws or warm rains later in the month. Neither warm rains, nor robins in numbers, came in 1960 till about mid-April. Our first two April counts (Table 1) yielded only 5-7 robins, but on April 18, following mid-April rains and balmy weather, we counted 36, the maximum number found on any of the April-June censuses. The first dying robin was brought in later in the day, 7 days later than the first East Lansing victim found in 1959 (5 days later than the first campus victim). The birds died off rapidly during the next 10-12 days. On April 30 our count of living robins was down to 15 (from 36) and we had 16 dead ones (13 specimens turned in, 3 others reported but not saved). By May 22 the campus population was down to about 3 and remained close to that number thereafter (until the late June-July summer influx of new birds), though obviously the 3 or 4 present through most of June were not the ones present in late May. Table 1 gives the details of our 13 weekly censuses and Table 2 gives the chronological history of the recovery of the dead and dying birds.

TABLE 1

North Campus Robin Counts at East Lansing, Michigan, Spring 1960

Date	Time	Number of Observers	Number of Robins	Accumulative Dead*	Active Nests	Abandoned Nests	Remarks
Apr. 2	7:10-8:20	4	5 (7)	0	0	—	4♂♂, 1♀, 2 flying over
Apr. 10	7:00:8:00	3	5	0	0	—	2 singing, 1 pr., + 1
Apr. 18	6:45-7:45	3	36	1	2	0	Mostly pairs, 2 building
Apr. 25	6:30-8:00	5	25	4 (5 "sick")	4	0	11 prs., 3 single
Apr. 30	7:00-8:00	5	15	16	6	1?	5 prs., + 5
May 9	6:45-8:00	3	8	20	5	4?	5♀♀, 3♂♂?
May 15	6:30-8:00	3	8	24†	5?	7?	3♀♀, 2♂♂, 3 undet.
May 22	6:30-8:00	2	3	28	3?	9?	1♀, 2 undet.
May 30	6:15-8:15	2	2 (5?)	29	1	11	1 pr., 1-3 strays
June 5	6:40-8:00	3	3 (new)	29	0	12	2 heard, 1 seen, in new places
June 11	6:00-7:30	3	3	31	—	—	New pair + 1
June 22	6:00-7:30	3	3 (6?)	31	—	—	2 imm. & 1 ad. seen; 1-3 others heard.
June 26	6:00-7:30	3	9 ±	31	—	—	4 flying over, ♀ & imm. seen, others heard.

*Includes specimens found during day *after* morning counts.
†Includes one from across river (South Campus) but believed to belong partly on North Campus.

Our recovery of dead robins in 1960 was lower than in 1959, when 45 specimens were retrieved or reliably reported from an area where our maximum count in 30 April-June censuses was 22 (Wallace, 1960). Two reasons are assigned for the lower recoveries in 1960: (1) fewer robins were available for replacements from peripheral areas surrounding the campus (the 246-acre residential section immediately north of the campus, for example, may have had fewer than 6 robins left in it during the last week in June), so that ingress from this source was limited; (2) many people did not bother to turn in or report dead birds, even though some were asked to do so. No general request was issued for turning in or reporting dead birds but students in two classes (Ornithology and Nature Study) were asked to save us specimens for analysis. The grounds maintenance crew was also asked to report and save specimens, but only one of them did so.

Detailed nesting studies were not carried out in the spring of 1960, but known campus nests were checked on our weekly surveys (Table 1), or more often in some cases. Ten of twelve nests were abandoned during nest building or incubation, apparently due to the death of the adults as dead robins were found in the vicinity of nearly all of the deserted nests. The other two nests contained two young in each, but these disappeared, probably before nest leaving, although it is conceivable that they fledged. Careful search in the vicinity of the empty nests at about nest leaving time, however, disclosed neither adults nor young. On June 22 two immatures were seen near the north border of the campus, but they were full grown; their sudden appearance as well as that of all robins seen in late June was thought to be due to ingress. Hence, ten out of twelve campus nests failed completely, and the remaining two were probably unsuccessful.

Chemical analyses of the 22 robins available from this spring's campus study have been made, as well as tests on unhatched eggs, embryos and one nestling. Details of these analyses (plus many others) are reserved for a more complete report (Bernard, unpublished). Suffice it to say that all of the robins, whether found dead or dying, had high, presumably lethal, accumulations of DDT in all of the tissues examined (brain, breast muscle, heart, liver, kidney, and gonads). DDT was also present in the developing egg follicles in the ovaries of females, in unlaid but completed eggs in the uterine portion of the oviducts, in unhatched eggs in deserted nests, in embryos within the eggs, and in a newly hatched nestling.

Other Species

In conjunction with the robin surveys and campus breeding bird censuses that have been going on for several years, records were

TABLE 2

History of Dead and Dying Campus Robins
at East Lansing, Michigan, Spring 1960

Date	Location	Collector	Sex & Condition	Remarks
Apr. 18	Mech. Engr.	Wm. Overlease	♀, with symptoms	Died in office with violent spasms
Apr. 20	Power Plant	W. VanVelzen	—, found dead	Seen "affected" on the 18th?
Apr. 22	Mech. Engr.	G. Wallace	♂, found dead	Day or so old, wet
Apr. 25	Mason-Abbott	D. Coller	♂, found dead	5 others "affected" (Wallace & Etter)
Apr. 26	Museum	Z. 303 class	♂, with symptoms	4 others reported: 3 dead, 1 with symptoms—Glover
	Union	Z. 303 class	♀, with symptoms	
	Snyder Dorm.	Z. 302 class	♂,dead;♂,symptoms	
Apr. 27	Agr. Bldg.	J. Hunt & Etter	♀, with symptoms	Seen in AM, caught later
	Union Bldg.	M. Pirnie	—, found dead	Specimen saved
Apr. 28	Power Plant	W. VanVelzen	♂, with symptoms	Found in AM, died in PM
Apr. 29	Phillips-Snyder	I. Glover	♂, with symptoms	Brought in dead at 4:00 PM
May 2	Phillips-Snyder	I. Glover	♀, found dead	Specimen saved
May 3	Physics-Math.	D. Coller	♂, with symptoms	Specimen saved
	Mary Mayo	J. Smith	♂, with symptoms	Specimen saved
May 4	Haslett Exit	I. Glover	♀, found dead	Not fresh, but saved
May 9	Auditorium	I. Glover	♀, found dead	Specimen saved
May 12	Mason-Ab., Art	I. Glover	2♀♀, found dead	Specimens saved
	Stadium	Z. 303 student	—, found dead	Specimen not turned in
May 16	Band Shell	A. Etter	♀, found dead	Near abandoned nest
May 17	Beaumont Tower	M. Pirnie	2 chopped up in mowers	Pieces not saved
May 18	Phillips-Snyder	I. Glover	—, found dead	Specimen saved
May 24	Haslett Exit	G. Wallace, Peters and Moldenhauer	♀, with symptoms	Seen at 4 PM, captured at 5:40, died at 9 PM
June 11	Mason-Abbott	I. Glover	2 dead, old	Saved, then discarded
June 29	Chemistry	E. Lucas	Seen with sympt.	Not there next day

Summary: 22 specimens saved (analyzed): 12 found dead, 10 with symptoms.
9 others not saved.
31 total specimens.
(18 others reported with symptoms, some of them probably picked up later as dead birds).

kept of dead birds recovered or reported on campus. In the spring of 1960 these included, in addition to the robins, about 64 individuals of 14 different species: 20 house sparrows, 15 mallards (semi-domestic on river), 6 common grackles, 5 starlings, 5 cardinals, 4 chimney swifts, 2 blue jays, and one each of 7 other species. Presumably others were not reported to us. Except for the chimney swifts, which were presumed to have died of starvation during a prolonged rainy spell, and a transient ovenbird, tested samples so far have usually yielded fairly high levels of DDT (Bernard, unpublished).

Analysis of Specimens

THE EARLY RESEARCH by Fish and Wildlife Service biologists on toxicity of DDT to wildlife (Hotchkiss and Pough, 1946, and others), the field and laboratory tests at Princeton (Benton, 1951; Blagbrough, 1952), and later the research on robin-earthworm relationships in Illinois (Barker, 1958) clearly indicated that mortality to birds was to be expected in other Dutch elm disease control programs. In spite of this, there has been a great need, and an insistent demand on the part of critics, for further analyses of specimens to demonstrate the presence of DDT in dead and dying birds.

Previous attempts to get specimens analyzed, however, have ended largely in frustration or failure. Samples of the Cranbrook specimens were sent to the Henry Ford Hospital for analysis, but technicians reported that they could not analyze frozen tissues satisfactorily. Repeated efforts to get specimens analyzed at Michigan State University were also unsuccessful, as available laboratories seemed to lack facilities or the personnel needed to conduct the analyses. Robins sent to University veterinarians in 1956 from Benton Harbor and Grand Rapids were diagnosed as dying from DDT (Belding, letters), but chemical analyses of the tissues were not made. In 1958 we sent specimens to the Patuxent Research Center, in Maryland, where some DDT analyses had been conducted; they are still in storage, unanalyzed, three years later. These and other experiences point to the great need for further analytical work.

Fortunately, a grant from the Bureau of Sport Fisheries and Wildlife in the summer of 1959 enabled us to set up facilities for such examinations in the Department of Agricultural Chemistry at Michigan State University, and a zoologist-chemist (junior author, Bernard) was enlisted to conduct tests on the many specimens saved for this purpose. The details of these analyses are reserved for a later report (Bernard, unpublished). Herewith follows a report on the analyses of a series of 67 specimens from Oakland County, a special project financed by the Cranbrook Institute of Science in the summer of 1960.

Methods

Except for two birds whose bodies were preserved in formalin, all of the specimens analyzed had been in refrigeration for several months to a year or more. The frozen carcasses were allowed to thaw, then sections of tissues were removed and analyzed separately. In most cases a variety of tissues (brain, breast muscle, liver, and heart) from each bird was tested in order to determine levels of DDT in different areas of the body. The tissues were weighed

and macerated with anhydrous sodium sulphate in a mortar. The DDT was extracted by repeated ether washes, pouring off the supernatent liquid each time into a filter tube attached to an Erlenmeyer flask.

After evaporation of the solvent on a steam bath, the samples were analyzed for DDT in accordance with the Schechter-Haller method of analysis (Schechter, et al, 1945) as prescribed by the Association of Official Agricultural Chemists (1955). Readings were made at a wave length setting of 600 mu on a Beckman Spectrophotometer. So far as is known, the only other substance that interferes with this determination is the compound, DDE. No attempts were made to separate DDT from any of its known metabolites.

In order to determine the efficiency of the extraction, a known quantity of insecticide was macerated with the tissues and extracted with ether to determine the percentage of recovery. Recovery ranged from 91 to 112 per cent. Blank samples (usually tissues from birds previously determined to be free from DDT) were carried along with each set of samples analyzed, to correct for deviations in technique and interfering substances (fat, waxes, pigments, etc.).

The moisture content of tissues was determined at random to find the amount of moisture lost during storage (about four years in one case). Loss of moisture invariably concentrates the solid constituents of the tissue and results in higher concentrations of DDT when results are expressed on a wet-weight basis. In the two birds whose bodies had been preserved in formalin, the formalin was evaporated in a steam bath and the residue was added to the samples.

Results

Table 3 indicates the residues of DDT, expressed in micrograms of DDT per gram of tissue (μg/g) or parts per million (ppm), found in various tissues of 67 specimens (34 species) from the Detroit area. All were from Oakland County, mostly from Birmingham or the Cranbrook campus, but several specimens (the gnatcatcher, oriole, red-wing, one robin and one warbler) were submitted from nearby communities.

Thirteen of the 67 specimens (19.4 per cent) examined were negative or free from DDT, at least in the tissues examined. All the robins secured in April or May (13) had high levels of DDT in the brain, breast muscle, heart and liver, compared to low levels in a June specimen and none in a July bird. The July specimen, an immature bird, and perhaps the one in June, may have been fringe robins, recently moving into the sprayed area. (From much more

extensive studies at East Lansing, we think it very unlikely that a robin could live for long in a DDT-treated area without accumulating some DDT.)

TABLE 3

DDT Residues in Avian Tissues
(In μg/g of wet-weight tissue)

Species	Date	Sex	Condition	Brain	Breast Muscle	Liver	Heart	Body*
Red-shouldered Hawk	Winter 59	♂	Tremors	14	48	37	20	—
Marsh Hawk	Winter 59	—	Tremors	5	4	4	6	—
Pigeon Hawk	Winter 59	—	Tremors	6	0	0	0	—
Screech Owl	Winter 59	♀	Tremors	20	0	0	0	—
Screech Owl	Winter 59	♀	Tremors	2	0	0	0	—
Saw-whet Owl	Winter 59	—	Dead	—	0	0	0	—
Black-billed Cuckoo	—	—	—	0	0	0	0	—
Nighthawk	—	—	—	0	0	0	0	—
Flicker	20 Apr. 60	♂	Dead	7	0	0	0	—
Flicker	1-10 May 60	—	Dead	63	133	—	97	—
Downy Woodpecker	18 Nov. 59	♂	Dead	—	9	13	4	—
Purple Martin	14 May 60	—	Dead	0	0	0	0	—
Blue Jay	15 May 60	♂	Tremors	45	50	117	72	—
Brown Thrasher	12 May 59	♂	Tremors	21	57	80	38	—
Robin	1-10 May 59	♀	Dead	52	54	100	46	—
Robin	1-10 May 59	♂	Dead	44	175	104	107	—
Robin	1-10 May 59	♀	Dead	77	240	367	155	—
Robin	14 May 59	♂	Tremors	98	264	129	257	—
Robin	15 May 59	♀	Tremors	109	173	169	143	—
Robin	18 May 59	♀	Tremors	99	164	149	94	—
Robin	8 June 59	♂	Dead	11	3	—	—	—
Robin	28 July 59	Juv.	Dead	0	0	0	0	—
Robin	20 Apr. 60	♂	Tremors	77	82	154	93	—
Robin	20 Apr. 60	♀	Tremors	71	34	60	16	—
Robin	20 Apr. 60	♂	Tremors	75	82	65	60	—
Robin	21 Apr. 60	♀	Tremors	69	155	183	154	—
Robin	23 Apr. 60	—	Dead	90	104	128	91	—
Robin	6 May 60	♀	Tremors	83	121	162	151	—
Robin	16 May 60	♂	Tremors	50	111	189	31	—
Wood Thrush	—	♂	—	16	26	43	20	—
Hermit Thrush	28 Apr. 60	—	Dead	5	10	11	4	—
Gnatcatcher	10 Apr. 59	♂	Tremors	—	—	—	—	147
Ruby-crowned Kinglet	21 Apr. 59	—	Tremors	—	—	—	—	195
Cedar Waxwing	20 Oct. 59	—	Dead	0	0	0	0	—
Cedar Waxwing	20 Oct. 59	—	Dead	0	0	0	0	—
Cedar Waxwing	26 Apr. 60	—	Tremors	76	107	141	99	—
Cedar Waxwing	11 May 60	♂	Tremors	84	106	116	152	—
Starling	23 Apr. 59	♀	Tremors	138	205	281	166	—
Starling	29 Apr. 59	♀	Tremors	78	30	68	34	—
Starling	1-10 May 59	♂	Dead	117	339	—	71	—
Starling	27 May 59	—	Tremors	37	30	68	31	—
Starling	—	♀	—	88	148	200	102	—
Bl-th-green Warbler	9 May 56	♂	Dead	—	—	—	—	122
Bl-th-green Warbler	10 May 56	—	Tremors	—	—	—	—	122
Mourning Warbler	27 May 60	♂	Dead	—	—	—	—	0

Ovenbird	19 May 59	♀	Dead	0	0	0	0	—
Ovenbird	29 April 60	♂	Dead	0	0	0	0	—
House Sparrow	1-10 May 59	♀	Dead	80	48	89	39	—
House Sparrow	15 May 59	♂	Tremors	105	130	197	125	—
Red-winged Blackbird	23 Apr. 59	♂	Tremors	—	157	—	98	—
Baltimore Oriole	10 May 59	♂	Tremors	—	102	—	43	—
Baltimore Oriole	8 May 60	♂	Tremors	122	76	133	100	—
Common Grackle	22 April 59	♂	Tremors	49	90	79	76	—
Common Grackle	29 May 59	Juv.	Tremors	22	13	29	44	—
Common Grackle	8 June 59	♂	Tremors	2	4	9	4	—
Cardinal	28 April 60	♂	Tremors	75	18	32	0	—
Rose-br. Grosbeak	5 May 60	♂	Dead	0	0	0	0	—
Rose-br. Grosbeak	Spring 60	♂	Dead	150	104	172	70	—
Rose-br. Grosbeak	Spring 60	♂	Dead	13	5	11	22	—
Pine Siskin	16 May 56	♂	Tremors	—	—	—	—	128
Goldfinch	26 Apr. 59	♂	Tremors	—	—	—	—	168
Goldfinch	27 Apr. 59	♂	Tremors	—	—	—	—	117
Towhee	10 May 60	♀	Tremors	50	15	35	—	—
Grasshopper Sparrow	1-10 May 59	—	Dead	0	0	0	0	—
Slate-colored Junco	22 Apr. 59	—	Dead	—	—	—	—	9
Slate-colored Junco	18 Nov. 59	—	Dead	0	0	0	0	—
Chipping Sparrow	1-10 May 59	♂	Dead	—	22	28	27	—

*Entire body, excluding feet, bill, and feathers, analyzed.

Of the other 33 species listed in Table 3, 7 species (12 specimens) had no DDT in the tissues examined. Two of these, the nighthawk and purple martin, were aerial feeders, not likely to be affected by a ground program treating elms; 3 negative warblers, a rose-breasted grosbeak and perhaps the grasshopper sparrow may have been newly arriving migrants (judging by the collection dates); and 2 waxwings and a junco were found dead in the fall. In addition, a negative black-billed cuckoo was submitted without any data and a negative saw-whet owl was found dead in the winter. All other specimens examined (55) had accumulated varying amounts of DDT. It seems probable that some of these birds, perhaps those with low (sublethal) levels of DDT, may have contained other toxic chemicals, such as chlordane which is widely used on lawns in the Birmingham area, but the Schechter-Haller test here employed is specific for DDT and does not indicate the presence or absence of other chemicals

The analyses of predatory birds (hawks and owls) present an unsolved problem. The red-shouldered, marsh and pigeon hawks, and two screech owls, all observed dying of apparent poisoning symptoms, had only low or medium levels of DDT, but in all except the red-shouldered hawk the tests proved unsatisfactory. Red colors appearing in the final solution indicate (1) contamination or interference of some other chemical (which seems unlikely here because the red reaction was not obtained in any of the other birds), or (2) a break-down of the DDT into its metabolites so that the original accumulation of DDT could not be measured. It seems likely,

though as yet unproven, that when the DDT passes through several links in a food chain—invertebrate, small vertebrate, predator—the final product in the predator may be altered chemically.

The average accumulation and distribution of DDT in various organs and tissues of 12 robins (excluding the unsexed specimen, and the June and July birds which are presumed to have died from some other cause) are expressed in Table 4.

TABLE 4

Levels of DDT in 5 Male and 7 Female Robins

Tissue	Male	Female	Average
Brain	68.8	80.0	75.4
Breast Muscle	142.8	134.4	137.9
Heart	109.6	108.4	108.9
Liver	128.2	170.0	152.6

Though the sample is small, it is evident from these figures (and from a larger series of unpublished analyses from East Lansing) that female robins are able to tolerate higher levels of DDT, except in the breast muscle, at least in the spring. It is thought that higher levels in breast muscles of males might be related to muscular activity and consequent deposition of DDT in muscle tissue, whereas the less active females on nests might store larger amounts in the liver and other organs. Amounts in the liver, in robins and other species, are high but variable, and probably related to the storage function of that organ.

Exact lethal levels are not known for robins or any of the other birds listed, nor is it known which organs are the chief centers for lethal accumulations; but from these and other analyses, as well as from the work of Barker (1958) and De Witt, et al (1955), we conclude tentatively that levels below 20 or 30 ppm in the brain or breast muscle may be sublethal (though not necessarily so in all cases) and that levels above 40 or 50 ppm in those tissues are lethal, though of course certain individuals can tolerate higher levels at times. The amount and distribution of DDT in different tissues may be a complicating factor also, as when a bird has low levels in one organ but high in another. We have, for example, a record of an East Lansing robin (juvenile) with no DDT in the breast muscle and 282 ppm in the heart!

It is interesting to note that nearly all song birds listed in Table 3 as having "tremors" had high levels of DDT. The chief exception, a male grackle retrieved on June 9, 1959, might be explained by (1) poisoning symptoms mistaken by the observer, or (2) the presence of some other poison such as chlordane.

Survey of Mortality by Communities

OTHER THAN THE STUDIES here described for the Birmingham-Crankbrook and East Lansing areas, no comprehensive survey of Michigan communities has been made, either as to the nature of their Dutch elm program or resultant mortality to birds. According to the 1959 Annual Report of the Michigan Department of Agriculture (Dutch Elm Disease Control Program) the disease has been detected in 261 cities or townships in 36 counties in southern Michigan. Lovitt (letter) indicated that at least 68 communities in Michigan have had a control program in operation over a period of years.

Though we have not made a complete survey of the situation in these other communities, our attention has been called to bird mortality in some of them by letters, personal communications, or newspaper reports. Sometimes information from these sources is inaccurate or misleading, but actual counts of dead birds are of course minimum. That is, one would have to set up a 24-hour vigil by a large corps of observers over a several-months period following spraying operations to assess the total mortality. In normal situations predators and scavengers, some of them nocturnal, would dispose of afflicted birds *before* they ended up as carcasses on the ground. In more artificial environments, as on campuses or in parks, predators and scavengers may be absent or scarce, so that some accumulation of dead birds results.

It is possible of course that some communities in Michigan have conducted a Dutch elm disease control program without significant losses of birds. We lack reports, of any kind, from about 40 communities known to have had such a program. These may have had (1) little or no loss of birds, (2) moderate losses but no one observing or interested in them—control officials seldom make follow-up observations, or report mortality if seen, (3) mortality recorded but not reported to the authors, who usually have not solicited such information.

The following comments summarize the meager data we have from these additional communities and is here appended to the more comprehensive data for the Birmingham-Cranbrook area and for East Lansing.

Albion.—Though a control program has been in effect here for a number of years, the only report we have on mortality is of birds, including tufted titmice and chipping sparrows with symptoms of poisoning, being turned in to the Biology Department at Albion College (Dixon, personal communication).

Ann Arbor.—We have little information on the Dutch elm disease situation here, but a Parks Department Communication (*Ann Arbor*

News) indicated that a control program was started in 1953. The program was termed "successful" and "the bird population high," but this view was not shared by some other observers (Boyce, Menefee, Parry, Wing—*Ann Arbor News*) who deplored the slaughter of useful songbirds that accompanied the spraying of the elms. Dr. R. W. Storer, Curator of Birds at the University Museums, when asked about the situation remarked that robins had been largely eliminated from the campus (in 1958) but were still numerous in some parts of the city that lacked elms in numbers, or an elm protection program.

Battle Creek.—Many reports and telephone calls are received at the Kingman Museum each spring (E. M. Brigham, Jr., personal communication) about dead and dying birds, presumed to be victims of the Dutch elm program, though other pesticides may also be involved. A robin and a blue jay submitted by Mabelle Isham had high levels of DDT; a black-billed cuckoo and a Swainson's thrush were not analyzed.

Benton Harbor.—Heavy mortality to robins reported, both in Benton Harbor and its twin city, St. Joseph, in 1956. Citizens' complaints were said to have modified subsequent spraying programs. Robins sent to Dr. Belding, Veterinarian at Michigan State University, were diagnosed as dying from DDT, but chemical assays of tissues were not made. Dr. Freier, who submitted the robins, wrote that a large number of them were being found dead or unable to fly and that the local police department was swamped with calls.

Berkley.—A black-throated green warbler picked up on May 9, 1956, "along with six or seven others," (Falconer, letter) was sent to M. S. U. for analysis. A resident who retrieved the bird said it died from Dutch elm sprays, but the city forester said that this was unlikely. The specimen was "lost" for several years in storage; when the mummified carcass was analyzed four years later, it was found to contain 122 ppm of DDT.

Birmingham.—This city is believed by Nickell to be one of the most intensively sprayed areas in the United States, and, because of the development of spacious estates and parks attractive to birds, to have suffered unusually heavy mortality. Spraying for Dutch elm disease began in 1953 with two or three treatments per year, but in the past three years spraying of the elms (16,000 in the city—8,000 municipally controlled) has been largely confined to the dormant spring treatment, usually beginning in late March and ending, if weather permits, in April. Charles Gale, city forester who supplied these spraying data, has been conscious of the bird mortality problem and has made efforts to conduct the program in ways to minimize hazards to birds; but some private operators, in response to demands of some home owners, or for more business, have not always followed recommended procedures.

Some of the ensuing mortality to birds in Birmingham has already been described. At least a thousand birds, involving 63 or more species, were reported dead, or dying with apparent poisoning symptoms, between 1955 and 1959 in the Birmingham-Bloomfield Hills area; many others of course were not retrieved or reported. How much of this mortality is due to DDT used in the Dutch elm program, and how much to other, usually private, operations, including the use of chlordane on lawns for grub control, is unknown.

Many citizens in Birmingham have become conscious of the hazards to wildlife associated with the intensive use of toxic insecticides and there has been a commendable tendency to reduce their use as much as seems consistent for the preservation of other values, such as elms, lawns and gardens.

Bloomfield Hills (Cranbrook campus).—The Cranbrook campus, a 300-acre area of private schools and institutions with spacious grounds and attractive plantings, has closely followed Birmingham in its treatment for Dutch elm disease. In addition, several parts of the area are quite thoroughly covered for mosquito control two or three times each summer. The result seems to have been a severe reduction in birdlife, from approximately 250 breeding pairs in former years to 25 or fewer pairs in recent years, and a corresponding reduction in resident winter birdlife.

Constantine.—Spraying of the trees in 1959 said to be followed by a dearth of birds, with many (especially robins) on their backs with their feet in the air (news clipping).

Detroit.—The control program to try to save this city's 800,000 elms has been in operation for at least seven years. Officials report that their protection program has been outstandingly successful, with losses from Dutch elm disease cut down to one per cent or less (Meyer, Vaydik); but unofficial observers, seeing large numbers of dying elms in the city, are inclined to wonder just what constitutes losses attributable to the disease. One observer recently counted 40 dead or dying elms on one street in Detroit, but of course their death may have been caused by other factors, or possibly these were unsprayed trees.

Bird losses in the city have not been assessed accurately. One city official placed the loss over the years at "six or seven birds"—a conservative figure indeed if Birmingham, with only 16,000 elms (1/50 the Detroit figure), recorded a mortality of about 1,000 birds during the same period. Some newspaper reports placed a high estimate on the mortality; other reports discredited these estimates.

East Lansing.—In addition to the rather comprehensive data from our six years of study on campus, several surveys, incidental observations, and records of mortality in other parts of this University city have been made. The city program apparently began in 1956

with the spraying of one section of the city, to which other sections and newly annexed areas were added in subsequent years. Both foliar and dormant sprays were used in the early years of the program, but foliar sprays (except for some private operations) were discontinued in 1959. (Emerson, Parks Superintendent).

Attempts to assess mortality to birds due to Dutch elm disease control is complicated by other overlapping programs also using DDT, such as private operations in the care of home grounds, a community-wide program for mosquito control in 1958 and 1959 and earlier treatment for gypsy moths in 1955 and 1956. In general, robin and other songbird numbers followed the campus trends, reaching a low in 1958. As observed in the Detroit area, there was some recovery in 1959, but mortality was higher (140 or more Lansing-East Lansing records) so that by the end of the breeding season few insectivorous birds were left. The 1960 East Lansing robin population was even lower than in 1958; four surveys taken in late June over 62 city blocks (246 acres) indicated that there might be fewer than six adult robins and no young in this entire area during the last week in June (Lucas). In the early 1950's there were believed to be one or more pairs of robins per block. Another 66-acre section of the city, which has an unusual density of sprayed elms (about 500) was visited 12 times in the spring of 1960, but no resident robins were found (Kettunen).

These and other studies are being continued at East Lansing and it is hoped that more comprehensive data will be available in the future.

Flint.—This city has a special problem in that only 9,000 of its 20,000 elms are city-owned. Though the city-owned elms have been sprayed regularly (at night), sanitation has been emphasized in the Flint program, as it is hardly feasible to control the disease by spraying where there are so many privately owned unsprayed elms (Ruth). No reports of bird mortality have come to our attention from this area. The city forester, who explained the Flint Dutch elm program at a meeting of the Genessee Audubon Society in April, 1960, remarked that they had had no special bird problem and none of the Audubon members present disagreed.

Grand Rapids.—Spraying for Dutch elm disease apparently started in Grand Rapids in the spring of 1955 and was continued until 1960 when the program was largely abandoned as a community-wide project (Dockeray). Lack of adequate funds for keeping up with sanitation and for carrying out a city-wide spraying program, especially on low ground where the disease is difficult to control, create special problems in this city (Janes).

Soon after the initiation of the control program in 1955 the Grand Rapids Public Museum "began receiving spotty reports of birds gasping, jerking and dying in people's yards." Such reports

continued to come in during the rest of the summer and during the springs of 1956, 1957 and 1958 with the peak reports in 1956 and 1957. Since then most of the inquiries have been, "Why aren't we seeing robins in our neighborhood any more?" (Dockeray).

Most of the recorded mortality pertained to robins, but blue jays, cardinals, orioles and warblers were also mentioned. Some newspaper publicity was given to the problem of declining robin populations and mounting reports of dead and dying birds (Gleason). During the past two winters (1958-59, 1959-60) the Museum has received "a continual stream of calls from people who formerly had busy feeders but now scarcely any birds" (Dockeray). Chickadees, nuthatches, and woodpeckers have been especially lacking.

In 1956, Mrs. Uhl and Mr. Hinrichs both sent affected robins to Dr. Belding at M. S. U. for examination. Mrs. Uhl found 6 dead robins within a week on her lawn that spring, and wrote that the same pattern existed in other sections of the city. The robins submitted for examination were diagnosed as dying of DDT poisoning, but chemical analyses were not made.

Grosse Pointe.—"Dead birds were all over during the spring spraying" (Ford, 1960). "Bird life in the Grosse Pointe area is almost extinct" (Wright, 1960).

Huntington Woods.—A trembling blue-gray gnatcatcher, picked up several days after spraying of the local elms in 1959 (Kreag), is our only clue concerning a program and ensuing mortality here.

Jackson.—Spraying of the 6,000 city-owned elms has been going on since 1956 on a contract basis as the city does not have sufficient equipment of its own. Funds have been lacking for a complete sanitation program and the many unsprayed private elms (about 3,000) add to the difficulties (White, City Forester).

Typically, newspaper reports of dead and dying birds have followed spraying operations. Owens, biology teacher at one of the schools, reported that a number of robins with symptoms and a tremoring brown creeper were turned in to him. Whiting, biology teacher at Jackson Junior College, sent robins to M. S. U. for examination but the final destination and disposal of these has not been learned. A curious incident followed the 1960 spraying. George Alexander, a biology teacher at the High School, received two tremoring robins. Holding a struggling bird in each hand, he took them to William Fedore, another biology teacher, and found the latter also holding a robin in each hand.

Jonesville.—A letter of protest, signed by 10 boys at a local school, was sent to the State Department of Conservation, deploring the death of birds in the Dutch elm spraying (Kent, 1959). According to a news clipping, the 1960 treatment of the elms was called off because of a petition signed by 222 people.

Kalamazoo.—Some concern has been expressed over losses to bird life from pesticide programs in this city (Hall, personal communication), but we have little real information on mortality or on the operations involved. C. H. Elliott, city manager, defended the elm protection program, saying that reports of bird mortality were greatly exaggerated and on close investigation usually proved to be false.

Lansing.—The Lansing Dutch elm program, which involves the care of about 25,000 city-owned elms plus increasing numbers in newly annexed areas (Haskell) is similar to that described for East Lansing. Like the latter, the situation is complicated, as far as interpreting the resultant mortality to birds is concerned, by several aerial applications (in 1955, 1956, 1958, and 1959) over large areas for mosquitoes and other pests. Most of the reported mortality to birds followed the late May or early June aerial applications, rather than the March-May elm treatments, perhaps because the unfavorable newspaper publicity given the mosquito program incited people to report their findings. When questioned, however, some remembered finding dead robins in April before the aerial spraying for mosquitoes. One lady (in East Lansing) who reported a "sick" robin had never heard of Dutch elm disease and did not know that the elms in her neighborhood had been sprayed.

Hence, it is not known whether the dead birds reported following the much criticized aerial applications were really victims of the mosquito control programs or were continued mortality from earlier elm sprays or both. All of the Lansing robins analyzed to date (Bernard, unpublished) had high levels of DDT, but specimens of other species from Lansing, with a few exceptions, have not been analyzed yet. Many of the reports, moreover, referred to the "sudden disappearance," "declines," or "wiping out of songbirds" rather than to retrieved specimens. Most of the reports of dead birds (other than robins) involved blue jays, cardinals, orioles, wrens and sparrows.

Marshall.—After several intermittant years of a ground program for Dutch elm disease, Marshall, in 1960, carried out a much criticized aerial program, perhaps the first in Michigan. Widespreading crown areas of large trees difficult to treat from the ground was given as the reason for this decision. Members of the local bird club, concerned over the possible effects of this new type of treatment, made some follow-up surveys, but found little or no significant mortality to birds (less than in previous years), although robins were said to be unsuccessful at nesting (Haefele, personal communication). Some experts on Dutch elm disease expressed grave doubts as to the efficiency of aerial methods of control because of the difficulty of complete and thorough coverage of the trees.

Mt. Pleasant.—In the winter of 1960 the city commission at Mt. Pleasant apparently favored a "protection" program for city elms, but later abandoned the project (press release). Some concern had been expressed by members of the Chippewa Valley Aubudon Society and University ornithologists about mortality to birds, but the reason given by the commission for dropping the project was that, since no elms were dying in the city, a full scale program might not be warranted at that time (Cuthbert). In spite of the apparent absence of the disease, however, the University went ahead with a "protection" program for campus elms. Although only a small number of elms on a small area was involved, some mortality to birds was observed.

Campus spraying was conducted on April 12; during May the following birds were picked up on campus: two robins, one found dead and another dying with symptoms; two adult flickers, both found alive and with DDT symptoms; two orioles, male and female dying with symptoms; and a rose-breasted grosbeak found dead. In June an indigo bunting was found with symptoms. Another dying robin and a ruby-throated hummingbird with typical symptoms were found off campus.

During the previous spring (1959) two other hummingbirds and two robins were found with apparent poisoning symptoms, but the relationship to known spraying programs is not clear. Possibly the hummingbirds, one of which was found at an unusually late date in the fall (September 22) were affected by sprays (not necessarily DDT) applied to private gardens. All of the above specimens (14 birds of 6 species) have been saved for possible analysis or for other uses (Mahan).

Oak Park.—A red-winged blackbird, picked up with symptoms following treatment of the elms in the spring of 1959 (Kreag), had high levels of DDT (Table 3). We have no other information on the program here.

Port Huron.—" . . . People called or brought in dead and dying orioles, warblers, and robins . . . " a day or so after considerable spraying in the northern section of Port Huron (Flinchbaugh, 1959). Claud Ludwig (personal communication) also reported robins nearly wiped out in 1958.

Rochester.—Rogers (personal communication) reported many robins dying in the early days of the program when he lived in the city. A brown creeper "with symptoms" was recovered here also.

Royal Oak.—Scarcity of robins in both 1959 and the spring of 1960 was very noticeable; where formerly they were common on lawns, now it is very rare to see one except in flight (Grayson, letter). Many specimens were also brought in to the Detroit Zoo (Kreag).

St. Joseph.—Dr. Freier, in sending robins to M. S. U. for examination, wrote that large numbers were being found in St. Joseph as

well as in Benton Harbor and that the police departments in both cities were swamped with calls. He also described the symptoms and suggested that earthworms might be the source of toxicity for the robins as they were so often found during rains.

Sylvan Glen.—A Baltimore oriole, recovered in a tremoring condition in the vicinity of recently sprayed elms (Kreag), had high levels of DDT (Table 3).

Three Rivers.—The city has had a spraying program since 1957 (Miles). City officials were apparently divided on whether or not to continue the program in 1960 because of the undesirable side effects. We have no specific reports of mortality to birds from this community, however.

Annotated List of Species

THE FOLLOWING SPECIES of birds have been found dead, or dying of poisoning symptoms, in the designated communities in southern Michigan following spraying operations for the control of Dutch elm disease. Merely finding a dead bird, even in a recently sprayed area, is not necessarily a good indication that it died of DDT. Yet nearly half of the reported victims in such cases have been alive when found, exhibiting the symptoms now so commonly associated with such poisoning. Most of the dead birds, when examined, show no trace of physical injury; often they are found lying on their backs with the head twisted to one side and the wings and feet stiffly extended—the position finally assumed by the many birds we have watched dying.

We have now analyzed nearly 100 birds that were reported to be "dying of symptoms" (or some similar designation). Nearly all birds so designated have had high levels of DDT. The rare exceptions might well be birds affected by some other poison (not DDT), or possibly the observer was mistaken about the symptoms. Several "sick" birds (not with tremors) have been free of DDT, or had only low, presumably sublethal, levels.

Many substitute theories have been advanced to explain the "tremors" and "symptoms" observed in dying birds. Among these are Newcastle's disease, encephalitis, bird malaria, rickets, trichomoniasis (dove disease), disease of the liver, salt on the roads, starvation and exhaustion; but, so far as we know, none of these has been definitely identified in a dead or dying bird picked up in a Dutch elm disease control program in Michigan. More work needs to be done on these other possible causes, however, as some of them, such as Newcastle's disease and rickets, produce a type of paralysis that might be confused with poisoning symptoms, and exhausted, sick, or injured birds sometimes tremble.

Since it is impossible to analyze the many hundreds of "suspected victims" that have been available in the past few years, it seems well to record the species that have been found dying in southern Michigan communities following spraying operations for the control of Dutch elm disease.

Mallard *(Anas platyrhynchos)*.—Six mallards, 3 "with symptoms," were turned in to the senior author in the spring of 1960 from the semi-domestic stock on the M.S.U. campus, and 9 others were reported dead. The die-off followed the spraying of the campus elms and preceded spraying along the banks of the river for mosquitoes. A brain sample of the only duck analyzed had 37 ppm of DDT—a medium dose. High pollution of the Red Cedar River may also have been a factor in the die-off.

Goshawk *(Accipter gentilis)*.—One found dead, Birmingham, winter 1959. Not analyzed.

Sharp-shinned Hawk *(Accipter striatus)*.—One "with symptoms", Birmingham area. Not analyzed.

Cooper's Hawk *(Accipter cooperii)*.—One "with symptoms", Birmingham area. Not analyzed.

Red-tailed Hawk *(Buteo jamaicensis)*.—Two "with symptoms", Birmingham area. Not analyzed.

Red-shouldered Hawk *(Buteo lineatus)*.—Two "with symptoms", winter, 1959, Birmingham. One analyzed (Table 3).

Rough-legged Hawk *(Buteo lagopus)*.—One "with symptoms", Birmingham area. Not analyzed.

Marsh Hawk *(Circus cyaneus)*.—One "with symptoms", winter, 1959, Birmingham. Analyzed (Table 3), but tests failed.

Pigeon Hawk *(Falco columbarius)*.—One "with symptoms", Birmingham, 1959. Analyzed (Table 3), but tests failed.

Sparrow Hawk *(Falco sparvarius)*.—Several "with symptoms", spring 1956, and subsequent years, Birmingham area. None analyzed.

Rock Dove *(Columba livia)*.—Numbers dead on M.S.U. campus, from various causes. Some probably poisoned by pest control officer to rid dormitories of pigeon nuisance. None analyzed.

Mourning Dove *(Zenaidura macroura)*.—Numbers dead or dying on M.S.U. campus. One reported "with DDT seizures" (student) had only low levels of DDT (but see Barker, 1958, regarding DDE in pigeon). A "sick" dove (dove disease?) observed by senior author did not have typical poisoning symptoms.

Yellow-billed Cuckoo *(Coccyzus americana)*.—One "with symptoms", summer 1958, Birmingham area. One at Battle Creek seen "falling from a bush" (Isham). Sent to M.S.U. for analysis, but not analyzed.

Black-billed Cuckoo *(Coccyzus erythropthalmus)*.—One "with symptoms", summer, 1958, Birmingham area. One analyzed (no data) was negative.

Screech Owl *(Otus asio)*.—We have reports of "4 or 5 with symptoms" from the Birmingham area, one from East Lansing (the campus residents disappeared), others from Wisconsin and Illinois. Probably this is the only predatory bird seriously affected by the Dutch elm program as it is the only one common to suburbs and parks in Michigan.

Tests on three specimens to date are inconclusive. The East Lansing bird had 33 ppm of DDT in the heart and 28 in the breast muscle, but none in the brain or liver. Tests on two Cranbrook specimens were unsuccessful (some DDT in the brain but decomposition products masked the results).

Great Horned Owl *(Bubo virginianus)*.—One "with symptoms", winter, 1957, Birmingham. Not analyzed.

Saw-whet Owl *(Aegolius acadicus)*.—Two found dead, Birmingham, fall, 1958, spring, 1959. The latter was negative for DDT.

Nighthawk *(Chordeiles minor)*.—Dead birds retrieved in Birmingham area and at East Lansing, but any relationship to Dutch elm program seems doubtful. A Birmingham speciman analyzed was negative for DDT.

Chimney Swift *(Chaetura pelagica)*.—One found dead on M.S.U. campus, May, 1959; 4 others on May 13, 1960. The latter, picked up during a prolonged cold rain, probably starved (much emaciated). A brain sample of two of them was negative for DDT.

Ruby-throated Hummingbird *(Archilochus colubris)*.—Five dead (picture windows?), Birmingham area. Three "with symptoms" at Mt. Pleasant believed more likely due to garden sprays than to elm sprays. None analyzed.

Belted Kingfisher *(Megacerule alcyon)*.—"Ripe" specimen along banks of Red Cedar on M.S.U. campus, May, 1959, had low, presumably sublethal, amounts of DDT.

Yellow-shafted Flicker *(Colaptes auratus)*.—Dead and dying birds retrieved or reported from Detroit area (many), East Lansing (one dead), and Mt. Pleasant (two "with symptoms"). Two analyzed (Table 2). Source of contamination poses an interesting problem—do they get it from ants, earthworms, beetles, or elm cambium?

Hairy Woodpecker *(Dendrocopus villosus)*.—One found dead, Birmingham area; specimen at C.M.U. (Mahan). Not analyzed.

Downy Woodpecker *(Dendrocopus pubescens)*.—Reported severely reduced in elm areas (e.g., Birmingham, East Lansing, Grand

Rapids) but few specimens have been retrieved. One watched dying with tremors, December 17, 1960, Cranbrook campus. The only one tested to date, found dead on November 18, 1959, in the Detroit area, had low levels of DDT.

Yellow-bellied Sapsucker *(Sphyrapicus varius)*.—Three found dead, fall, 1959, Birmingham. (Several dying of symptoms, Wisconsin, spring, 1959—Hickey, personal communication.)

Red-bellied Woodpecker *(Centurus carolinus)*.—One found dead, spring, 1959, Birmingham. Not analyzed.

Kingbird *(Tyrannus tyrannus)*.—One found dead on M.S.U. campus in early June, 1959 (Glover) believed to be a victim of aerial spraying for mosquitoes (3 days after spraying) rather than elm sprays.

Eastern Phoebe *(Sayornis phoebe)*.—Of the various flycatchers (9 species in Michigan) this species might be the most susceptible to insecticides because of its habit of feeding at low levels and frequenting the vicinity of water where contaminated insects might be available. Six or seven nesting pairs along the M.S.U. portion of the Red Cedar in the early fifties declined to one or two doubtful pairs after elm protection and mosquito control programs began (the campus decline *preceded* the much publicized die-off of phoebes in the southern states during the hard winter of 1957-58). The only specimens actually retrieved, however, are from the Detroit area (Nickell). None analyzed.

Traill's Flycatcher *(Empidonax traillii)*.—One with tremors caught in net, spring, 1960, Cranbrook campus. Not analyzed.

Horned Lark *(Eremophila alpestris)*.—A tremoring juvenile picked up by Ornithology class in vicinity of recently sprayed elms on M.S.U. campus on April 28, 1960, had 46 ppm of DDT (body test).

Swallows (Hirundinidae).—Because of their habit of foraging almost entirely on living insects gleaned from the air, swallows might be expected to be affected more by insect shortages following spraying operations than by direct poisoning from feeding on contaminated insects. Many purple martins *(Progne subis)*, some tree swallows *(Iridoprocne bicolor)*, and some barn swallows *(Hirundo erythrogaster)* have been picked up in the Dutch elm disease areas, but it is not clear whether they died of poisoning, starvation, cold, exhaustion or other factors. The only swallow analyzed (a purple martin) was negative. Elm sprays as a cause of death in aerial feeders seem rather doubtful.

Blue Jay *(Cyanocitta cristata)*.—Many dead or dying blue jays have been reported from Michigan communities having a Dutch elm

disease program, but their numbers seem to have held up well, perhaps because their versatile feeding habits enable them to avoid some toxic foods. Frequency of reports may be due to their conspicuousness. Early analyses of four specimens from Princeton (Benton, 1951) indicated that blue jays do accumulate DDT and our tests on specimens from East Lansing and Battle Creek (Bernard, unpublished) and Birmingham (Table 3) have disclosed high concentrations in most specimens.

Common Crow *(Corvus brachyrhynchos)*.—Several "with symptoms" among the Crankbrook specimens seem a little surprising. The source of contamination is not clear, but crows are both predators and carrion-eaters and may incur secondary poisoning, as in hawks and owls.

Black-capped Chickadee *(Parus atricapillus)*.—Chickadees have been widely reported as suffering from Dutch elm programs, but not many specimens have actually been found (3 from East Lansing and several from the Detroit area). Scarcity at feeding stations in recent winters gives rise to the suspicion that elm protection programs are responsible. The only analyses made to date (Bernard, unpublished) indicate high contamination with DDT. One with tremors caught in net, November, 1960, Cranbrook campus.

Tufted Titmouse *(Parus bicolor)*.—Specimens recovered at Albion (Dixon) and in the Birmingham area (one with tremors caught in net, November, 1960, Cranbrook campus) seem to be the only records. None analyzed.

White-breasted Nuthatch *(Sitta carolinensis)*.—Like chickadees, nuthatches appear to have suffered severe reductions, presumably because of their close association with elm trees, but our only records of dying birds are from the Birmingham area and East Lansing. Two specimens from East Lansing (of 5 reported) had high levels of DDT.

Brown Creeper *(Certhia familiaris)*.—Specimens "with symptoms" reported from Birmingham, Jackson (Owens), and Rochester (Rogers).

House Wren *(Troglodytes aedon)*.—Several found dead; nests generally unsuccessful in recent years at Cranbrook. Specimens recovered at East Lansing (1 adult, 6 young) followed aerial spraying for mosquitoes in 1959 rather than the Dutch elm program; the adult, the only one analyzed, had 92 ppm of DDT (body test).

Catbird *(Dumetella carolinensis)*.—Four specimens in Cranbrook collection, others reported from Birmingham area. Several from the M.S.U. campus have not yet been analyzed. (Catbirds nearly

disappeared from the M.S.U. campus in the early years of the elm program, but have demonstrated a remarkable capacity to continue to exist in, or come back to, contaminated areas, a feature also noted on the Cranbrook campus.

Brown Thrasher *(Toxostoma rufum).*—Two specimens in Cranbrook collection from Birmingham area (one analyzed—Table 3). One apparently on territory on M.S.U. campus in late April, 1960, was observed in labored flight on April 27, after spraying of the elms, was reported "affected" but still able to fly the following morning and was picked up in the afternoon. It had 64 ppm in the brain, 127 in the breast muscle, 61 in the heart, 64 in the liver, and 4 in the testes.

Robin *(Turdus migratorius).*—The most conspicuous victim in the Dutch elm disease program. Mortality has been reported from about 60 different communities in the midwest. We have yet to find a DDT-free spring specimen (April to June) from an area with a Dutch elm disease control program (nearly 100 analyzed to date).

Wood Thrush *(Hylocichla mustelina).*—Several found dead or dying (Birmingham area). The only specimen analyzed had from 16 to 43 ppm of DDT in various tissues (Table 3).

Hermit Thrush *(Hylocichla guttata).*—Strictly a transient (chiefly April) in the Birmingham area, this species would not be exposed to local insecticides over a long period. The only one examined had low levels (5-11 ppm) of DDT in various tissues, probably sublethal amounts unless the bird was in poor condition or had higher levels in the tissues not examined.

Swainson's Thrush *(Hylocichla ustulata).*—Strictly a transient (chiefly late May), this species would be subjected to local insecticides for a short period only. No "suspects" analyzed. (Fall migrants of this species picked up at a TV tower and used as test "blanks" were negative).

Eastern Bluebird *(Sialia sialis).*—Ordinarily this "vanishing American" is not an inhabitant of city or suburban elms, but one was included among the Cranbrook specimens. None analyzed.

Kinglets *(Regulus).*—Both the ruby-crowned *(R. calendula)* and golden-crowned *(R. satrapa)* kinglets have been reported as victims of Dutch elm disease programs in various communities in Michigan, Wisconsin, and Illinois in spite of their brief stay in these areas. They feed chiefly on insects on the terminal twigs of trees, including elms. The only kinglet examined to date (a ruby-crowned picked up on April 21, 1959) had 195 ppm of DDT (body test).

Blue-gray Gnatcatcher *(Polioptila caerulea).*—One picked up with violent tremors under recently sprayed elm trees in Huntington Woods on April 10, 1959 (an extremely early date) had 147 ppm of DDT (body test).

Cedar Waxwing *(Bombycilla cedrorum).*—Theoretically, waxwings might be expected to be quite susceptible to DDT poisoning in late April and early May, when they are budding in the elm trees, but not in fall and winter when they are feeding chiefly on fruit. This assumption is borne out by the analyses of four specimens from the Cranbrook collection; two spring specimens had high concentrations of DDT, two fall specimens were negative. (The many fall and winter specimens reported at East Lansing are chiefly picture window casualties).

Starling *(Sturnus vulgaris).*—Some mortality reported, including birds "dying of symptoms" from the Dutch elm areas; yet except for local or temporary reductions in the population, starling numbers have held up well or even shown increases (influx?), even in heavily sprayed areas. This indicates either (1) lack of exposure to insecticides because of their versatile or selective diet (not dependent on insects) or (2) high tolerance to DDT when it is ingested. Numerous examinations to date (Bernard, unpublished) support both viewpoints: we have found negative or low level specimens in heavily sprayed areas and some with extremely high levels. The five Cranbrook specimens had high levels of DDT, ranging from 30-339 ppm in various tissues.

Vireos *(Vireo).*—Three species of vireos, the yellow-throated *(V. flavifrons),* the red-eyed *(V. olivaceus)* and the warbling *(V. gilvus)* were once locally common or abundant summer residents among suburban and village elms. With certain species of warblers, they are among the most important guardians of Michigan shade trees, as nearly 100 per cent of their diet consists of insects (beetles, caterpillars, larvae) gleaned from the leaves and branches. Except for temporary appearances each spring, these birds seem to have disappeared as summer residents in heavily sprayed communities. It may well be that the spread of Dutch elm disease over southern Michigan has been accelerated by the sharp reduction in these insectivorous birds, which, theoretically at least, would feed on elm bark beetles when the latter emerge to feed on terminal twigs of elms in late spring.

Oddly perhaps, only the red-eyed vireo seems to have been included in the Cranbrook specimens and no vireos of any species have been available to us for analysis. Possibly their scarcity is explained by insect shortages in the elms rather than by direct mortality from insecticides.

Warblers (Parulidae).—More than 30 species of warblers inhabit or pass through the elm areas in southern Michigan each spring, though several species live in such a way that they might not come into contact with elm sprays. Most Michigan warblers are foliage gleaners and would be very susceptible to late April and May spraying of the trees in which they feed. Unfortunately, a late cold spring in 1956 delayed spraying of the elms into mid-May so that operations coincided with an unusually heavy flight of warblers. The Cranbrook specimens included 17 species of warblers, most of them picked up in the spring of 1956. It is not unlikely that some of the dead warblers were victims of the inclement weather, but the many tremoring birds can hardly be explained in this way, unless cold and exhaustion can produce symptoms similar to poisoning effects.

Two ovenbirds and a mourning warbler, found dead in 1959 and 1960, were negative for DDT, but two black-throated green warblers from the 1956 spring casualties (May 9 and 10 respectively) had 122 ppm in their bodies. The warblers identified by Nickell in the Cranbrook specimens follow:

Black-and-White Warbler *(Mniotilta varia)*
Nashville Warbler *(Vermivora ruficapilla)*
Yellow Warbler *(Dendroica petechia)*
Magnolia Warbler *(D. magnolia)*
Cape May Warbler *(D. tigrina)*
Black-throated Blue Warbler *(D. caerulescens)*
Black-throated Green Warbler *(D. virens)*
Blackburnian Warbler *(D. fusca)*
Chestnut-sided Warbler *(D. pensylvanica)*
Bay-breasted Warbler *(D. castanea)*
Blackpoll Warbler *(D. striata)*
Pine Warbler *(D. pinus)*
Ovenbird *(Seiurus aurocapillus)*
Northern Waterthrush *(S. noveboracensis)*
Mourning Warbler *(Oporornis philadelphia)*
Canada Warbler *(Wilsonia canadensis)*
Redstart *(Setophaga ruticilla)*

House Sparrow *(Passer domesticus)*.—Like starlings, house sparrows appear to be quite resistant to DDT, or able to avoid ingesting lethal amounts. The two Cranbrook specimens analyzed had from 80 to 197 pp (high levels) in various tissues, but considerable preliminary testing on East Lansing birds (Bernard, unpublished) have indicated very variable amounts in both living (collected) and dead birds.

Red-winged Blackbird *(Agelaius phoeniceus)*.—Though not ordinarily frequenting elm areas, a few specimens were included in the Cranbrook collection. The only one analyzed had 157 ppm in the breast muscle and 98 in the heart.

Baltimore Oriole *(Icterus galbula)*.—As might be expected both from their conspicuous colors and frequent association with elms, orioles have been among the more commonly reported victims of Dutch elm programs. The two tested (Table 3) had high levels of DDT.

Common Grackle *(Quiscalus quiscula)*.—This hardy aggressive bird seems remarkably adjusted to continuous treatment of its environment with pesticides and has become the dominant species in many suburbs now largely vacated of insectivorous birds. Some have died, but many survive. Three analyzed (Table 3).

Brown-headed Cowbird *(Molothrus ater)*.—One found dead, Birmingham area. Not analyzed.

Scarlet Tanager *(Piranga olivacea)*.—One found dead, spring, 1956, Birmingham area. Not analyzed.

Cardinal *(Richmondena cardinalis)*.—In spite of its primarily seed-eating (non-insectivorous) habits, the cardinal has been a widely reported victim in the Dutch elm disease programs in Michigan as well as in other states. Possibly they eat elm buds, contaminated prey, or even grit under the elms. One analyzed (Table 3). (Five found dead on M.S.U. campus this spring—1960—half or more of the resident population.)

Rose-breasted Grosbeak *(Pheucticus ludovicianus)*.—Reported as common victims, particularly in the spring of 1960 (5 specimens). Of three analyzed, however, one was negative for DDT, one had low or medium levels, the other high levels (Table 3).

Indigo Bunting *(Passerina cyanea)*. — Two or three specimens brought to the Institute, one a picture window casualty. One "with symptoms" at Mt. Pleasant in June, 1960 (Mahan). None analyzed.

Purple Finch *(Carpodacus purpureus)*.—One found dead, spring, 1960, Birmingham. Not analyzed.

Pine Siskin *(Spinus pinus)*.—Blagbrough (1952) originally reported pine siskins and goldfinches dying in the Dutch elm program in Princeton, apparently from budding in the elms. He found five specimens of each. A 1956 specimen from Bloomfield Hills had 128 ppm (body test). One from M.S.U. campus was too decayed for testing.

American Goldfinch *(Spinus tristis)*.—Two late April, 1959, specimens from the Cranbrook collection had high dosages (117 and 168 ppm of DDT, Table 3). Tremoring bird caught in net, August, 1960, Cranbrook campus. Fall and winter specimens from M.S.U. campus (not analyzed) were believed to have died of other causes.

Rufous-sided Towhee *(Pipilio erythropthalmus)*.—One found dead, spring, 1956, Birmingham (analyzed, Table 3). One "with symptoms" at Mt. Pleasant in June, 1960 (Mahan).

Savannah Sparrow *(Passerculus sandwichensis)*.—One found dead, spring, 1960, Birmingham.

Grasshopper Sparrow *(Ammodramus savannarum)*. — One found dead in early May, 1959, in Birmingham area, was negative for DDT.

Slate-colored Junco *(Junco hyemalis)*.—A spring specimen from Birmingham had 9 ppm (probably sublethal) in the carcass; a fall specimen, as might be expected, was negative (Table 3).

Chipping Sparrow *(Spizella passerina)*.—One or two "with symptoms" at Albion (Dixon). One found dead, Birmingham (analyzed, Table 3). (Now limited to a few pairs of stragglers on M.S.U. campus; formerly more common.)

Field Sparrow *(Spizella pusilla)*.—One found dead, Birmingham. Not analyzed.

White-throated Sparrow *(Zonotrichia albicollis)*.—Found dead, Birmingham and M.S.U. campus (picture windows?). None analyzed.

Fox Sparrow *(Passerella iliaca)*.—One found dead, spring, 1960, Birmingham.

Swamp Sparrow *(Melospiza georgiana)*.—One found dead, spring, 1960, Birmingham.

Song Sparrow *(Melospiza melodia)*.—Several found dead, Birmingham area. None analyzed. (Now limited to a few pairs, chiefly along the river, on M.S.U. campus; formerly common.)

Summary: Total species listed, 94.
Total species analyzed, 42.
Total species with DDT, 34.

Conclusions and Recommendations

FROM THE EVIDENCE submitted in this report it should be clear that mortality to birds has been high in many of the control programs designed to protect elms from disease. Losses undoubtedly vary, with the many variables associated with different programs in different communities; but mortality is believed to be closely associated with distribution patterns and density of elms and with the numbers of birds associated with the elms at the time of spraying. Included among the victims are several feeding types: (1) terrestrial feeders, (2) bark-foragers, (3) foliage gleaners, (4) bud-eaters and (5) predatory birds. When control programs are conducted in aquatic areas, water birds as well as fish and aquatic invertebrates are affected. DDT also accumulates in the ovaries and testes of breeding birds and is transmitted to the next generation through the egg.

It is most regrettable that there is no known way of combatting Dutch elm disease without serious side effects from the toxic materials used. Since the early trials at Princeton, various modifications in the program have been suggested to try to reduce losses to bird life, but for the most part the recommendations have been only partially successful. Research people now face the difficult responsibility of working out more effective, and less dangerous, methods of control. In the meantime, some of the suggestions outlined below may be helpful in reducing, but not eliminating, hazards to wildlife in Dutch elm disease control operations.

1. Study the need for a Dutch elm disease control program. "Protection" programs in communities that do not have the disease may be ill advised as this eliminates whatever natural control agencies may be present. Sometimes spraying within a community can be confined to known areas of infestation. Welch and Matthysse (1958) advise against community-wide programs in New York, but this type of spot control might not be effective in Michigan communities that have continuous stands of elms.

2. Mist blowers have an advantage over hydraulic sprayers by applying the spray directly on the trees, with less danger of puddling and drift, but recent studies in Wisconsin (Hickey and Hunt, 1960) have disclosed high mortality to ground-feeding birds in the first year of a program where only mist-blowers were used.

3. Using dormant (rather than foliar) sprays should eliminate or reduce hazards to foliage gleaners, such as orioles, warblers and vireos.

4. If a dormant treatment is applied after leaf drop in the fall—and this is not always feasible because of freezing weather—fewer

birds are affected, but birds that forage over the trunks and branches of elms in fall and winter are exposed to the insecticides.

5. If spring applications can be completed before elm buds start to open, which again is sometimes impossible in a late spring, birds that feed in the elms in late April might be spared.

6. Try to avoid excesses, both to conserve costly material and to spare wildlife. (Though operators need to cover the elms as completely as possible, in order to do a good job, sometimes excesses accumulate under the trees, on surrounding shrubbery, or drift considerable distances when the spray is directed away from instead of toward the center of the tree.)

7. Operators should be well informed both on the pros and cons in the Dutch elm control program, and be able to give factual answers. It is not good public relations to condemn any citizen's viewpoint, regardless of whether he is for or against the program.

These suggestions may help to alleviate, but certainly not eliminate, bird problems that arise in connection with control operations for Dutch elm disease. Though it is not within the scope of this report to criticize or evaluate the earnest efforts of operators and administrators to try to save valuable elm trees, we are inclined to question the whole program, as currently conducted, on ecological grounds. Any program which destroys 80 or more species of birds and unknown numbers of beneficial predatory and parasitic insects needs further study.

Summary

1. Dutch elm disease, first found in the United States in 1930, spread rapidly over the eastern states both before and after control measures were adopted.

2. In the mid-forties the use of DDT to control the bark-beetle vectors of the disease was visualized and a program involving its use carried out at Princeton, New Jersey, in 1947.

3. Earlier tests on toxicity of DDT to wildlife, and the results of the field trials at Princeton, confirmed the expectation of considerable mortality to birds, but the use of DDT for the control of Dutch elm disease has continued and greatly expanded.

4. Dutch elm disease reached Michigan in 1950 and spread rapidly. By 1959 some 261 communities in 36 counties in southern Michigan had known infestations.

5. Community programs for the control of the disease got underway in the early 50's, with the cooperation and help of the State Bureau of Plant Industry. By 1959 at least 68 cities and villages had control programs underway.

6. Complaints of bird mortality followed many of the early programs. In 1956 the Cranbrook Institute of Science attempted to measure the amount of mortality by asking for reports and specimens of dying birds. Between 1955 and 1959 about one thousand birds were received or reported to the Institute. Some 63 species were represented in the collection, including terrestrial feeders (mainly robins), foliage gleaners, budders, bark-foragers, and predatory birds.

7. Severe declines of robins and most insectivorous birds were noted in nearly all of the sprayed communities. The breeding bird population on the Cranbrook campus declined from 250 pairs to 25 or less, and was accompanied by a corresponding reduction in wintering birds.

8. The 1960 spring die-off of robins on the Michigan State University campus is described in detail. A mid-April (maximum) population of about 18 pairs died off rapidly in late April and May, until only 3 were known to be left by May 22.

9. Ten of 12 nests failed in early stages due to the death of the adults, and the other two nests, with two young in each, were believed to be unsuccessful.

10. The 22 adult robins available for analysis from this study had high levels of DDT in all of the tissues examined—brain, breast muscle, heart, liver, kidney and gonads. DDT was also present in the developing egg follicles in the ovaries of females, in fully developed eggs in the uterine portion of the oviducts, in unhatched eggs in deserted nests, in developing embryos, and in one newly hatched nestling.

11. Sixty-seven birds (34 species) from the Birmingham-Cranbrook collection were also analyzed. The results are presented in Table 3: 54 contained DDT and 13 were negative. The DDT-free birds were mainly aerial feeders, transients and specimens picked up in the fall.

12. A list of communities in southern Michigan that have reported mortality to birds in their Dutch elm disease programs is given, with whatever data (largely unsolicited) have come to our attention.

13. A list of the 94 species found dead or dying in these areas is appended. Samples of 41 of the 94 species listed have been analyzed; 34 of the species had varying amounts of DDT.

14. Some recommendations for conducting spraying operations in ways that might possibly reduce some of the hazards to birds are offered. These are mainly techniques and suggestions that have been devised over the years by wildlife biologists and conscientious operators and administrators.

December 17, 1960

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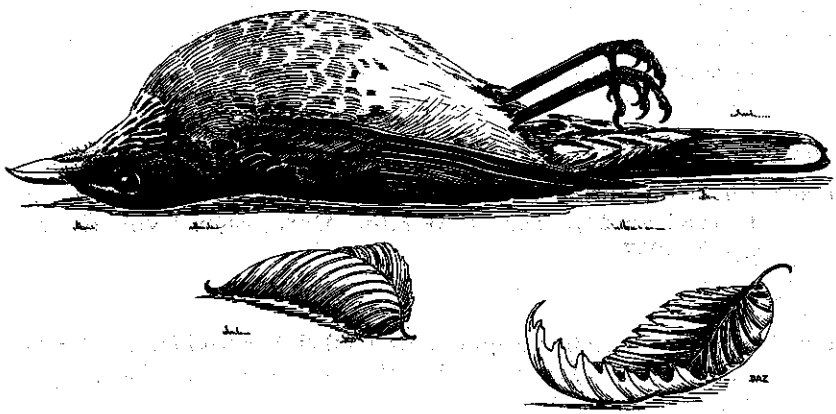


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