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CHARACTERIZATION OF REPRODUCTION AND GROWTH OF AMERICAN ROBINS AT THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT, 1991 - (USED AS A REFERENCE IN OU5 RI REPORT)

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by
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November 1992

PREPARED FOR THE

FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
Westinghouse Environmental Management Company of Ohio
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CINCINNATI, OHIO 45239-8704

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U.S. Department of Energy
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EXECUTIVE SUMMARY

As part of a Biological and Ecological Site Characterization of the Fernald Environmental Management Project (FEMP), suppressed growth in onsite American robin nestlings was discovered in 1987 and in 1990. However, the causal factors relating to suppressed growth were not investigated. This study was initiated to determine if growth suppression still existed, and if so, the possible relationship of FEMP land management practices and soil contaminants through food chains to growth and reproductive fitness. This study was expanded to include five offsite sampling sites, as well as analyses of soils and earthworms for uranium, pesticides/herbicides, and heavy metals.

FEMP robins showed a clumped nesting distribution along roadside berms and did not nest in large numbers in the pine plantations as they did in 1987. This is interpreted as a response to restricted optimal nesting and foraging habitat.

Clutch sizes, egg weights and nesting success were similar for FEMP and for offsite robin populations. FEMP robins fledged normal percentage of young. FEMP robin nestlings showed suppressed growth in two of four growth parameters measured.

Total uranium and herbicide/pesticides were not detected in most soil samples and all earthworm samples so the possibility of uranium or pesticides affecting growth through earthworm-robin food chains is not a factor in this study. There was no conclusive evidence of the bioaccumulation of heavy metals through robin food chains. It was concluded that the current growth

suppression in nestling American robins is related to land management practices affecting food availability and diet quality.

CHARACTERIZATION OF REPRODUCTION AND GROWTH IN AMERICAN ROBINS AT THE FERNALD ENVIRONMENTAL MANAGEMENT PROJECT, 1991

INTRODUCTION

As part of a comprehensive ecological study of the Fernald Environmental Management Project (FEMP) and formerly Feed Materials Production center (FMPC) conducted in 1987, Facemire et al.(1990) reported American Robins (*Turdus migratorius*) breeding onsite showed suppressed growth in four of five prefledging growth parameters measured. Similar suppressed growth, in FEMP robin nestlings, was reported for robins breeding onsite in 1990 (Osborne and Jones 1991; Westinghouse Materials Company of Ohio 1991). There was no attempt in either report to determine a cause for the apparent suppressed growth.

Possible factors involved included nestling diet quality with respect to radiological, heavy metal or herbicide/pesticide contamination; or food abundance and food availability resulting from land management of the FEMP. Activities at the FEMP have resulted in trace amounts of radioactive and non-radioactive metal contaminants in soil and surface water on and in the vicinity of the plant property (Operations Safety and Health Department 1988; FMPC Restoration Department 1989). Martin and Coughtrey (1975) demonstrated that other thrushes are known to accumulate heavy metals in tissues. Perdel'sky et al. (1960) showed that earthworms were quite important in dispersing radioisotopes through soil. Animals can accumulate heavy metals and other

materials in their tissues when exposed to contaminants at low levels for long terms. Cadmium, lead and mercury concentrations have been found (Curnow et al. 1977) in the tissues of Ohio Ring-necked pheasants *(Phasianus colchicus)*. Levine et al. (1989) determined heavy metal concentrations in three trophic levels in an old field community. They found the detritivore (earthworm) trophic level bioaccumulated heavy metals more than producer or primary consumer levels. In addition, growth in nestlings has been known to be affected by food availability (Bryant 1978).

In this study we characterize patterns of nestling growth and reproduction of breeding FEMP robin populations in 1991. The number of offsite locations surveyed was increased from two to five. We include the characterization of soil and earthworms for total uranium, selected heavy metals, and selected herbicides and pesticides known to be toxic to biological systems. These analyses were conducted to find a possible stressor that may be suppressing the growth of robins at the FEMP, if FEMP robins indeed were smaller than offsite robins in 1991.

METHODS

STUDY SITES

This study was conducted from March through July, 1991. Robin populations were sampled onsite within the 425 ha of the FEMP site, excluding 55 ha covered by the FEMP operations complex, parking lots and associated construction facilities. The FEMP was divided into a northern and southern section as a continuation of the original study during the 1987 site characterization (Facemire

et al. 1990).

An attempt was made to find offsite locations similar to the FEMP in its landscape and mowing practices. Five offsite stations (Fig. 1) used for statistical comparisons with FEMP robin populations included the Miami University Oxford campus, Greenwood Cemetery, Miami University Hamilton campus, Nieman's Nursery and Spring Grove Cemetery. The campuses and cemeteries were chosen because robin nests could be located in abundance and were easily accessible. Nieman's Nursery, just north of the FEMP, was also included because it is within a five mile radius from the perimeter of the FEMP, it supported a population of nesting robins similar to that previously reported for the FEMP (Facemire et al. 1990), and robin nestlings at Nieman's Nursery exhibited supressed growth in 1990.

All sites have a history of using herbicides and or pesticides for weed and pest control. Spring Grove Cemetery applied 17 herbicides and pesticides during the study period while FEMP and Greenwood Cemetery only used one herbicide for weed control. Nieman's Nursery used two, Miami Hamilton campus three and Miami Oxford campus used four different herbicides/pesticides.

NESTING

All sites were intensely searched twice weekly during the nesting season from March through July. All active (those with eggs or young) robin nests were followed from the egg stage through fledging or predation. Nest locations were plotted on site maps (Figs. 2-7).

PRODUCTIVITY

Robin productivity was determined by measuring clutch size, hatching success, and fledging success for each nest. Clutch size was recorded in the field as the number of eggs laid in a brood. Hatching and fledging successes were determined after completion of the field work as the percentage of eggs in the clutch that hatched and percentage of nestlings that fledge from the nest, respectively.

Eggs were weighed to the nearest 0.1 g with Pescola scales. The maximum weight of each egg before predation or hatching was used in the calculations. Hatchlings are defined as birds that have emerged from the egg, but have not yet left the nest. Fledglings are young that have left the nest under their own power. Since it is difficult to determine precisely when the bird left the nest, nestling weights were monitored and young that were close to the 50-60 gram range of body weight for a hatchling and then not found in the nest the following sampling day were assumed to have fledged. We often observed fledglings being fed by their parents.

GROWTH

The standard growth parameters (N. A. Bird Banding Manual 1984) we measured included the chord length of the wing, outermost primary, culmen and egg and chick weights. Wing chord is defined as the bend of the wing to the tip of the longest primary when the wing is folded and not flattened. The outermost primary is the distal most feather on the wing. The culmen is the chord length

of the dorsal bill of the robin, measured from the top. These growth parameters were chosen because they allowed an unlimited number of measurements without harming nestlings. Weights were measured to the nearest 0.1 gram, using Pescola scales. Lengths were measured using a caliper and scale. Measurements of each parameter were taken three times weekly until fledging. FEMP and offsite birds were measured at the same age. Average asymptotic values (Ricklefs 1968; Springer and Osborne 1983) were used in the final computations of the growth data. Nestling growth parameters were not used unless nestlings were known or assumed to have fledged.

SOIL ANALYSES

Approximately 20 surface (0-6 inches) soil samples within robin breeding territories (Figs. 8-13) were collected at each site by Westinghouse Environmental Management Company of Ohio (WEMCO) sampling technicians. The 20 samples for each site were composited and divided into two separate composite samples. The two composites were then submitted to the FEMP laboratory for analyses. Each sample was analyzed for:

1. total uranium.

2. heavy metals (arsenic, mercury, lead, selenium, barium, cadmium and chromium).

3. herbicides/ pesticides (Chlordane, Endrin, Heptachlor, Heptachlor epoxide, Lindane, Methyoxychlor, and Toxaphene, 1,4-D and Silvex).

EARTHWORM ANALYSES

An attempt was made to collect earthworms from each site and analyze them for the same parameters as the soils (i.e. total uranium, heavy metals and pesticides/herbicides). Mechanical and electrical methods of collection were unsuccessful. Digging, hand sorting, and surface collection were the only effective means of obtaining earthworms. These methods were only marginally successful because of the dry soil conditions late in the nesting season. Because of this, adequate amounts of earthworms for all analyses were collected only from The Miami University Oxford campus. Enough earthworms were collected at Nieman's Nursery and Miami University Hamilton campus to analyze for heavy metals and herbicides/pesticides. Northern FEMP and southern FEMP earthworms were composited to obtain an adequate amount for heavy metal analysis. Insufficient amounts of earthworms were collected at both cemeteries; thus no analyses were conducted. Even though earthworms seemed scarce, the robins continued to feed their nestlings throughout the nesting period. They probably switched to more available foods such as leafhoppers and other insects.

STATISTICAL ANALYSIS

An ANOVA was used to test for statistical differences ($P < 0.05$) across sites. If significant differences were found, an *a priori*, one degree of freedom contrast with weight proportionate to sample size was used to further interpret the results. In this manner each nest, egg or nestling contributed equally to the means being compared. The northern and southern FEMP sites were

combined to yield a total FEMP population. These were then tested against all composite offsite stations (Nieman's Nursery excluded), and against Nieman's Nursery. Because Nieman's Nursery is adjacent to the FEMP, the Nursery was treated separately in order to determine whether growth and reproductive fitness of American Robins breeding at the Nursery were more similar to onsite or to offsite populations.

RESULTS

NESTING

American robin nests were first located on March 30, 1991 at the southern FEMP. Nests were located at all other sites, except Nieman's Nursery, by April 18. Nieman's Nursery was not surveyed until May 11 due to delays in obtaining access to the property. Last nestings ranged from June 22 to June 28, except for the Miami University Oxford campus, whose last nesting was on July 9. Northern and southern FEMP nests were mostly clumped along the roadside berms; sparse distributions of nests were present in the southern pine plantation (Fig. 2.). Nests were rather uniformly spaced within all offsite locations (Figs. 3-7).

A total of 223 robin nests were monitored for this study (Table 1). The Miami University Oxford campus had the most nests at 61. The southern FEMP supported nearly four times more nests than did the northern FEMP (25 vs 7 respectively); by far the least populated site was the northern FEMP. Evergreens were the preferred nesting substrate on all sites followed by ornamental trees and low shrubs.

PRODUCTIVITY

Reproductive success of 223 robin nests (Table 1) was examined during the study. Average clutch size ranged from 3.2 eggs per nest at Nieman's Nursery to 3.7 eggs per nest for the northern FEMP. Hatching success ranged from 1.1 young per nest at the Miami Hamilton campus to 2.0 young per nest at Spring Grove cemetery. The lowest fledgling success was 25 % for nests on the Miami Hamilton campus, while Nieman Nursery had the highest fledgling success at 54%. No significant differences (ANOVA; $P>0.05$) were found with regard to average clutch size, hatching success, the average number of fledglings and fledgling success across sampling location. No significant differences ($P > 0.05$) were found (Table 1) when total FEMP was compared to total non-contiguous sites or to Nieman's Nursery.

EGG SIZE

Six hundred and twenty six eggs were weighed in this study with average egg weights ranging from 6.2 g to 6.6 g (Table 2). An ANOVA showed significant differences across sites ($P < 0.05$). However, an *a priori* test showed that average weights of total FEMP eggs did not differ significantly ($P > 0.05$) from collective offsite or Nieman's Nursery robin eggs.

GROWTH

Two hundred and sixty five (265) young were measured for morphometric analysis (Table 3). Bill length (culmen) ranged from

14.3 mm to 15.4 mm but did not differ significantly (ANOVA $P > 0.05$) between any of the populations. Average body weights were highest (58 g) for Greenwood cemetery and lowest (53 g) for northern FEMP nestlings; differences were not significant across site (ANOVA $P > 0.05$). Significant differences (ANOVA $P < 0.05$) were found in the other two growth parameters measured, Wing chord and primary (Table 3). Collective FEMP nestlings had statistically ($P < 0.05$) smaller wings and shorter primaries than did nestlings from collective offsite locations and from Nieman's Nursery.

SOIL AND EARTHWORM ANALYSES

Total Uranium.

Uranium concentrations of 15 ppm were found at two southern and one northern FEMP soil samples. Total uranium was not found in the combined FEMP earthworm sample. There was no detection of uranium in soils or earthworms at any of the offsite stations. There is no evidence of bioaccumulation of uranium in earthworms.

Pesticides/Herbicides.

No herbicides or pesticides tested were detected in soils or earthworms at any site. Therefore, there is no evidence of bioaccumulation of pesticides/herbicides in earthworms from any of the sampling locations.

Heavy Metals in Soils.

Analysis of heavy metals in soils was variable across

replicate samples and across sites (Table 4). Selenium was the only metal found below detection limits for all replicates at all sites. Silver was not detected in soils from robin territories at Greenwood Cemetery, Nieman's Nursery and the southern FEMP. Spring Grove Cemetery soils had the highest levels of Arsenic (9.4 and 10.1 ppm). Mercury in soils ranged from 0.01 ppm to 0.2 ppm. FEMP sites had <0.16 ppm of Mercury. Lead in soils ranged from 34.4 ppm to 75.2 ppm. Spring Grove Cemetery soils had the highest lead values (64.8, 44.5 ppm) for off-site stations. Values for lead in FEMP soils ranged from 42.5 ppm to 75.2 ppm. An *a priori* contrast analysis showed that total FEMP soil lead values were significnatly higher ($P < 0.05$) than consolidated offsite stations. Of the eight heavy metals screened in soils, barium existed in the highest concentrations ranging from 79.2 ppm to 161.8 ppm. Cadmium soil values ranged from 0.63 ppm to 1.0 ppm. Chromium existed in soils ranging from 8.7 ppm to 40.1 ppm. The northern FEMP soils had the highest chromium values.

Heavy Metals in Earthworms.

Four of the eight metals screened (silver, barium, cadmium, and chomium) were not detected in earthworms from any site and lead values in earthworms were considerably lower than in soils collected from the same locality (compare tables 4 and 5). Thus, earthworms showed no evidence of concentrating these heavy metals.

Because of the variabilty among samples a pattern of bioaccumulation of the other heavy metals is not clear (see Tables

4 and 5). For example, composite FEMP earthworms had arsenic values of 9 ppm, similar to values reported by one laboratory for soils, but twice as much as reported by the other laboratory. Mercury showed some indication of bioaccumulation in earthworms at the Miami University Hamilton Campus and in composite samples from the FEMP. Also, earthworms showed detectable concentrations of selinium from the FEMP whereas selinium was not found in soils taken from these sites.

DISCUSSION

NESTING

In this study, few FEMP robins nested in either the northern or southern pine plantations. Only seven active nests were recorded in the southern pine plantation, and none were found in the northern pine plantation. These habitats supported 310 and 274 breeding robins per 40 ha, respectively, in 1987 (Facemire et al. 1990). While mowing was very infrequent this year (seldom more than twice a month) both plantations were mowed approximately once each week in 1987.

Robins prefer mowed lawns for foraging. Because of the infrequent mowing schedule, the FEMP pine plantations were not optimal habitats for nesting during this study and thus avoided by robins. A similar pattern was reported in 1990 (Osborne and Jones 1991). Therefore, the only areas suitable for extensive nesting and foraging by robins at the FEMP during 1991 were the weekly mowed berms of the northern and southern entrance roads. Thus,

FEMP robins had few nesting birds and clumped nest distributions at these sites. It is interesting to note that later broods of robins did not nest in the pine plantations even after they were mowed later in the year.

Nieman's Nursery, Miami University Oxford and Hamilton campuses, and Greenwood and Spring Grove Cemeteries, which were mowed on a weekly schedule, had uniformly spaced nests. These sites also supported substantially higher numbers of nests than FEMP sites. This was probably because of the greater availability of optimal habitat. Thus,the temporal factors of nesting (Young 1955; Trautman and Trautman 1968) and available habitat quality seem important in accounting for the low nest densities and clumped distributions on the FEMP in this study.

REPRODUCTIVE SUCCESS

We found no significant statistical differences in reproductive success across sampling sites when total FEMP is compared to collective offsite locations and when total FEMP is compared to Nieman's Nursery (Table 1). The 3.2 to 3.7 eggs/nest is considered normal for robins (Young 1955). When compared to previous years, clutch sizes for offsite robins and FEMP robins were higher than our findings in 1990 (range = 2.9-3.4; Osborne and Jones 1991 and similar to those of 1987 (range = 3.3-3.7; Facemire et al., 1990), suggesting that dietary stress prior to nesting was not an important factor affecting egg production. Thus, although nest numbers were low, FEMP robins still produced normal numbers of eggs per clutch.

In addition, FEMP robins also laid clutches of eggs which were statistically similar in weight when compared to offsite populations and Nieman's Nursery. No significant differences were found with regard to hatching success, the average number of fledglings and fledgling success across total FEMP, offsite and Nieman's Nursery. Hatching success in 1990 averaged from 1.8 (offsite) to 1.8-2.3 young per nest (onsite) as compared to 2.8 (offsite) to 2.3 (onsite) in 1987 (Facemire et al., 1990). Differences in embryonic mortality can be related to temporal differences in nesting (Young 1955), weather, or differential predation (Osborne and Jones 1991).

Our 1991 fledgling success values are considerably lower than have been found elsewhere. Young (1955) reported a three year average of 78% for robins breeding in Wisconsin. Because there were no significant differences in fledgling success across site, reduced fledgling success in this study seems related to geographic variation or to seasonal variations in nesting, diet or food availability.

GROWTH

In 1987 Facemire et al. (1990) found FEMP robins showing suppressed growth in four of five of the growth parameters measured. We found a similar pattern of suppressed growth in 1990 (Osborne and Jones 1991.) In this study FEMP robin nestlings were suppressed in two of the four parameters measured (length of the wing and length of the outermost primary) when compared to populations offsite and to Nieman's Nursery.

One factor affecting nestling growth is nestling competition. Ricklefs (1973) showed that brood sizes affect growth in birds; single-nestling clutches tended to have slower growth rates than two or three-young clutches. Werschkul and Jackson (1979), and Ricklefs (1982) concluded that sibling competition on nestling development is a dominant force determining the evolution of growth rates. In 1991 average brood sizes (number of hatchlings; Table 1) ranged from 1.1-2.1 young per nest.The average number of hatchlings of FEMP robins was not significantly different from collective offsite populations, and values were similar to those found in 1990 (range = 1.8-2.3 young per nest; Osborne and Jones 1991) and in 1987 (2.3 for both the FEMP and offsite stations; Facemire et al., 1990). Thus, sibling competition does not appear to be affecting growth in FEMP robin populations.

Other possible factors affecting nestling growth is dietary stress affected by the temporal nature of the food supply (Gill 1990 and food quality (Lack 1956; Bryant 1978) due to land management practices. The food of robins is chiefly insect larvae and earthworms (Martin et al., 1951) which they obtain on defended territories (Young 1951; Welty and Baptista 1988) in optimal habitats such as mowed clearings, lawns and orchards (Welty and Baptista 1988). Similar habitats, e.g. pine plantations, were available to robins on the FEMP and supported large robin populations (Facemire et al., 1990), probably because the lanes were mowed frequentlty. The reduction in the frequency mowing in 1990 and 1991 produced habitats that apparently were not optimal for breeding and feeding as they were in 1987 resulting in

territories being clumped along the northern and southern entrance berms. This could have led to intensive competition for a limited available food supply. In 1991 earthworms may have been equally abundant, but less available on the FEMP than at offsite locations where frequent mowing promotes earthworm accessibility by foraging robins. This could lead to inadequate nestling diets, and eventually suppressed growth of the nestlings, in terms of feather and wing length.

SOIL AND EARTHWORM ANALYSES

The number of hatchlings (hatching success) is no different at the FEMP than at the offsite locations, so the chronic low doses of radiation which occur on the FEMP and in the vicinity of the plant property (Westinghouse Material Company of Ohio 1988; Westinghouse Materials Company of Ohio 1989) do not appear to be affecting robin reproduction in the current study.

Chronic radiation, documented to cause growth depression in nestling birds (Zach and Mayoh 1984,1986; Muller and Moreng 1966) is not an important causal factor suppressing robin growth in this study. Although nestling tissues were not analyzed, uranium was not detected in most soils and all earthworms. This suggests that uranium was not transported through robin food chains as has been documented for other radioactive compounds (Levy et al. 1976, 1982).

Pesticides and herbicides in the diets of birds have long been known to affect embryonic development and fledgling growth (Welty and Baptista 1988). The reduced growth of FEMP robin

nestlings in 1987 and 1990 was proposed to be the result of the bioaccumulation or chemo-toxicity of pesticides/herbicides in the FEMP earthworm-robin food chain (Osborne and Jones 1991). Pesticides and herbicides do not appear to account for suppressed growth in nestling FEMP robin populations in the current study. No pesticides/ herbicides were detected in soils and earthworms across sites.

Earthworms have been shown to accumulate heavy metals (Helmke et al., 1979; Hughes et al., 1980; Beyer 1981) and transsfer them to birds (Scanlon et al., 1979) and shrews (Brueske and Barrett (1991). Similarly, Peredel'sky et al., (1957, 1960) showed that earthworms were important in dispersing radioisotopes through soil. Because undigested soil is a major constituent of the digestive tract of earthworms, any contaminated soil present in the gut may represent a potential impact on birds which feed on them. Bioaccumulation studies by Martin and Coughtrey (1975) showed that thrushes (robins are members of the thrush family) accumulated heavy metals in kidney tissue.

However, results from our study show no strong evidence of bioaccumulation of heavy metals in earthworms. Considerable interlab and intersite variation existed. Of 8 metals assayed, arsenic showed a two-fold increase in earthworms at only 2 of 7 sites (the FEMP and Miami University Hamilton campus). Lead was the only heavy metal whose concentrations were significantly higher in FEMP soils as compared to soils of collective offsite and Nieman's Nursery stations.

CONCLUSIONS

FEMP robin nestlings showed suppressed growth in two of four growth parameters measured, was not as pronounced as in previous years, and was related to land management practices and resulting food availability and diet quality

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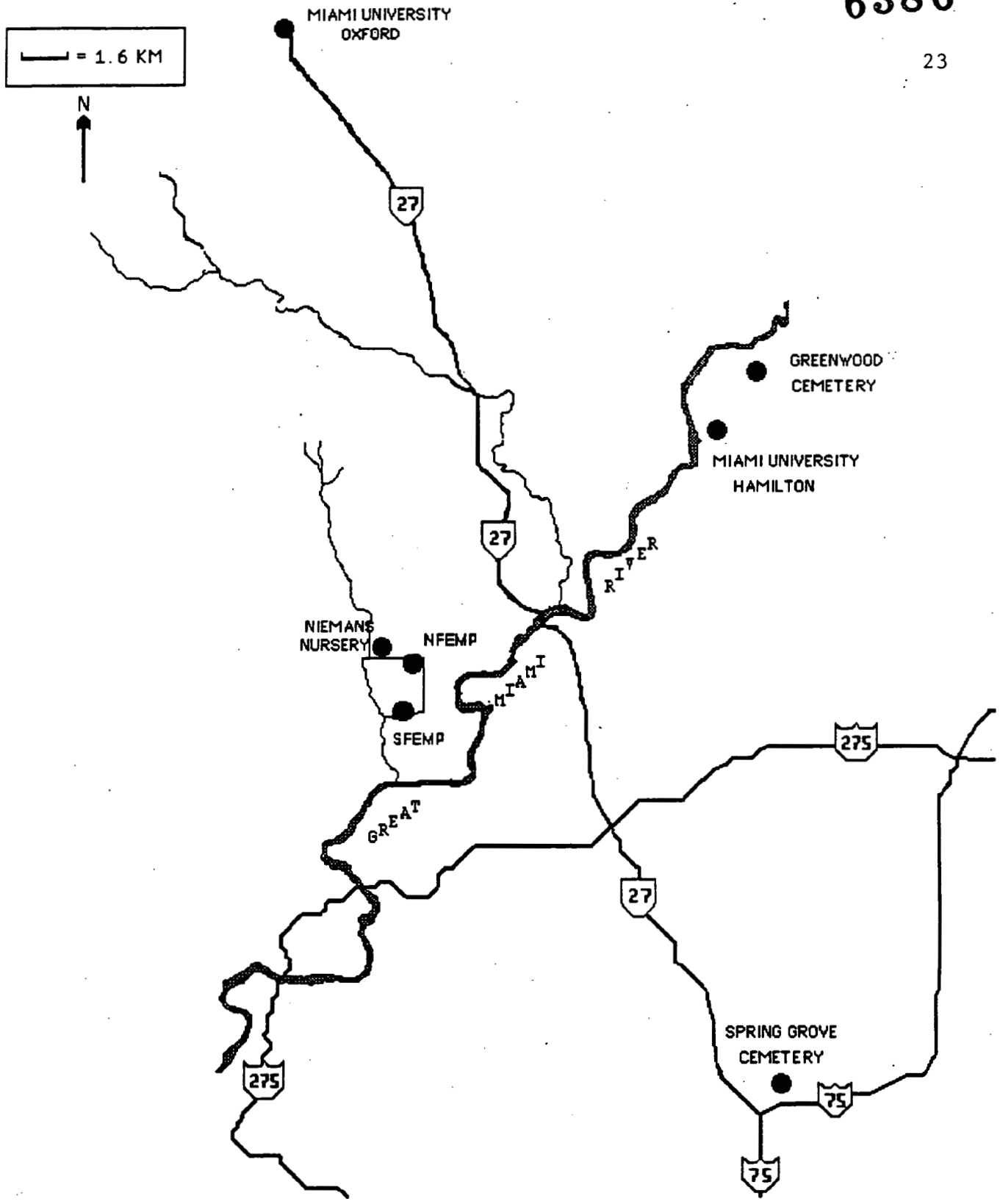

Figure 1. Location of sampling stations, solid circles, for American Robins in the vicinity of the FEMP, Spring 1991.

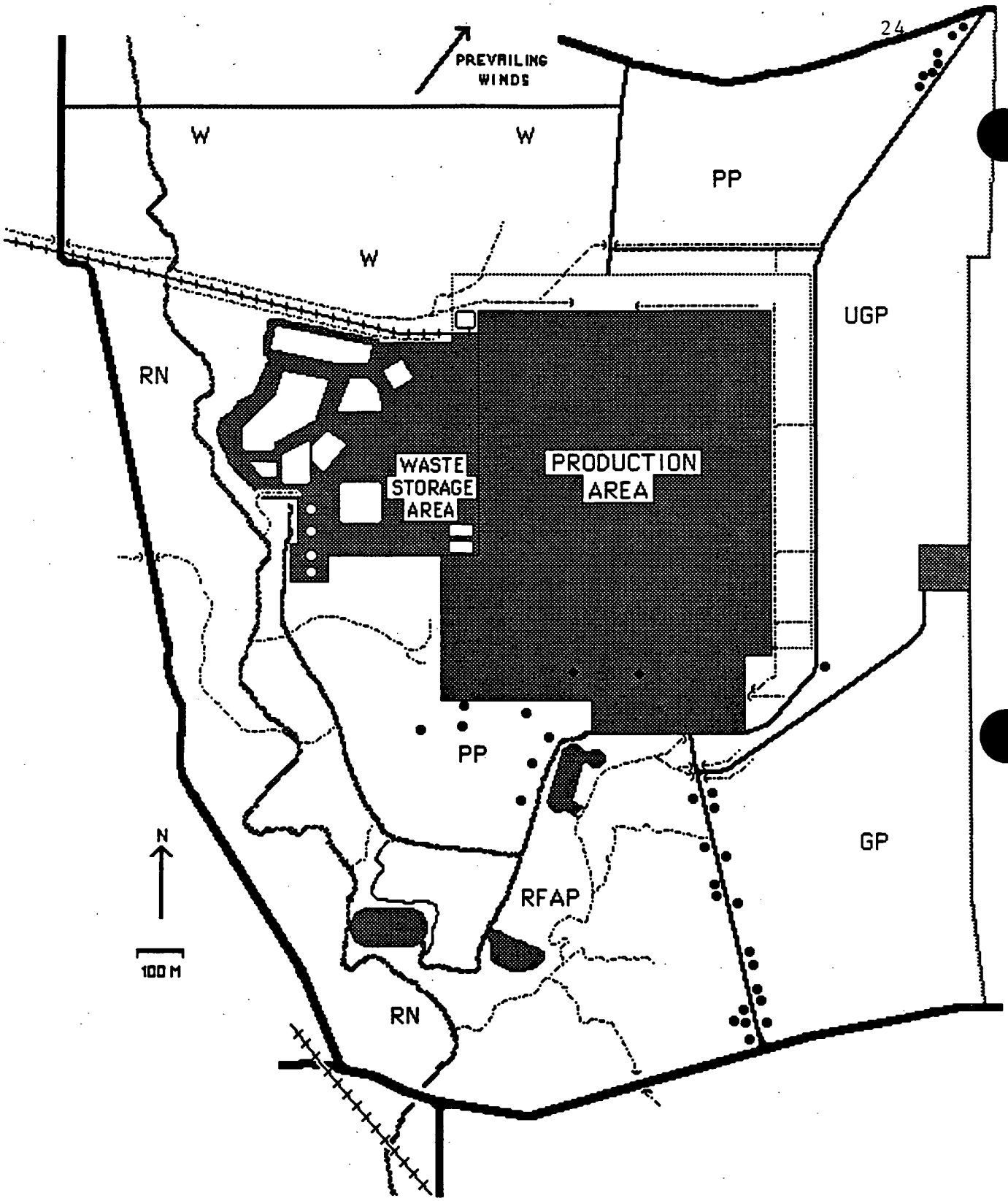

Figure 2. Distribution of American Robin nests on the FEMP, Spring/Summer 1991. Habitats: UGP=ungrazed pasture; GP=grazed pasture; PP=pine plantation; RFAP=reclaimed flyash pile; W=woodlot; RN=riparian.

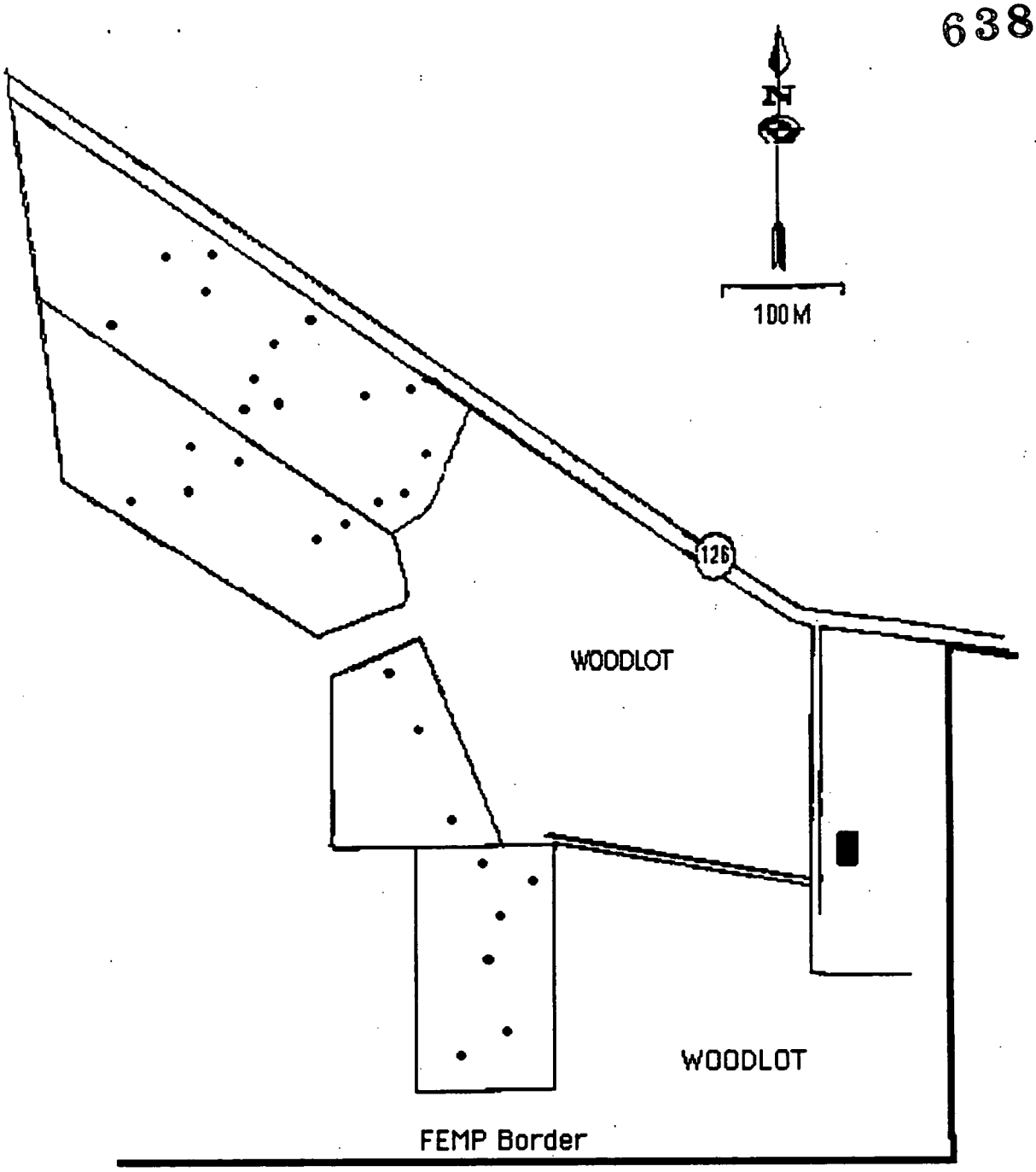

Figure 3. Distribution of American Robin nests at Nieman's Nursery, Spring/Summer, 1991.

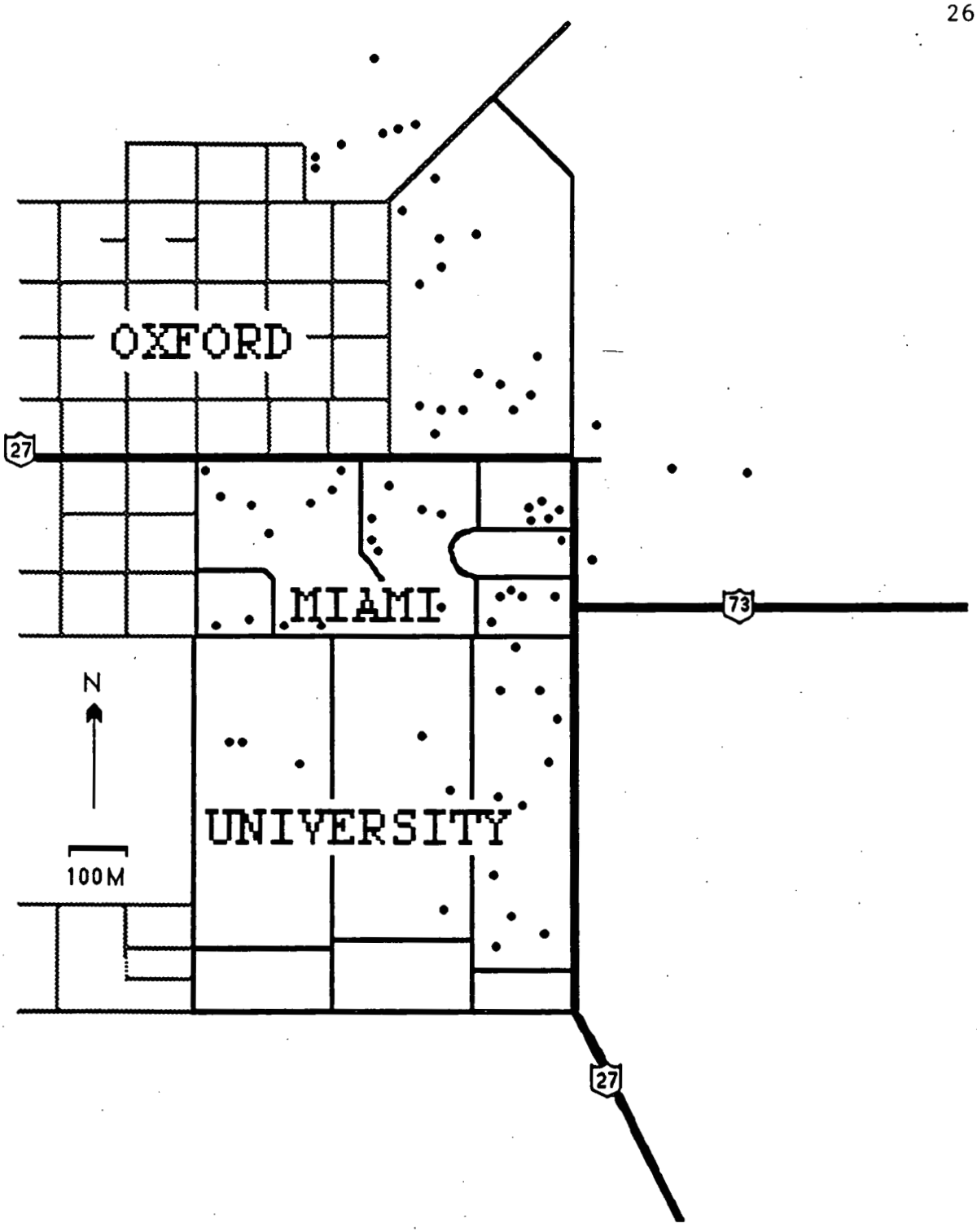

Figure 4. Distribution of American Robin nests on the Miami University campus, Oxford, OH, Spring/Summer, 1991.

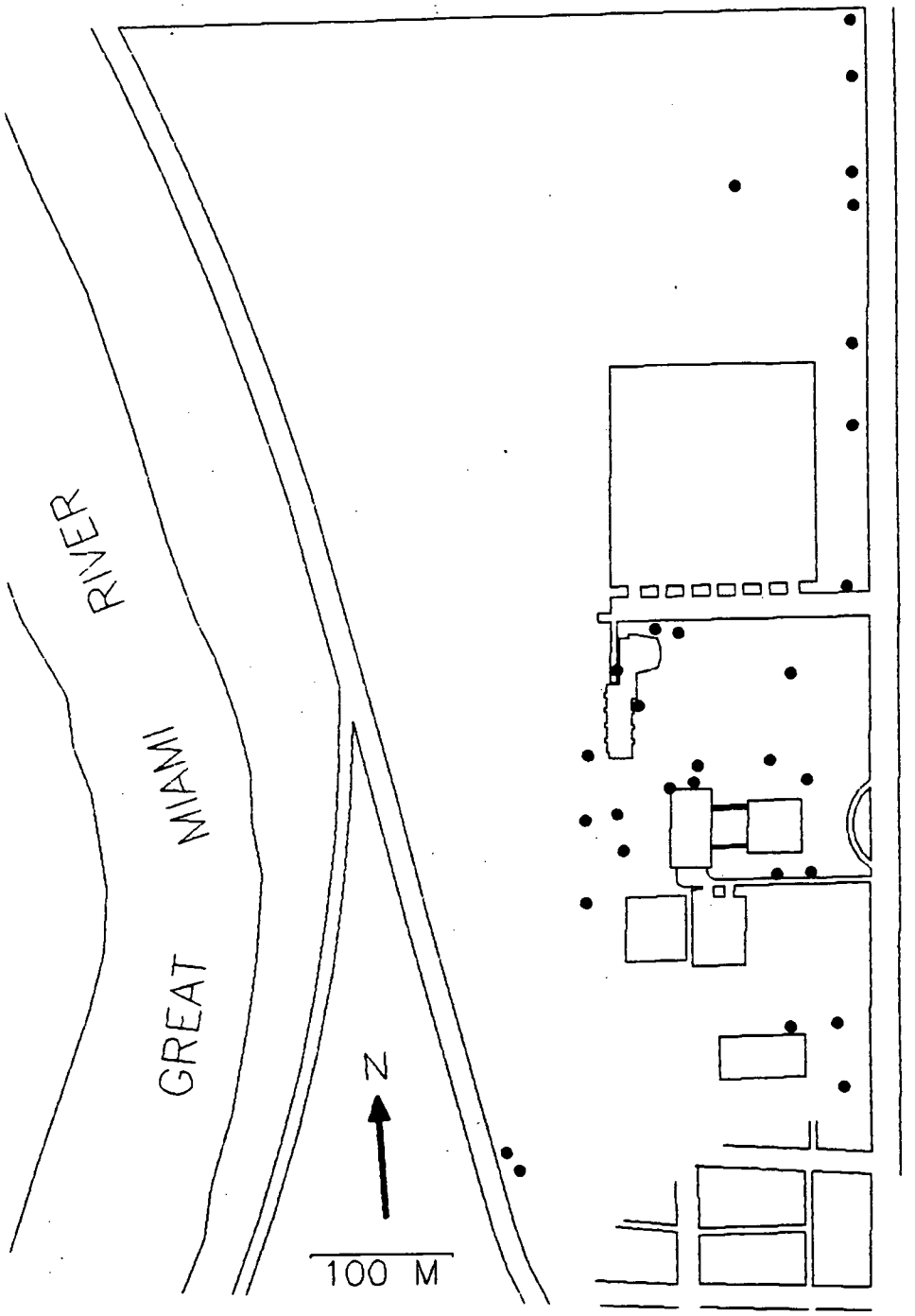

Figure 5. Distribution of American Robin nests on the Miami University Hamilton Campus, Spring/Summer, 1991.

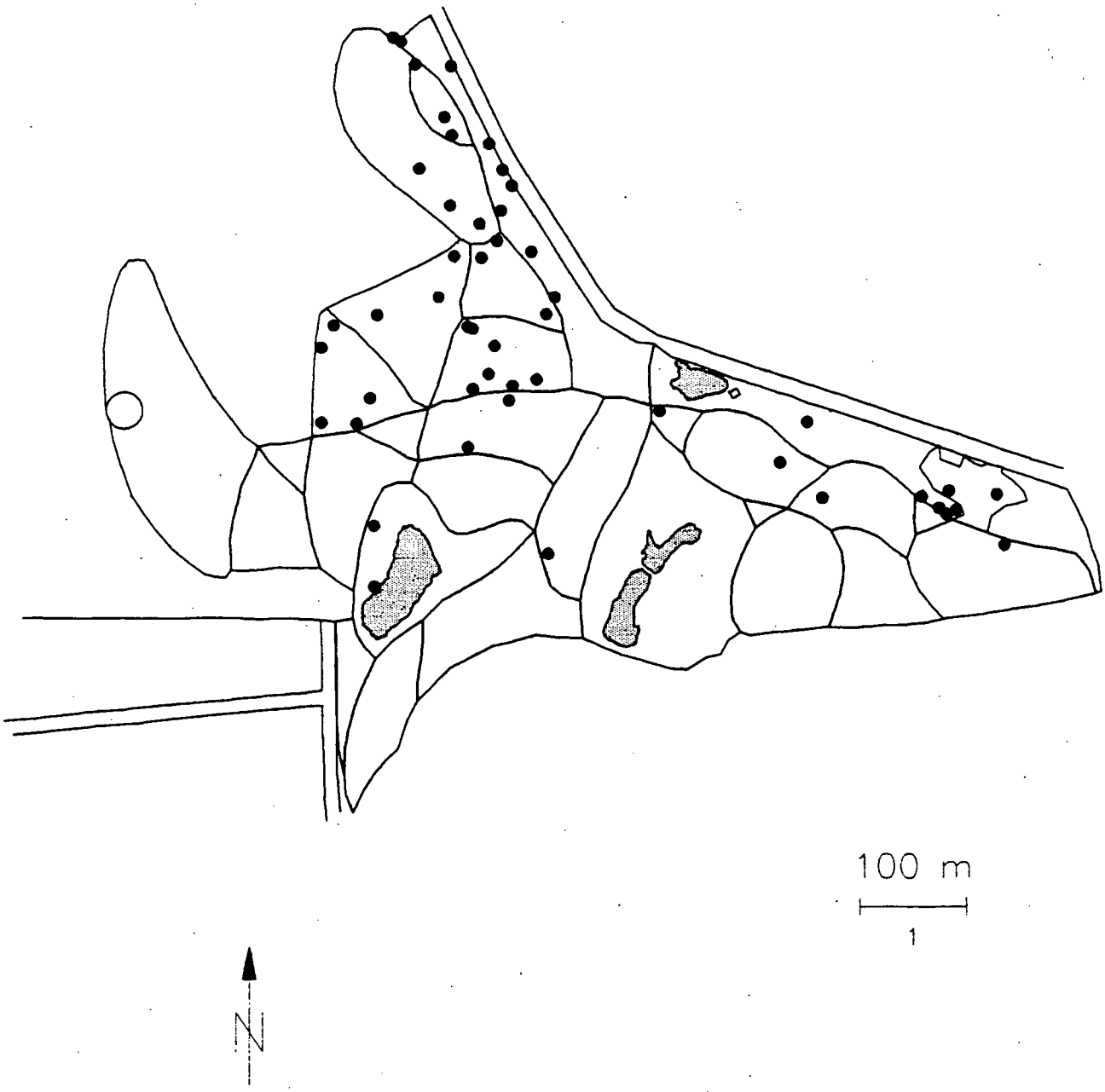

Figure 6. Distribution of American Robin nests at Spring Grove Cemetery, Spring/Summer, 1991.

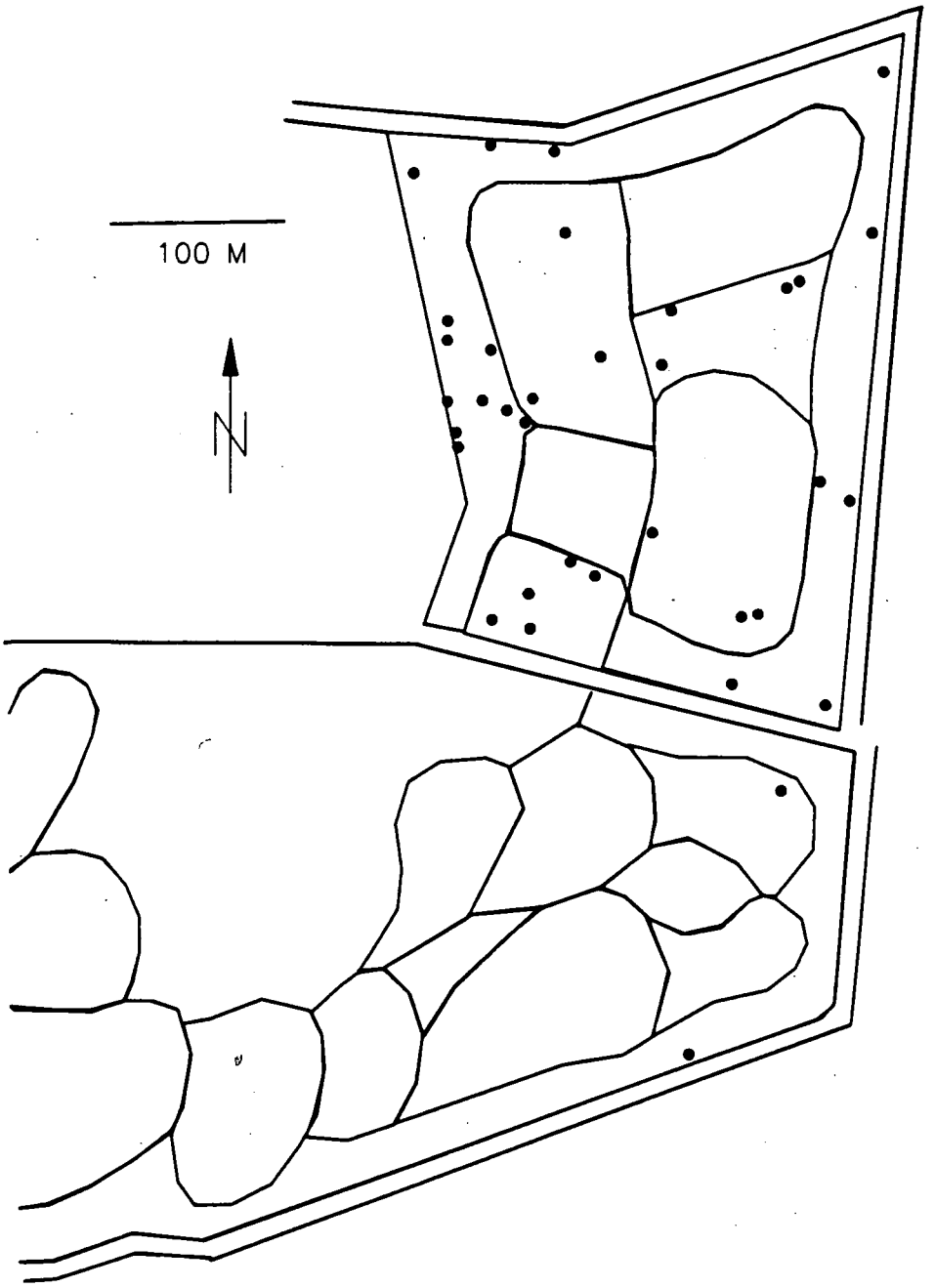

Figure 7. Distribution of American Robin nests at Greenwood Cemetery, Spring/Summer, 1991.

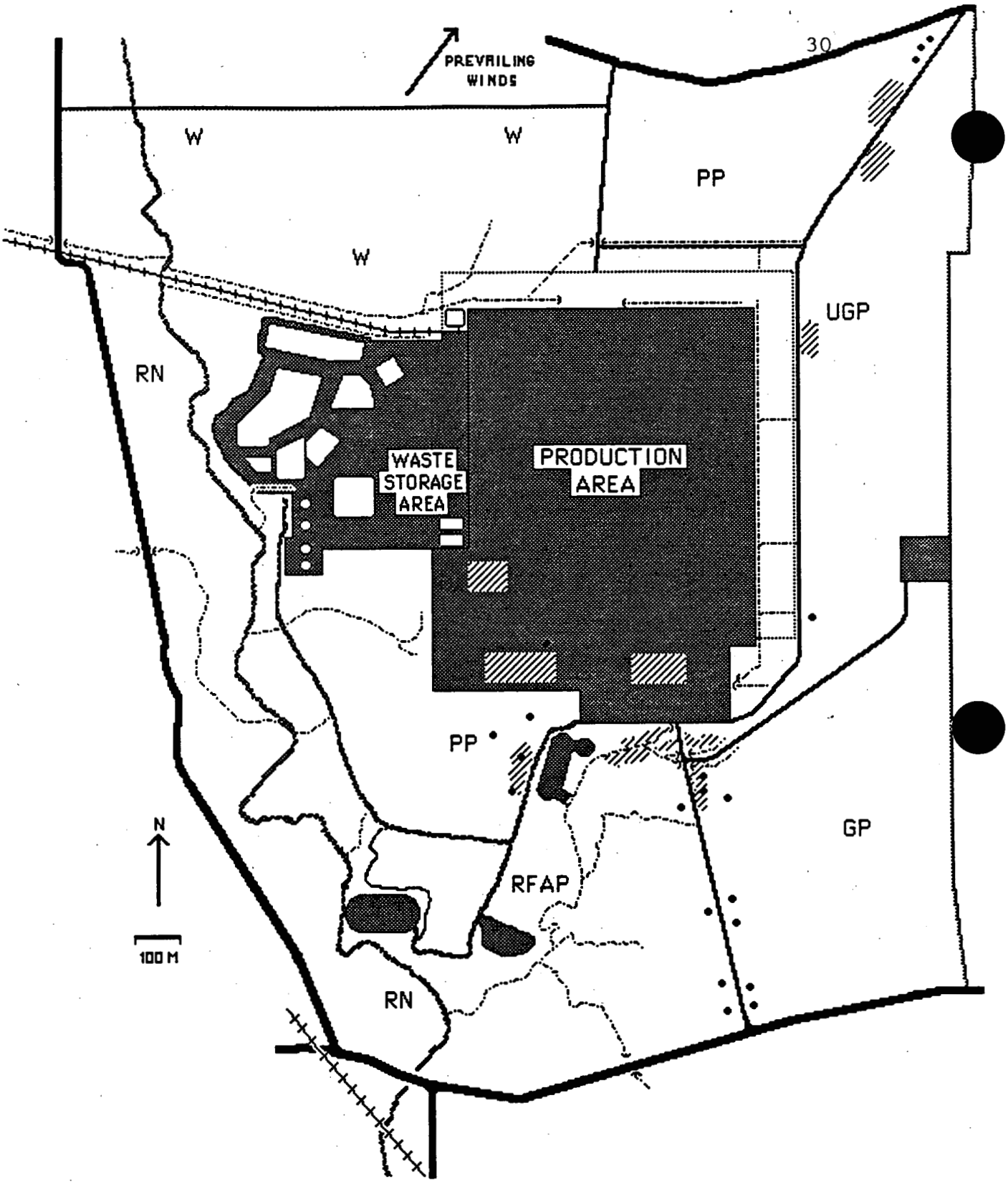

Figure 8. Earthworm sampling locations, hatched area, and soil sampling locations, solid circles, at the FEMP, 1991.

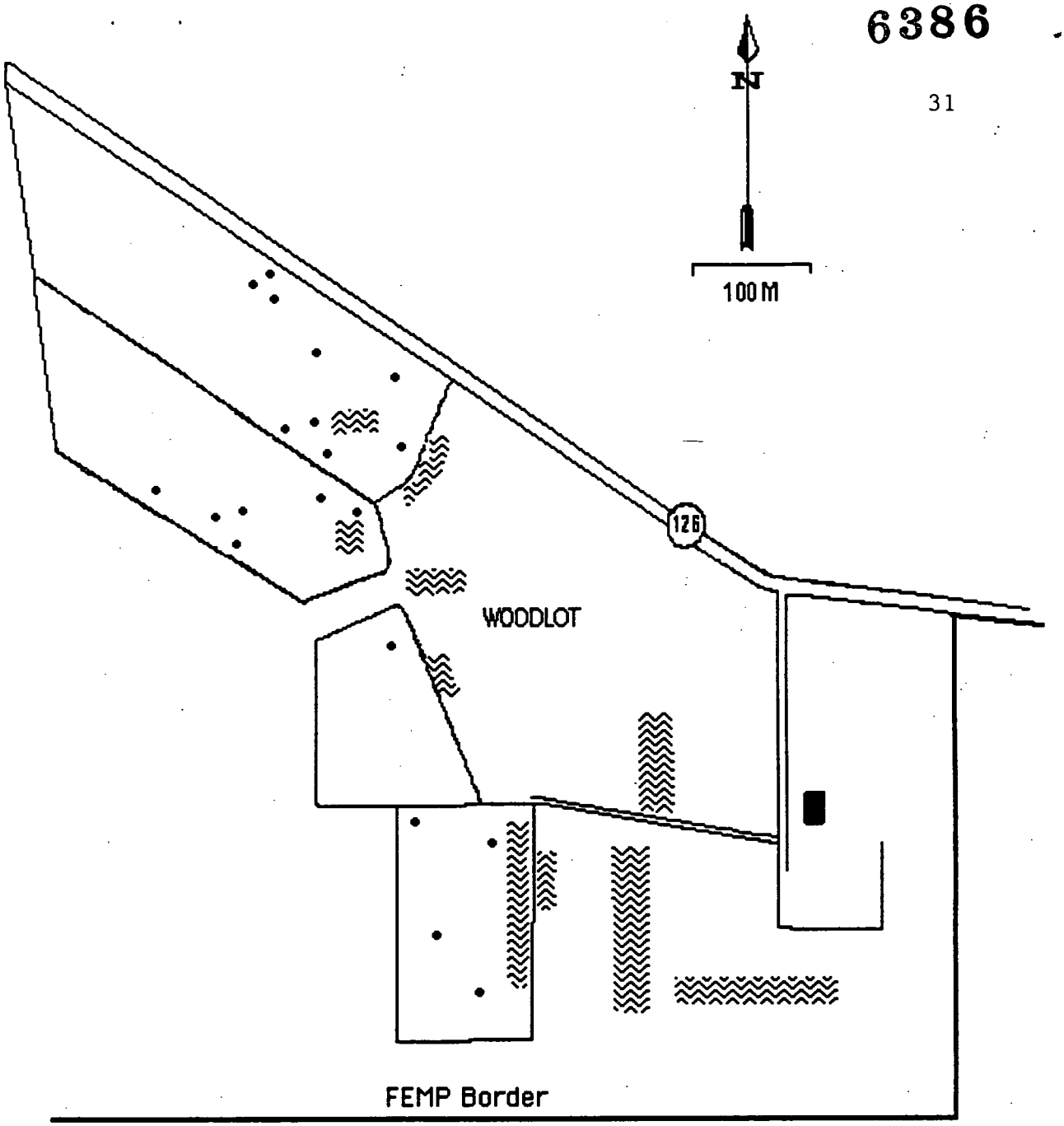

Figure 9. Earthworm sampling locations, hatched area, and soil sampling locations, solid circles, at Nieman's Nursery, 1991.

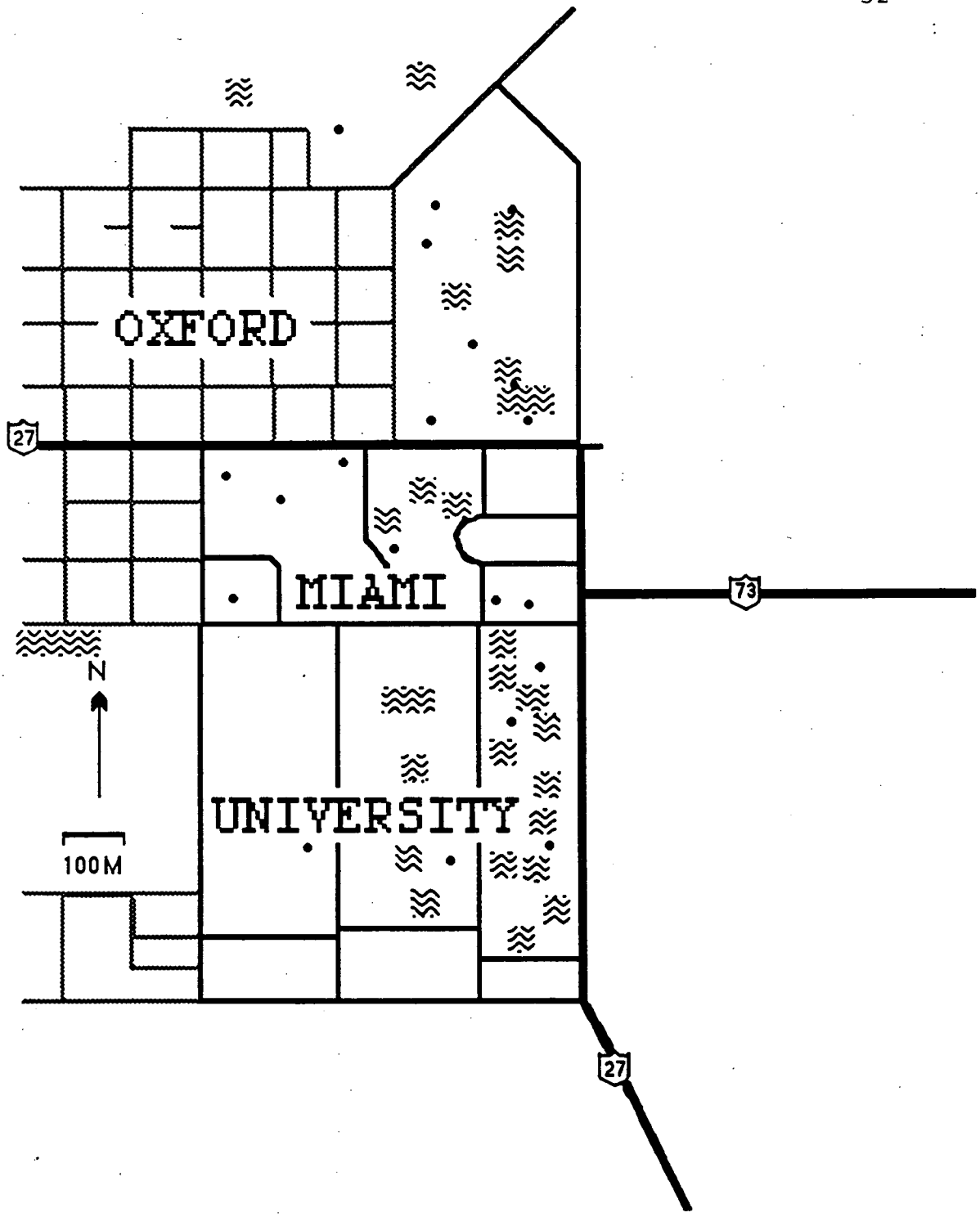

Figure 10. Earthworm sampling locations, hatched area, and soil sampling locations, solid circles, on the Miami University Oxford campus, 1991.

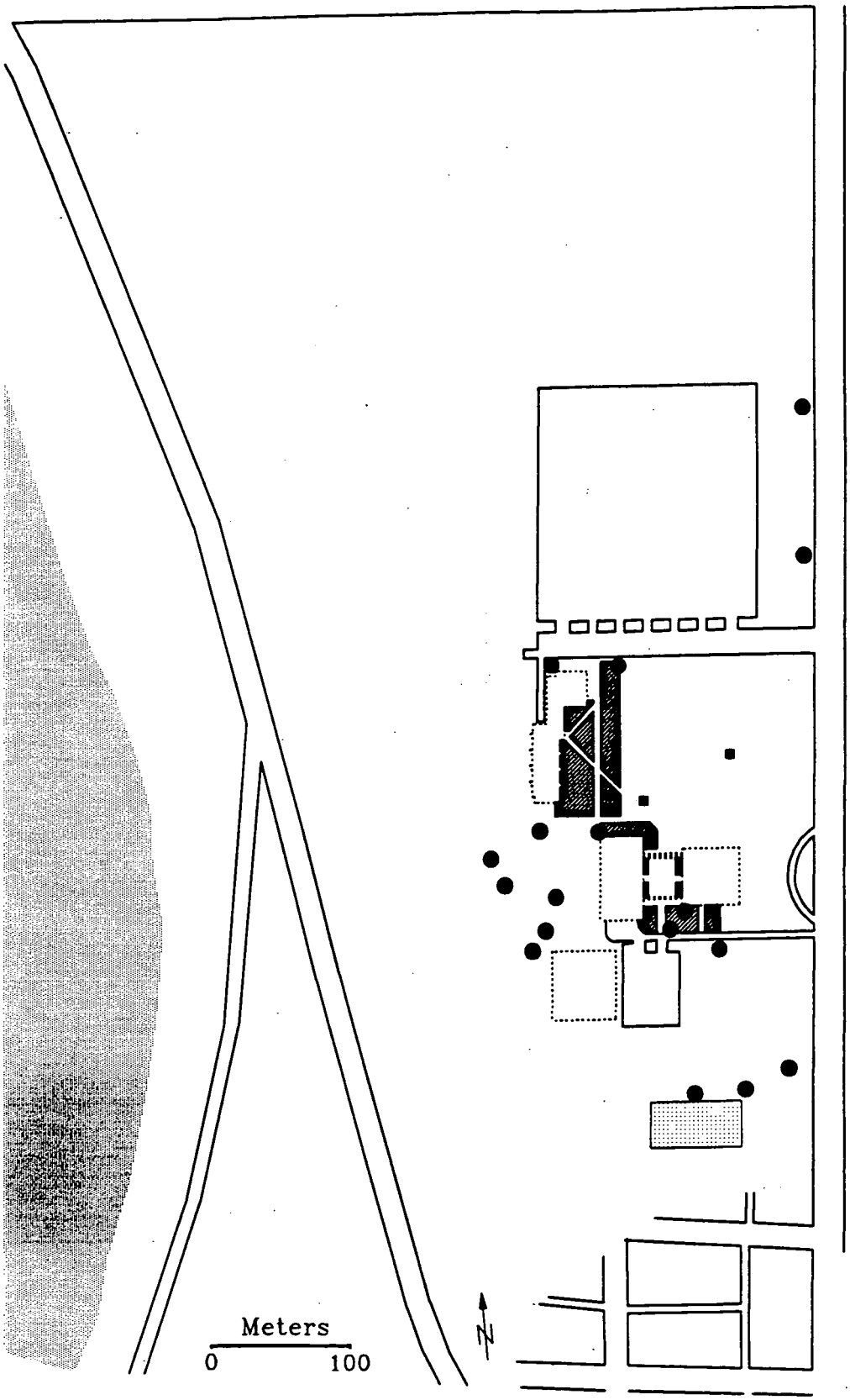

Figure 11. Earthworm sampling locations (hatched areas), and soil sampling locations (solid circles), on the Miami University Hamilton campus, 1991.

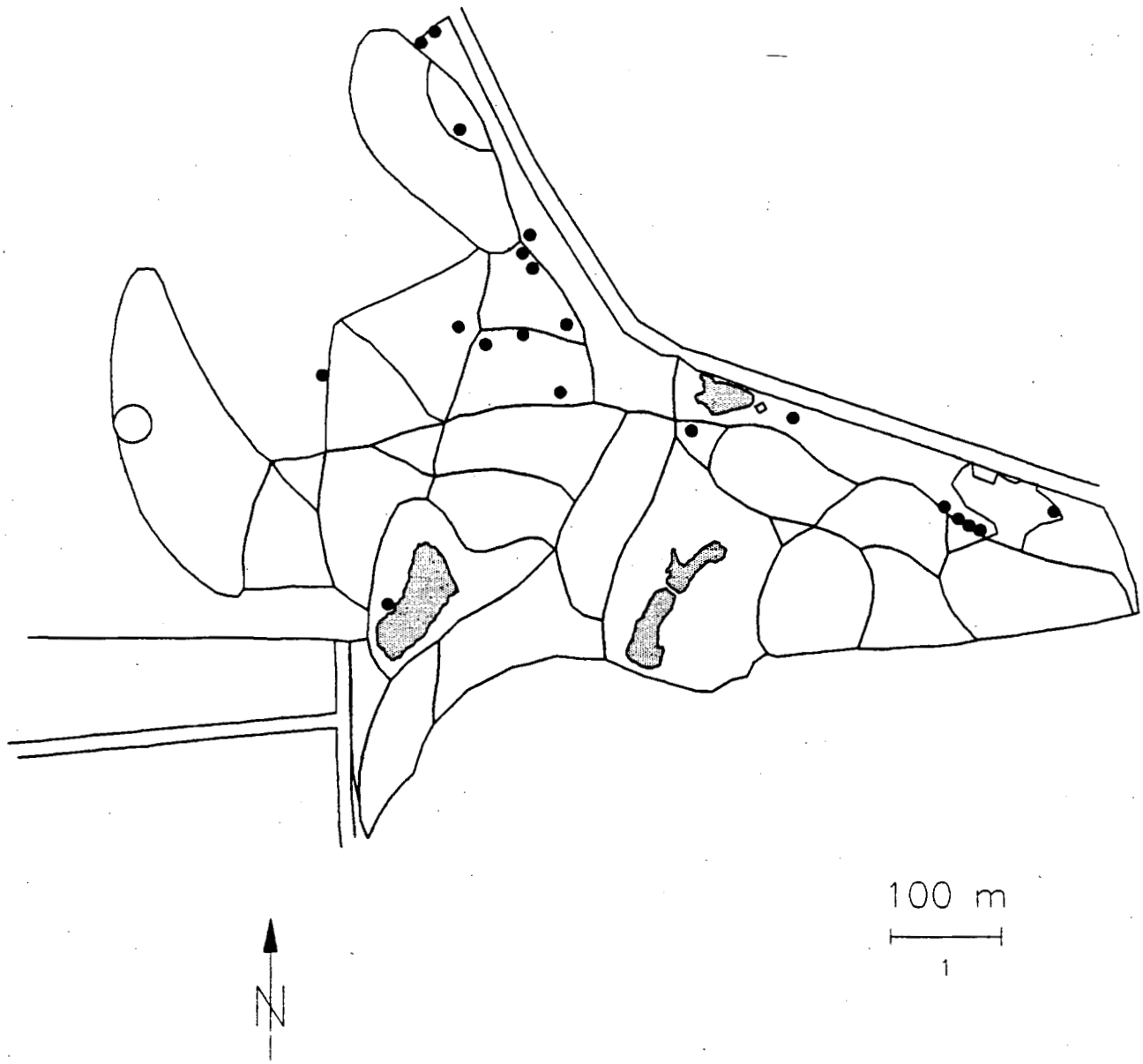

Figure 12. Soil sampling locations at Spring Grove Cemetery, 1991.

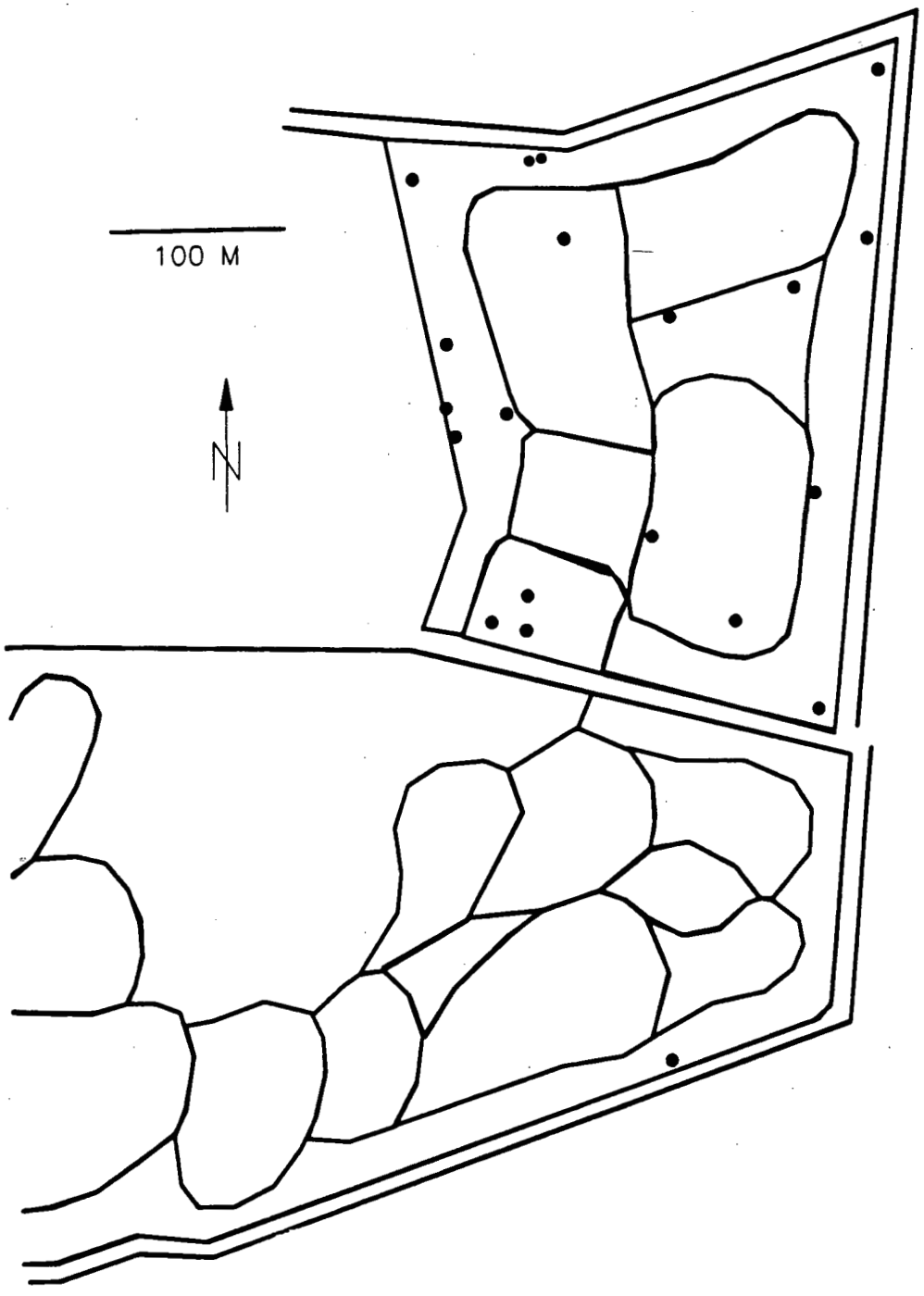

Figure 13. Soil sampling locations at Greenwood Cemetery, 1991.

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Table 1* Reproductive parameters [means(SE)] for American Robins in Greenwood Cemetery (GRNWD), Miami University Hamilton campus, Miami University Oxford campus, Nieman's Nursery, north FEMP, south FEMP, and Spring Grove Cemetery (SPR. GR.), Spring, 1991.

REPRODUCTIVE PARAMETER	GRNWD	MIAMI HAM.	MIAMI OX.	NIEMAN'S	NFEMP	SFEMP	SPR. GR.
Number of Clutches	33	27	61	26	7	25	44
Clutch Size	3.2	3.3	3.4	3.2	3.7	3.4	3.3
SE	0.1	0.2	0.1	0.2	0.2	0.2	0.1
Number of Hatchlings	1.8	1.1	2.1	2.0	2.0	2.0	2.0
SE	0.3	0.2	0.2	0.3	0.6	0.3	0.2
Number of Fledglings	1.5	0.9	1.4	1.6	1.4	1.0	0.9
SE	0.3	0.3	0.2	0.3	0.6	0.3	0.2
Percent Fledged	46.0	25.3	39.7	54.5	39.3	29.9	28.1

* a priori test of total FEMP vs non-contiguous offsites yielded no significant difference ($P > 0.05$)
a priori test of total FEMP vs Nieman's Nursery yielded no significant difference ($P > 0.05$)

Table 2*. Maximum egg weights [mean (SE)] for American Robins in Greenwood Cemetery (GRNWD), Miami University Hamilton campus, Miami University Oxford campus, Nieman's Nursery, north FEMP, south FEMP, and Spring Grove Cemetery (SPR. GR.), Spring, 1991.

	GRNWD	MIAMI HAM.	MIAMI OX.	NIEMAN'S	NFEMP	SFEMP	SPR. GR.
Total Number of Eggs	88	85	178	62	22	70	121
Maximum Egg Weights (g)	6.3	6.2	6.3	6.5	6.6	6.3	6.3
SE	0.1	0.1	0.1	0.1	0.1	0.1	0.1

* a priori test of total FEMP vs non-contiguous offsites yielded no significant difference ($P > 0.05$).
a priori test of total FEMP vs Nieman's Nursery yielded no significant difference ($P > 0.05$).

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Table 3. Mean weights and morphometrics of prefledgling American Robins of Greenwood Cemetery (GRNWD), Miami University Hamilton campus, Miami University Oxford campus, Nieman's Nursery, north FEMP, south FEMP, and Spring Grove Cemetery (SPR. GR.), Spring, 1991. Values [means (SE)] represent asymptotic values before fledging.

PARAMETER	GRNWD	MIAMI HAM.	MIAMI OX.	NIEMAN'S	NFEMP	SFEMP	SPR. GR.
Number of Fledglings	52	23	75	39	10	27	39
Culmen (mm)	15.2	15.0	15.0	15.4	15.2	14.7	14.3
SE	0.2	0.4	0.2	0.3	0.7	0.2	0.2
*Wing Chord (mm)	76.4	72.4	73.4	73.2	65.6	72.0	72.1
SE	0.9	1.5	0.9	1.2	3.6	1.4	1.3
*Primary (mm)	40.9	37.9	38.7	38.9	33.3	37.7	36.1
SE	0.9	1.2	0.6	0.9	3.2	1.0	1.0
Weight (g)	58.0	55.7	55.7	54.3	52.7	56.1	56.1
SE	0.7	0.7	0.6	1.1	2.0	0.6	0.7

* a priori test of total FEMP vs non-contiguous offsites yielded significant difference at $P < 0.05$.
a priori test of total FEMP vs Nieman's Nursery yielded significant difference at $P < 0.05$.

Table 4. Laboratory analyses (ppm) of soil samples for heavy metals from Greenwood Cemetery (GWD), Miami University Hamilton campus (MUHAM), Miami University Oxford campus (MUOX), Nieman's Nursery (NIEM), north FEMP, south FEMP, and Spring Grove Cemetery (SPG), Summer 1991.

	GWD		MUHAM		MUOX		NIEM		NFEMP		SFEMP		SPG	
TOTAL METALS	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
As	4.7	5.9	3.1	3.8	4.5	4.6	4.2	4.4	9.4	4.1	9.15	4.2	9.4	10.1
Hg	0.2	0.11	0.05	0.08	0.08	0.01	0.2	0.11	0.15	0.02	0.11	ND	0.1	0.17
Pb	36	34.4	44.1	44.3	39.8	36.4	39	45.2	54.9	75.2	58.7	42.5	65	44.5
Se	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ag	ND	ND	2.56	2.37	0.96	2.06	ND	ND	ND	4.34	ND	ND	1	ND
Ba	97	92	90	79.2	111	83.6	8.1	81	139	87.6	114	124	162	83.7
Cd	0.9	0.78	0.93	0.94	0.68	0.83	0.7	0.7	1.25	0.55	1.46	1	0.9	0.91
Cr	13	12.5	11	8.69	14.2	14.7	12	12	17	40.1	14.2	18.2	15	15.7

* L1 and L2 are WEMCO Laboratories 1 and 2, respectfully.

** *a priori* contrast analysis, total FEMP significantly higher ($P<0.05$) when compared to composite offsite stations.

ND= Not detectable.

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Table 5. Laboratory analyses (ppm) of earthworm samples for heavy metals from Greenwood Cemetery (GWD), Miami University Hamilton campus (MUHAM), Miami University Oxford campus (MUOX), Nieman's Nursery (NIEM), north FEMP, south FEMP, ans Spring Grove Cemetery (SPG), Summer 1991.

TOTAL METALS	GWD	MUHAM	MUOX	NIEM	NFEMP	SFEMP	SPG
As	-	10	ND	ND	9	9	-
Hg	-	0.24	ND	0.02	0.86	0.86	-
Pb	-	8.5	ND	4.95	7	7	-
Se	-	1	ND	ND	9.2	9.2	-
Ag	-	ND	ND	ND	ND	ND	-
Ba	-	ND	ND	ND	ND	ND	-
Cd	-	ND	ND	ND	ND	ND	-
Cr	-	ND	ND	ND	ND	ND	-

ND= Not detectable.