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TECHNICAL REPORT N-89
May 1980

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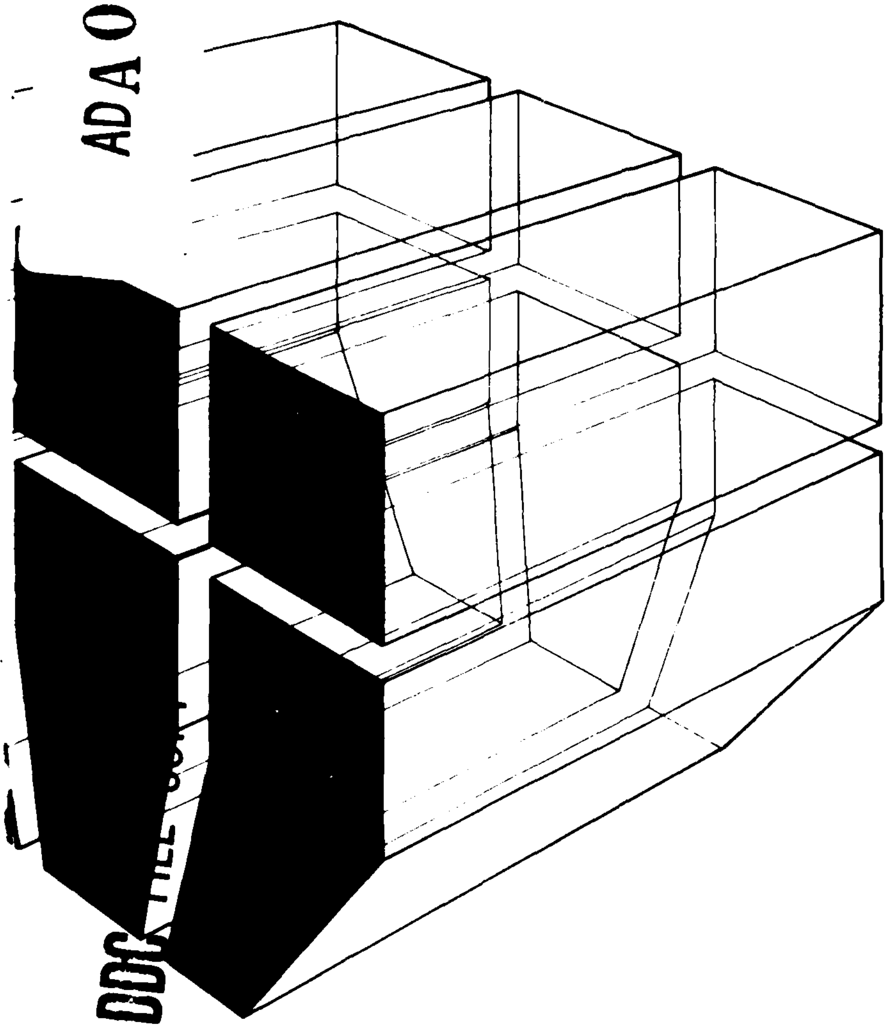
LEVEL II

GUIDELINES FOR TERRESTRIAL ECOSYSTEM SURVEY



by
W. D. Severinghaus

MAY 1980

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This report provides guidelines that will enable Army installations to compile and maintain enough information on flora and fauna to produce satisfactory environmental impact assessments and statements. The report outlines a three-stage method for data acquisition and contains appendices listing literature resources and specialists. By completing Stage I, users create a series of maps, overlays, and tables that give an estimate of the amount of habitat, types of vegetation, and types of

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animals existing on the installation. Stage II involves a field verification of the information from Stage I. Stage III requires the explicit documentation of population densities and other ecological parameters of the various organisms on the installation.

FOREWORD

This document was prepared by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL) under the In-Laboratory Independent Research (ILIR) program.

Dr. E. Novak is Acting Chief of EN. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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GUIDELINES FOR TERRESTRIAL ECOSYSTEM SURVEY

1 INTRODUCTION

Background

The National Environmental Policy Act of 1969 requires that the probable impact from major actions of U.S. Government agencies be analyzed. These analyses are prepared and presented as a portion of Environmental Assessments (EA) or Environmental Impact Statements (EIS), and usually require that a considerable amount of time and money be spent surveying biota -- the flora and fauna -- of the proposed area of impact. The major problem is the shortage of time available to do necessary fieldwork. Generally Government agencies attempt to avoid this difficulty by hiring experts from a variety of disciplines (e.g., botany, entomology, herpetology, mammalogy, ornithology) to perform field surveys. Even with this expertise, however, the ecological data usually consist of a "laundry list" of those species that are readily identifiable, controversial, or economically important. Information about population is limited to categories such as abundant, common, uncommon, and rare. These categories are seldom quantifiable, are the interpretation of the individual researcher, and are not comparable among researchers.

A final problem is that during the course of the survey, some uncommon or rare -- and perhaps controversial -- species can be missed, as shown by the discovery of the Furbish Lousewort in New England and the Snail Darter in Tennessee after construction was partially completed.

Objective

The objective of this report is to present guidelines to help Army installations compile and maintain enough information on the biota of the installation to produce satisfactory input for EA/EIS. Following the procedures outlined here will allow installations to: (1) reduce expenditures by using technician-level personnel, since persons with minimal expertise can collect the required data; and (2) generate precise quantitative data on the location of various types of habitat, the acreage of each type, and the number of individuals of each animal and plant species per unit area in each habitat.

Approach

The terrestrial ecosystem survey guidelines in this report are products of basic ecological research to identify cause-effect relationships between Army activities and resulting impacts on terrestrial ecosystems. As part of this research it was necessary to acquire ecological field data. Both by examining the literature on ecological survey methods, and by actually using various methods in the field, survey techniques were developed for ecological sampling so that quantitative data could be obtained on habitats, their locations, acreage, and species composition.

Use of the Guidelines

These techniques are part of a three-stage process. While the information obtained at the end of any one stage will be useful, the system will be even more accurate and useful as additional stages are completed. Of course, completion of each successive stage will also require increasing investments of time and money.

After finishing Stage I, users of this report will have produced a series of maps, overlays, and tables that will give an estimate of the amount of habitat, types of vegetation, and types of animals existing on the installation. Stage II will involve a field verification of the information obtained in Stage I. Stage III will involve the explicit documentation of population densities and other ecological parameters of the various organisms on the installation.

Before starting this program, investigators should study the entire report because some stages will require field work. If field work is necessary, it might be more efficient to conduct different portions of this program simultaneously.

2 STAGE I. ESTIMATION OF TERRESTRIAL BIOTA

Stage I is essentially a compilation of available information requiring little, if any, field work. Completion of this stage will provide a series of maps, overlays, and tables that will give an estimate of the amount of habitat, types of vegetation, and types of animals existing on the installation. Investigators will compile a list of species that might exist on the installation, and will determine a range in possible population levels for some species. Although some of this information is already available at Army installations and is being used for the preparation of EA or EIS, Stage I will give more detailed information than is presently in the files of most installations. The information gathered in Stage I will be compiled in two formats: overlays to an aerial photograph, and a series of descriptive tables.

Vegetation

The first step in estimating vegetation parameters on the installation is to obtain United States Geological Survey (USGS) topographic maps of scale 1:24,000 and aerial photographs of approximately 1:15,000. These items will be used throughout the study as the base for overlays. The literature available on the trees, shrubs, and herbs should be acquired (Appendix A lists much of the literature available). Soil survey maps and terrain analysis reports should be obtained, if available. Most of the mapping can be completed by examining aerial photographs occasionally supplemented with a brief field examination. Accurate completion of the vegetation mapping is very important because the faunal mapping and some detailed vegetational mapping will be based on these overlays.

The following discussion is a step-by-step presentation of the procedures to be followed for vegetation mapping and tabulation. First, *Vegetational Characteristics Mapping* discusses general definitions to be used for vegetational mapping. Then *Vegetation Characteristics Description* explains how to tabulate information gathered through mapping.

Vegetational Characteristics Mapping

The base for overlays should be an aerial photograph of a scale approximately 1:15,000. Production of the overlays themselves should conform to the guidelines described below; this will result in six overlays, one each for tree type, tree canopy closure, shrub type, shrub crown cover, herb type, and herb ground cover; see Figures 1 through 6 for examples. A seventh overlay should be produced on the aquatic relationships of the installation (Figure 7). This can be done by transferring the appropriate information from the 1:24,000 topographic maps to an overlay. Thus, by placing the overlays on the aerial photograph, users

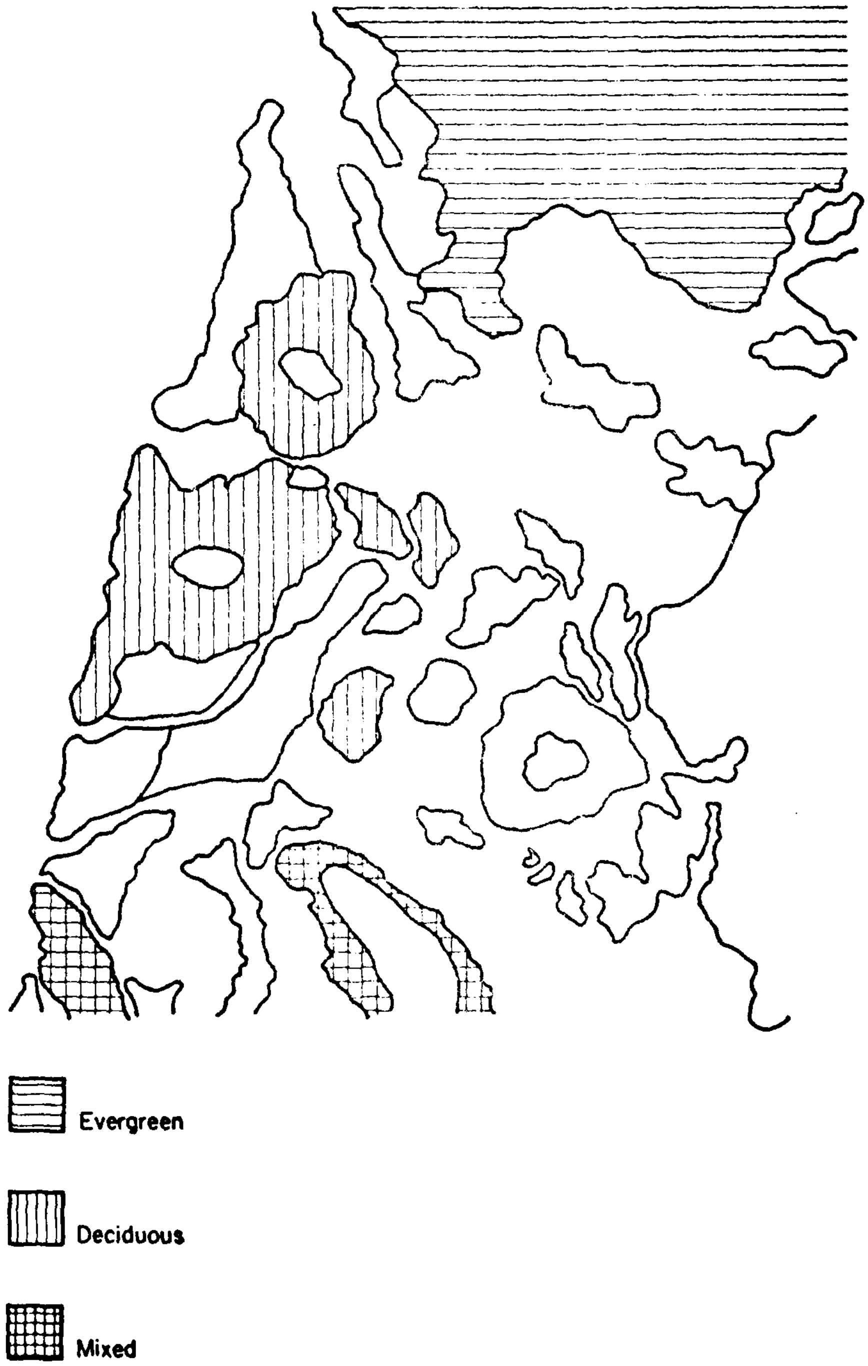

Figure 1. Tree types.

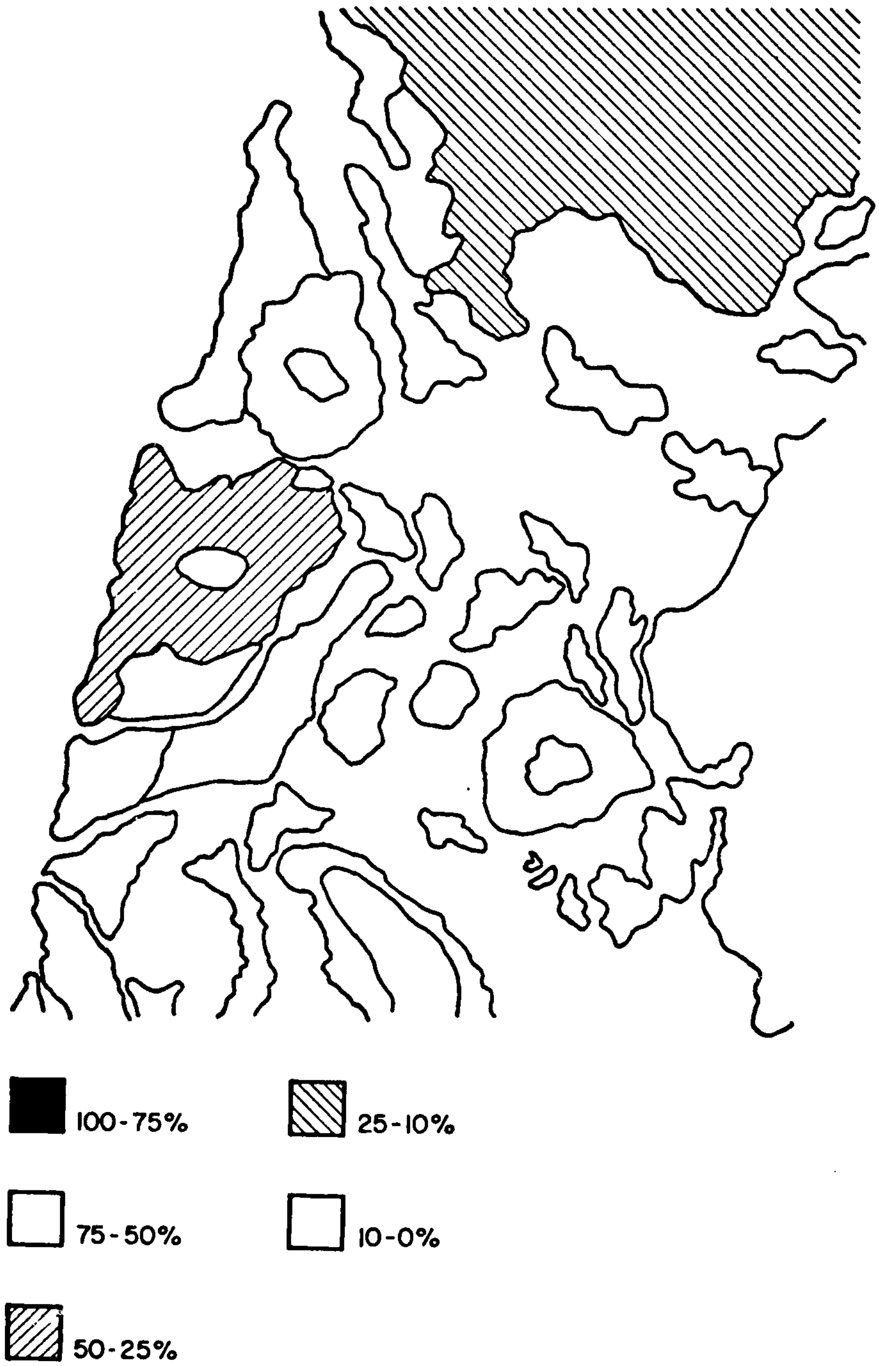

Figure 2. Tree canopy closure.

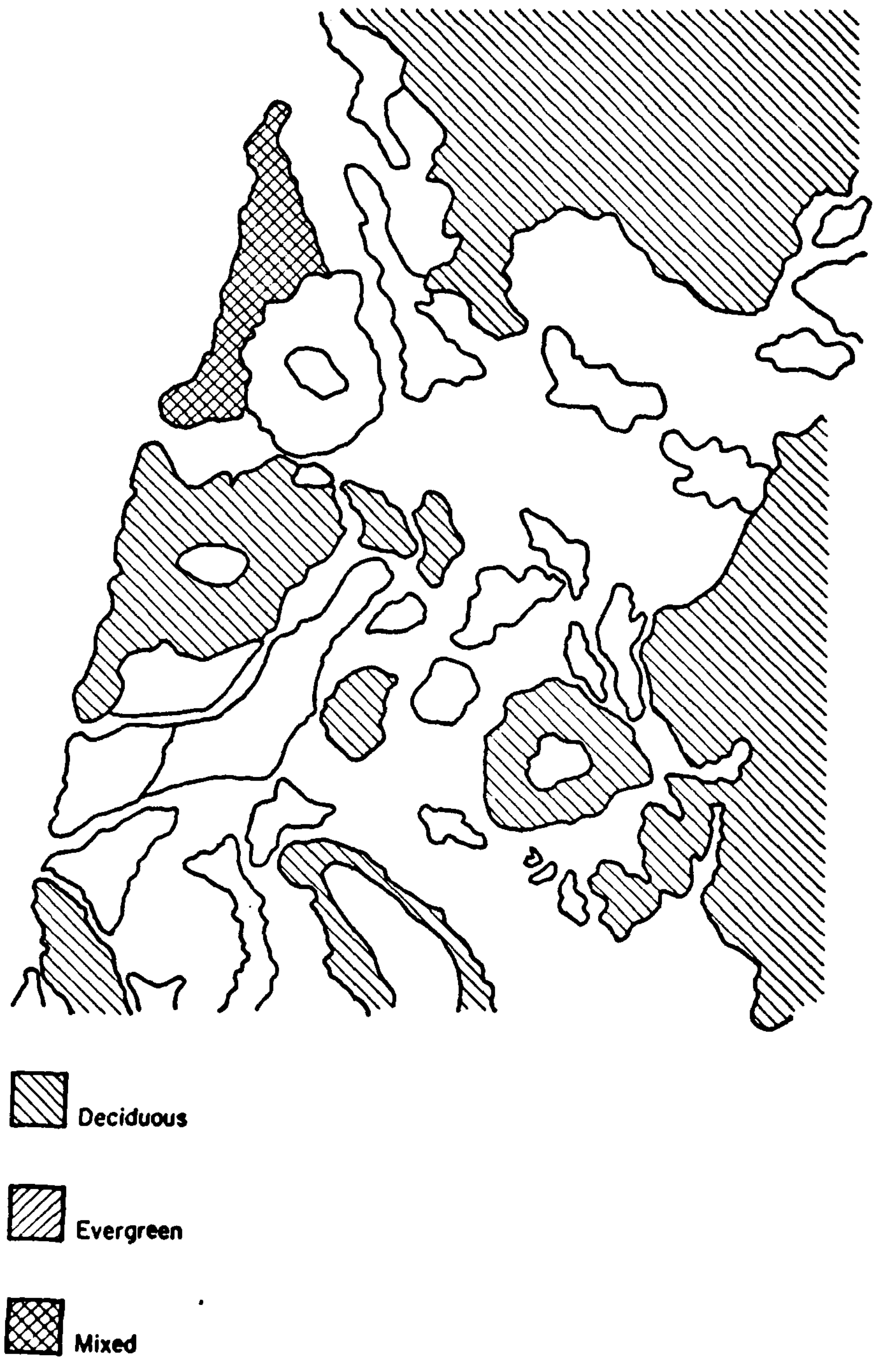

Figure 3. Shrub types.

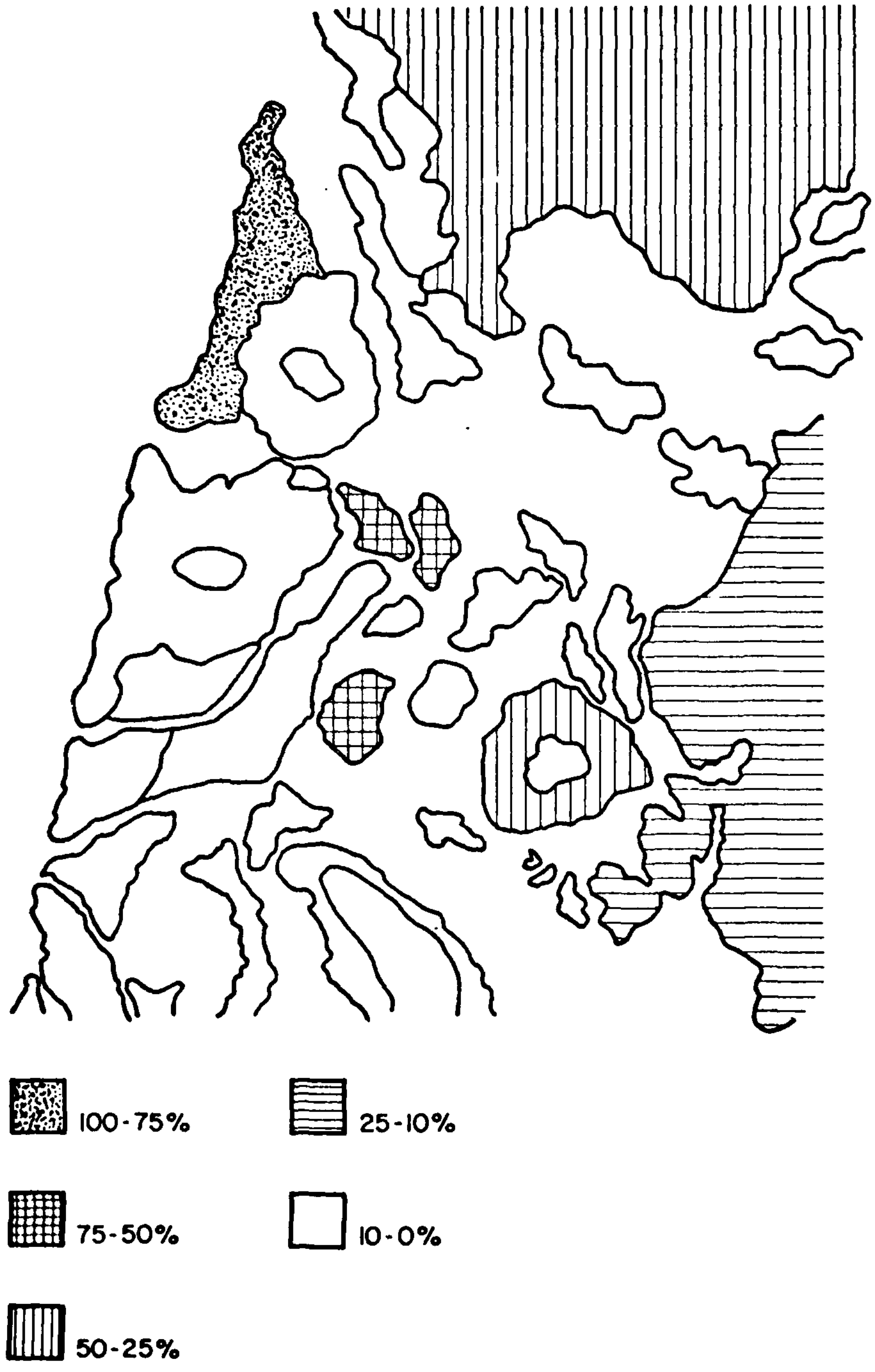

Figure 4. Shrub crown cover.

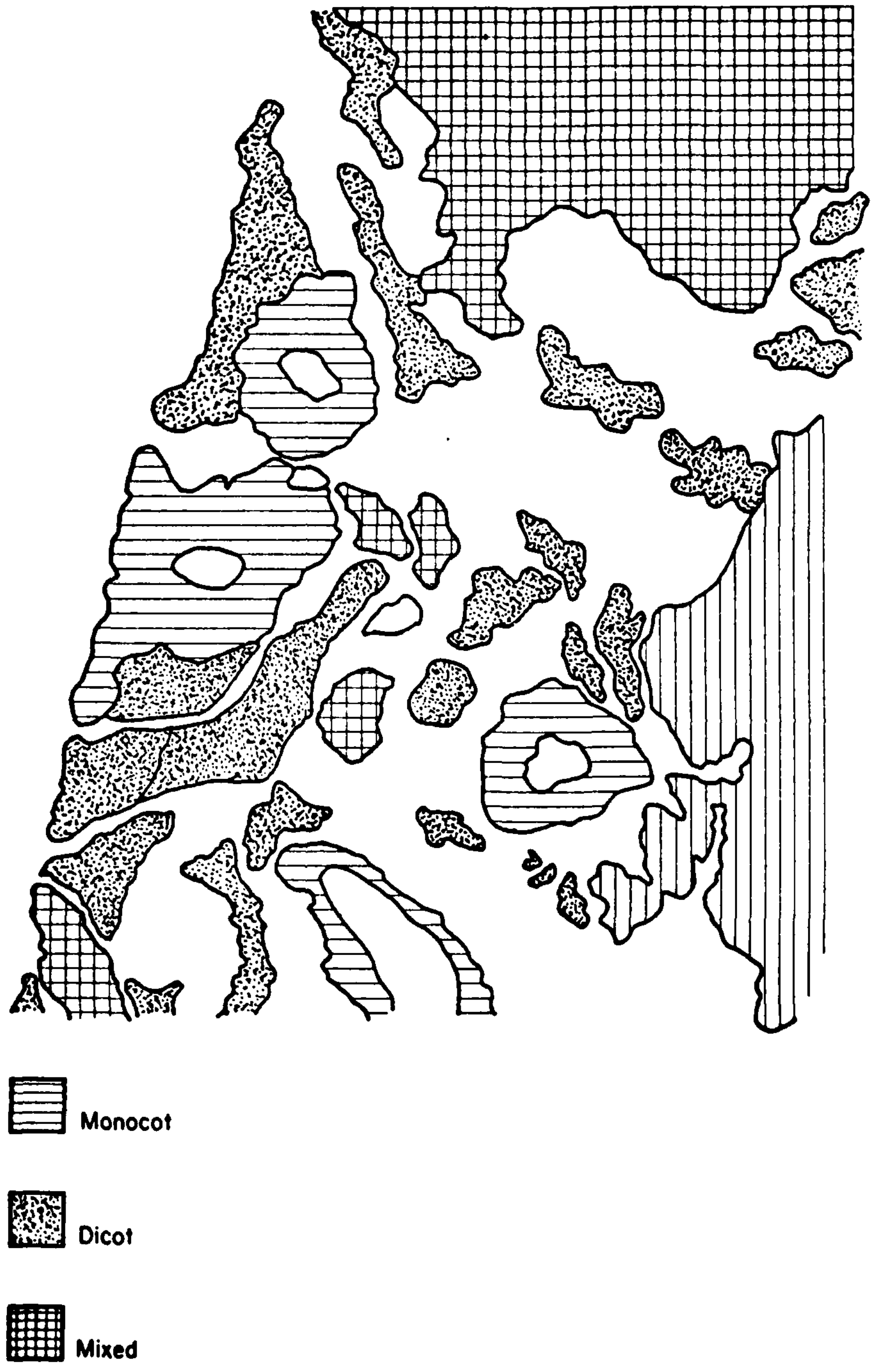

Figure 5. Herb types.

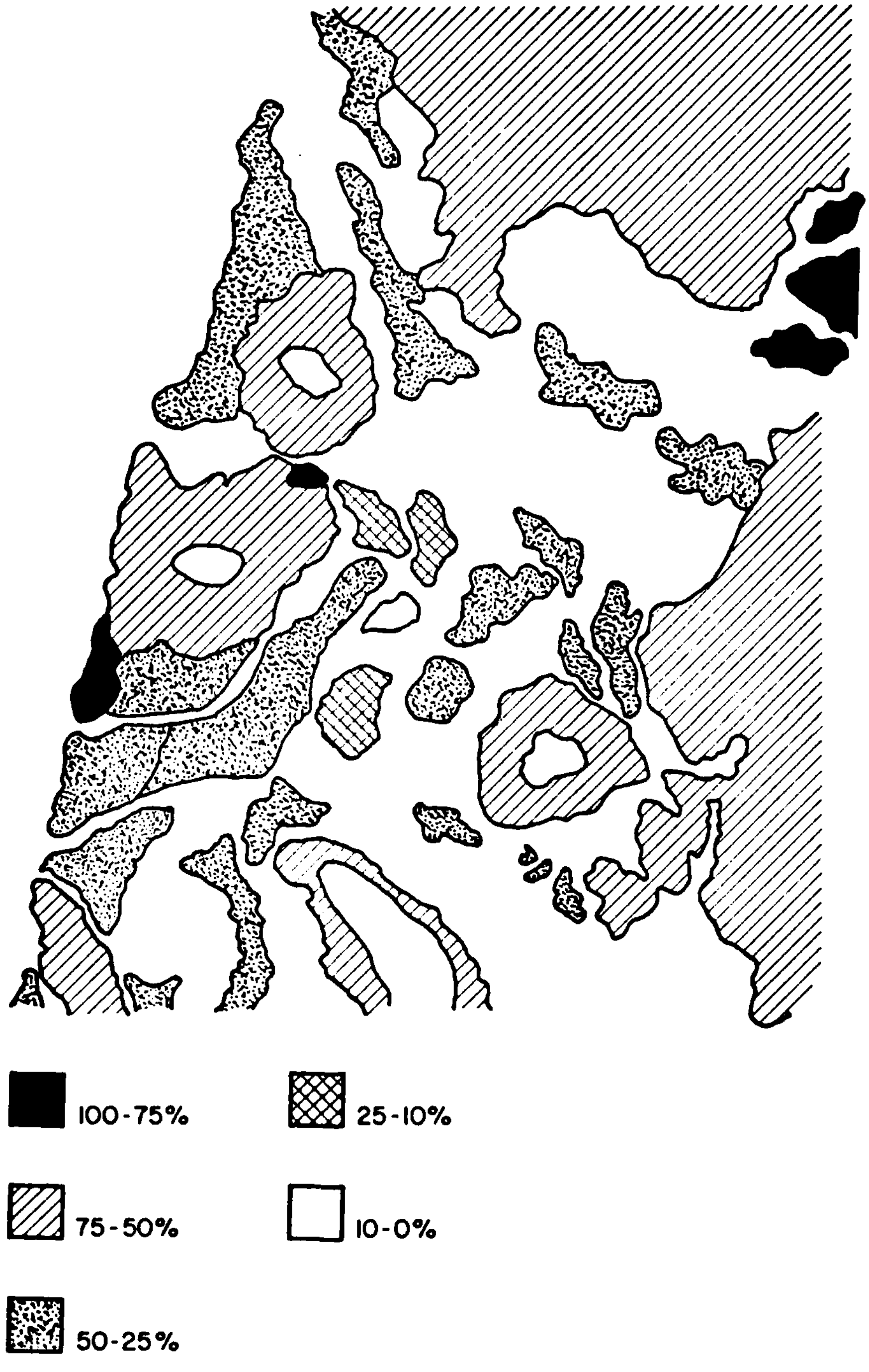

Figure 6. Herb ground cover.

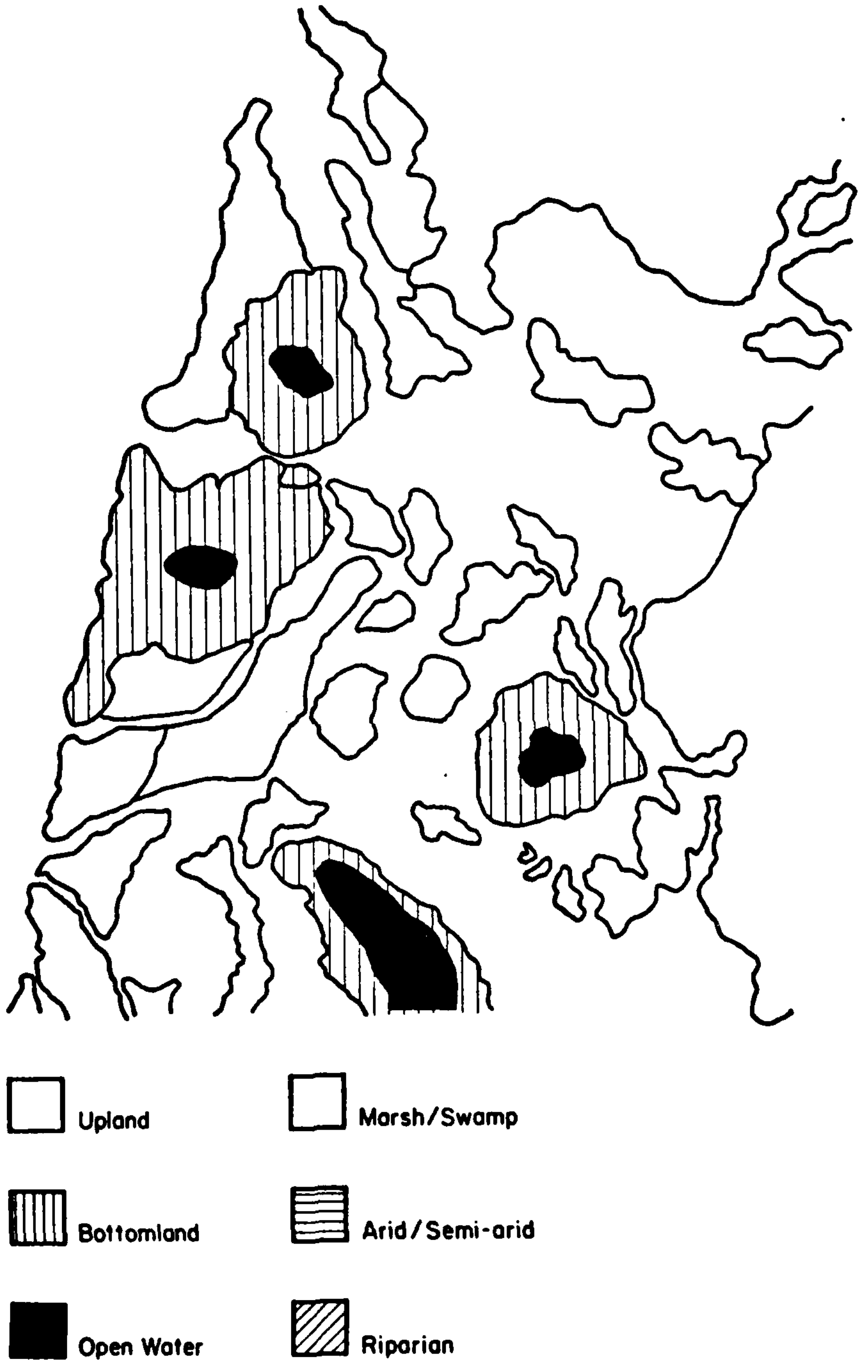

Figure 7. Aquatic relationships.

will be able to estimate the amounts, types, and locations of vegetation and habitats on the installation.

The parenthetical symbols accompanying definitions below will be used as a code for tabulating information later in *Vegetation Characteristics Description*.

Trees. Trees are woody plants with a stem that has a diameter of at least 10 cm at breast height. Personnel can map trees for an installation by examining aerial photographs and transferring to a transparent overlay plots of the following characteristics:

1. Tree Types (Figure 1).

a. Evergreen (I): defined as predominantly evergreen-coniferous forest.

b. Hardwood (II): defined as predominantly deciduous-hardwood forest.

c. Mixed (III): defined as a mixture of between 40 percent to 60 percent hardwood-coniferous.

2. Canopy Closure: measured as the percent of the canopy that is closed to direct sunlight making contact with lower strata or ground (Figure 2).

a. 100 percent to 75 percent closed canopy (A).

b. 75 percent to 50 percent closed canopy (B).

c. 50 percent to 25 percent closed canopy (C).

d. 25 percent to 10 percent closed canopy (D).

e. 10 percent to trees absent (E).

The minimum area for the characterization of canopy closure should be 1 hectare, which is approximately 2.5 acres or 100 m x 100 m. The 1 hectare minimum is used because some species need that much area to maintain viable breeding populations.

Shrubs. Shrubs are multiple-stemmed woody plants which usually remain less than 5 m tall at maturity. Mapping shrubs for an installation requires some field work when the presence of trees or the poor resolution of aerial photographs hinders visual interpretation. If field work is necessary in some areas to complete Stage I, it may be desirable to complete Stages I and II simultaneously. To reduce unnecessary field work, all information from topographic maps and aerial photographs should be recorded on the "shrub overlay" before any field work is started.

1. Shrub Types (Figure 3).

a. Evergreen (I): predominantly evergreen-coniferous shrub strata; includes desert and arctic shrubs that are not gymnosperms (conifer and their allies) but maintain their foliage to reduce their leafing time and energy budgets during the growing season.

b. Deciduous (II): predominantly a deciduous shrub strata.

c. Mixed (III): a mixture of between 40 percent to 60 percent evergreen-deciduous.

2. Crown Cover. This is an estimate of the percentage of surface area shaded by the crown of the shrub strata (Figure 4).

a. 100 percent to 75 percent (1).

b. 75 percent to 50 percent (2).

c. 50 percent to 25 percent (3).

d. 25 percent to 10 percent (4).

e. 10 percent to shrub crown cover absent (5).

The minimum area for the characterization of crown cover should be 0.25 hectare, which is approximately 0.60 acre or 50 m x 50 m.

Herbs. Herbs are soft-stemmed, nonwoody plants. Mapping the herbaceous strata for any installations requires considerably more field work than either trees or shrubs. The only information available from aerial photographs is in those areas where the tree or shrub strata are absent or reduced, and even this information is generally limited to the presence or absence of an herb strata. Again, it should be emphasized that before beginning any field work, all portions of Stage I should be as complete as possible. Much of the field work will be repetitious or can be completed simultaneously with other parameters, thus reducing the overall, labor-intensive portion of Stage I.

1. Herb Types (Figure 5).

a. Monocots (I): predominantly grasses (monocot).

b. Dicots (II): predominantly broadleaf (dicot) species.

c. Mixed (III): a mixture of between 40 percent to 60 percent monocot-dicot.

2. Ground Cover. This is an estimate of the percentage of ground surface covered or shaded by herbaceous organisms (Figure 6).

a. 100 percent to 75 percent (A).

b. 75 percent to 50 percent (B).

c. 50 percent to 25 percent (C).

d. 25 percent to 10 percent (D).

e. 10 percent to herb strata absent (E).

The minimum area for characterization of ground cover should be 0.25 hectare, which is approximately 0.60 acre or 50 m x 50 m.

Aquatic Relationships. To determine these characteristics, aerial photographs, soil surveys, and topographic maps are necessary. By combining information from the photographs, surveys, and maps, investigators will be able to produce an overlay for aquatic relationships (Figure 7).

1. Upland (1): areas of well-drained soils not subject to periodic flooding.

2. Bottomland (2): areas subjected to periodic flooding that are at least 20 m from any moving or standing body of water.

3. Riparian (3): areas, whether or not they are subject to periodic flooding, that are within 20 m of a moving or standing body of water.

4. Marsh/Swamp (4): areas that normally maintain standing water that is not open and free flowing.

5. Arid/Semi-Arid (5): areas that normally receive less than 20 in. (50.8 cm) of rainfall per year.

Vegetation Characteristics Description

The following discussion tells how to prepare descriptive tables compiling more definitive data than on the overlays, and Table 1 is an outline for presenting the required data.

1. Trees.

a. Tree Species Estimate. The last step in completing Stage I for trees is to prepare a list of tree species that could inhabit the installation. The literature on the range, distribution, and habitat requirements for trees must be searched (see Appendix A). For each species whose range includes the installation, its common name, scientific name, and habitat (niche) requirements should be provided. This information should then be cross-referenced with the code listing of

Table 1

Vegetational Composite

Description				Approximate Acreage	Species Present In This Habitat
Code			Verbal		
Tree	Herb	Shrub			
IIBI	II4	III	Upland hardwood forest with 75 percent to 50 percent closed canopy, deciduous shrubs with 25 percent to 10 percent crown cover, mixed herbs with 10 percent to absent ground cover	3250	Plants Mammals Birds Reptiles

tree types, canopy closure, and aquatic relationships. This would result in a table containing information such as that in Table 1.

b. Estimation of Acreage. With this information laid out on an overlay, it is easy to use standard planimetry to estimate the approximate amount of acreage for each sequence of tree parameters.

2. Shrubs.

a. Shrub Species Estimate. The last step in completing Stage I for shrubs is to prepare a list of shrub species that could inhabit the installation. The literature on the range, distribution, and habitat requirements for shrubs must be searched (see Appendix A). The common name, scientific name, and habitat requirements of each species whose range includes the installation should be listed. This information should then be cross-referenced with the coded listing of shrub types, etc. The results should be presented in a table containing information such as in Table 1.

b. Estimation of Acreage: see tree section above.

3. Herbs.

a. Herb Species Estimate: see shrub section.

b. Estimate of Acreage: see tree section.

c. Matting: defined as the dead plant material lying on the surface of the ground. This includes <u>all</u> plant material but does not include standing dead material. Matting is measured as the material's vertical thickness and should be based on the same minimal area as described under ground cover (may require field work and can be delayed until the completion of Stage II or III). The thickness should be coded as follows:

(1) Thick: 8 cm or more (1).

(2) Medium: 4 to 8 cm (2).

(3) Thin: up to 4 cm (3).

(4) Absent: (4).

4. Algae, Fungi, Lichens, and Other Plant Species. The "other plant species" in this category are groups such as the ferns, liverworts, and mosses. Mapping this category is only slightly useful in obtaining a satisfactory overview of an installation since these plants do not play a major role in the trophic structure (energy flow) of the terrestrial ecosystem. However, the plants may be significant in an ecosystem -- rock, for example -- that is biologically and nutritionally barren. The most efficient and useful method of analyzing these plants is first to prepare a master list of the species, as was done in the "Species Estimate" sections for trees, shrubs, and herbs above. Second, the information presented in the literature on habitat requirements could be matched with the information obtained from topographic maps, aerial photographs, and the tree, shrub, and herb maps, and the listing of species assigned to the basic areas of the installation.

5. Rare, Endangered, or Threatened Plant Species. This category requires extremely definitive analysis. Any information gathered during Stage I will be useful in identifying specific problems. A list of all rare, endangered, or threatened plant species should be formulated along with a description of the habitats and a statement on their known or probable range. This list and discussion should be compared with all the information gathered to this point, and the species that have the potential to exist on the installation should be determined.

Animals

The successful completion of Stage I for animals will depend heavily on how well the vegetational portion has been completed, particularly the sections on trees, shrubs, and herbs.

At first, most animals are mapped on the basis of groups of species. Some species -- such as large and small mammals, game birds, and rare, endangered, or threatened species -- require separate mapping. Although the topographic maps and aerial photographs are of some aid, the completed vegetational maps are most helpful.

The literature on each category of animals described in this section should be consulted (see Appendix A) and a list of all species, or each group, compiled. The list should include not only those species whose known ranges include the installation, but also all those species whose ranges are reasonably close -- since, as mentioned earlier, Stage I is a compilation of floral and faunal parameters that potentially exist on the installation. Stages II and III are used to verify the presence of these organisms or habitats to document population dynamics. The example given for mammals in Table 2 is based on Fort Knox, KY, and lists 57 species. Of these 57 species, 10 are either on the edge of their ranges or close enough to require consideration in mapping.

Mammals

Mammals should be mapped in two different ways; to explain these methods the information on Fort Knox is used as an example. All mammals that are hunted and trapped (edible or fur bearers) or that are rare, endangered, or threatened should be mapped separately by species. The remainder of the mammalian species should be grouped on the basis of habitat.

Hunted, Trapped, Rare, Endangered, Threatened Species. Figure 8 is a list of such species at Fort Knox. An overlay indicating areas of suitable habitat should be completed for each species (Figures 9 and 10).

Other Mammalian Species. These species should be organized by habitat, and no mapping is necessary at this level. Each species should be cross-referenced with the various types of vegetational characteristics of the installation. This can be done by completing Table 3.

Birds

Table 2 should be completed for birds as it was for mammals. Birds should be mapped in two stages. All birds that are considered game, rare, endangered, or threatened should be mapped separately on the basis of habitat. Then remaining bird species also should be grouped on the basis of habitat. To explain this method, the information on Fort Knox will be used as an example.

Game, Rare, Endangered, and Threatened Species. Figure 11 is a list of game, rare, endangered species at Fort Knox. An overlay indicating areas of suitable habitat should be completed for each of the species. The residency of each species should be determined and indicated as follows: AY = year round resident; B = breeding range only; W = winter resident; M = migrant.

It may be relatively simple to combine species into an overlay representing several species -- for example, ducks, geese, and other waterfowl.

Table 2

Mammals (Fort Knox, Kentucky)

Common Name	Scientific Name	Habitat	Economic Status: Hunt	Edible	Furbearing	Pest	Pest Control	Pop. State Potential
Opossum	Didelphis marsupialis	Woodlands along streams	X	X	X		?	
Smoky Shrew	Sorex fumeus	Birch and hemlock forests with decomposing leaf litter on ground					?	May be abundant
Southeastern Shrew	Sorex longirostris	Open fields and woodlots, moist areas preferred					?	
Least Shrew	Cryptotis parva	Open grass-covered area, scattered brush, also marshes					?	
Shorttail Shrew	Blarina brevicanuda	Forests, grasslands, marsh areas; not restricted					?	Up to 25 per acre
Eastern Mole	Scalopus aquaticus	Sandy loam; lawns, golf courses, gardens, field meadows, avoid extremely dry soil				X	?	
Little Brown Bat	Myotis lucifugus	Caves, mine tunnels, hollow trees, buildings				?	X	
Mississippi Myotis	Myotis austroriparius	Caves, mine tunnels, hollow trees, buildings, culverts, bridges				?	X	

X = definitely important
? = probably or possibly important
* = ranges approximate installation

Table 2 (cont'd)

Common Name	Scientific Name	Habitat	Economic Status: Hunt	Edible	Furbearing	Pest	Pest Control	Pop. State Potential
Gray Myotis	Myotis grisescens	Caves				?	X	
Indiana Bat	Myotis sodalis	Caves, possibly man-made structures, hollow trees				?	X	Endangered
Small-footed Myotis	Myotis subulatis	Caves, mine tunnels, crevices in rocks, buildings, near forested areas				?	X	
Silver-haired Bat	Lasionycteris noctivagans	Forested areas, possible buildings and caves				?	X	
Eastern Pipistrel	Pipistrellus subflavus	Caves, mine tunnels, crevices in rocks, buildings, wooded areas, near water				?	X	
Big Brown Bat	Eptesicus fuscus	Caves, tunnels, crevices, hollow trees, buildings, wooded areas				?	X	
Red Bat	Lasiurus borealis	Wooded areas, roosts in trees, occasionally caves				?	X	
Hoary Bat	Lasiurus cinereus	Wooded areas				?	X	
Evening Bat	Nycticeius numeralis	Buildings and hollow trees				?	X	
Western Big-Eared Bat	Plecotus townsendi	Caves, mine tunnels, buildings				?	X	
Eastern Big-Eared Bat	Plecotus rafinesquei	Caves, mine tunnels, buildings				?	X	
Raccoon	Procyon lotor	Along streams and lakes with wooded areas or cliffs nearby	X	X	X	X	X	

Table 2 (cont'd)

Common Name	Scientific Name	Habitat	Economic Status: Hunt	Edible	Furbearing	Pest	Pest Control	Pop. State Potential
Longtail Weasel	Mustela frenata	Not restricted but near water			X		X	
River Otter	Lutra canadensis	Along streams and lakes			X			
Spotted Skunk*	Spilogale putorius	Brushy or sparsely wooded areas, along streams, among boulders, prairies			X	?	X	Possible rabies carrier
Striped Skunk	Mephitis mephitis	Semi-open country; mixed woods, brushland, and open prairies preferred within 2 miles of water			X	?	X	Possible rabies carrier
Coyote*	Canis latrans	Prairies, open woodlands, brush or boulder strewn areas	X			X	X	
Red Fox	Vulpes vulpes	Mixture of forest and open country preferred	X		X		X	Home range 1-2 sq mi
Gray Fox	Urocyon cinereoargenteus	Chaparral, open forests, rimrock country	X		X		X	Rare
Bobcat*	Lynx rufus	Swamps and forests in the east	X		X		X	Rare
Woodchuck	Marmota monax	Open woods, brushy and rocky ravines	X	?		X		
Eastern Chipmunk	Tamias striatus	Deciduous forests, brushy areas				?		Aesthetically pleasing
Eastern Gray Squirrel	Sciurus carolinensis	Hardwood forests with nut trees, river bottoms	X	X	X			Home range 2-7 acres, pop. 2-20 per acre
Eastern Fox Squirrel	Sciurus niger	Open hardwood woodlots in northland, pine forests in south, both with clearing interspersed	X	X	X			Home range, pop. 0.5 to 3.0 per acre

Table 2 (cont'd)

Common Name	Scientific Name	Habitat	Economic Status: Hunt	Edible	Furbearing	Pest	Pest Control	Pop. State Potential
Red Squirrel*	Tamiasciurus hudsonicus	Pine and spruce or mixed hardwood forests, swamps	X	X				Aesthetically pleasing, 1-10 per acre
Southern Flying Squirrel	Glaucomys volans	Woodlots and forests of deciduous, mixed deciduous-coniferous trees						1-2 per acre
Beaver	Castor canadensis	Streams and lakes with trees or alders on banks		X	X	?		
Eastern Harvest Mouse	Reithrodontomys humulis	Old fields, marshes, wet meadows						
Deer Mouse	Peromyscus maniculatus	Dry land habitat; forests, grasslands or mixtures						Home range, 1/2 - 3 acres 10-15 per acre
White-footed Mouse	Peromyscus leucopus	Wooded or brushy areas preferred, open areas occasionally						Home range, 1/2 - 1 1/2 acres
Cotton Mouse*	Peromyscus gossypinus	Wooded areas, along streams or bordering fields, swampland						
Golden Mouse*	Ochrotomys nuttalli	Forests, edges of canebrakes, moist thickets, honeysuckle, greenbriar, Spanish moss						
Eastern Woodrat	Neotoma floridana	Rocky cliffs; hammocks, swamps						2-3 per acre
Rice Rat	Oryzomys palustris	Marshy areas, grasses and sedges						
Southern Bog Lemming*	Synaptomys cooperi	Low damp bogs and meadows with heavy growth of vegetation				?		Home range, 1/3 acre up to 35 per acre

Table 2 (cont'd)

Common Name	Scientific Name	Habitat	Economic Status: Hunt	Edible	Furbearing	Pest	Pest Control	Pop. State Potential
Meadow Vole	*Microtus pennsylvanicus*	Low moist areas or grasslands with rank growths of vegetation; near swamps, lakes, streams, occasionally in forests with little ground cover; orchards with grass undergrowth				?		Home range
Prairie Vole	*Microtus ochrogaster*	Open prairies, fence rows, railway right-of-way, old cemeteries, fairly dry places				?		
Pine Vole	*Microtus pinetorum*	Forest floor, orchards				?		
Muskrat	*Ondatra zibethica*	Marshes, edges of ponds, lakes, and streams, cattails, rushes, water lilies, open water			X	?		
Norway Rat	*Rattus norvegicus*	Buildings and rubbish pile				X		Pop. 1 per 5 or 6 people
Black (Roof) Rat	*Rattus rattus*	Buildings, rubbish, occasionally fields				X		
House Mouse	*Mus musculus*	Buildings, rubbish, occasionally fields				X		
Meadow Jumping Mouse	*Zapus hudsonius*	Prefers low meadows, but unrestricted						Scarce Home range, 1/2 - 2 acres

Table 2 (cont'd)

Common Name	Scientific Name	Habitat	Economic Status: Hunt	Edible	Furbearing	Pest	Pest Control	Pop. State Potential
Eastern Cottontail	Sylvilagus floridanus	Heavy brush, strips of forest with open areas, edges of swamps, weed patches	X	X	X			Home range, 3-20 acres 1 per 4 acres
Swamp Rabbit	Sylvilagus aquaticus*	Swamps, marshes, wet bottom-lands	X	X	X			Home range, 11-27 acres
Whitetail Deer	Odocoileus virginianus	Forests, swamps, open brushy areas	X	X	X			Home range, up to 1 sq mile
Masked Shrew	Sorex cinereus*	Moist situations; forests, open country, brushland				?		
Keen Myotis	Myotis keeni	Mine tunnels, caves, buildings, hollow trees, storm sewers, forested areas				?	?	

1. Opossum
2. Raccoon
3. Longtail Weasel
4. Mink
5. River Otter
6. Spotted Skunk
7. Striped Skunk
8. Coyote
9. Red Fox
10. Gray Fox
11. Bobcat
12. Woodchuck
13. Eastern Gray Squirrel
14. Eastern Fox Squirrel
15. Red Squirrel
16. Beaver
17. Muskrat
18. Eastern Cottontail
19. Swamp Rabbit
20. Whitetail Deer
21. Indiana Bat

Figure 8. List of critical mammal species at Fort Knox.

Table 3

Vegetational Composite With List of Mammals

Description: Code: Tree	Herb	Shrub	Description: Verbal	Approximate Acreage	Species Present In This Habitat
IIB1	II4	III	Upland hardwood forest with 75 percent to 50 percent closed canopy, deciduous shrubs with 25 percent to 10 percent crown cover, mixed herbs with 10 percent to absent ground cover	3250	Mammals 1. *Blarina brevicauda* 2. *Myotis lucifugus* 3. *Myotis sodalis* 4. *Myotis subulatus* 5. *Lasionycteris noctivagaus* 6. *Pipistrellus subflavus* 7. *Eptesicus fuscus* 8. *Lasiurus borealis* 9. *Lasiurus cinereus* 10. *Nycticeius humeralis* 11. *Lynx rufus* 12. *Tamias striatus* 13. *Sciurus carolinensis* 14. *Sciurus niger* 15. *Glaucomys volans* 16. *Peromyscus maniculatus* 17. *Peromyscus leucopus* 18. *Odocoileus virginianus* 19. *Myotis keeni*

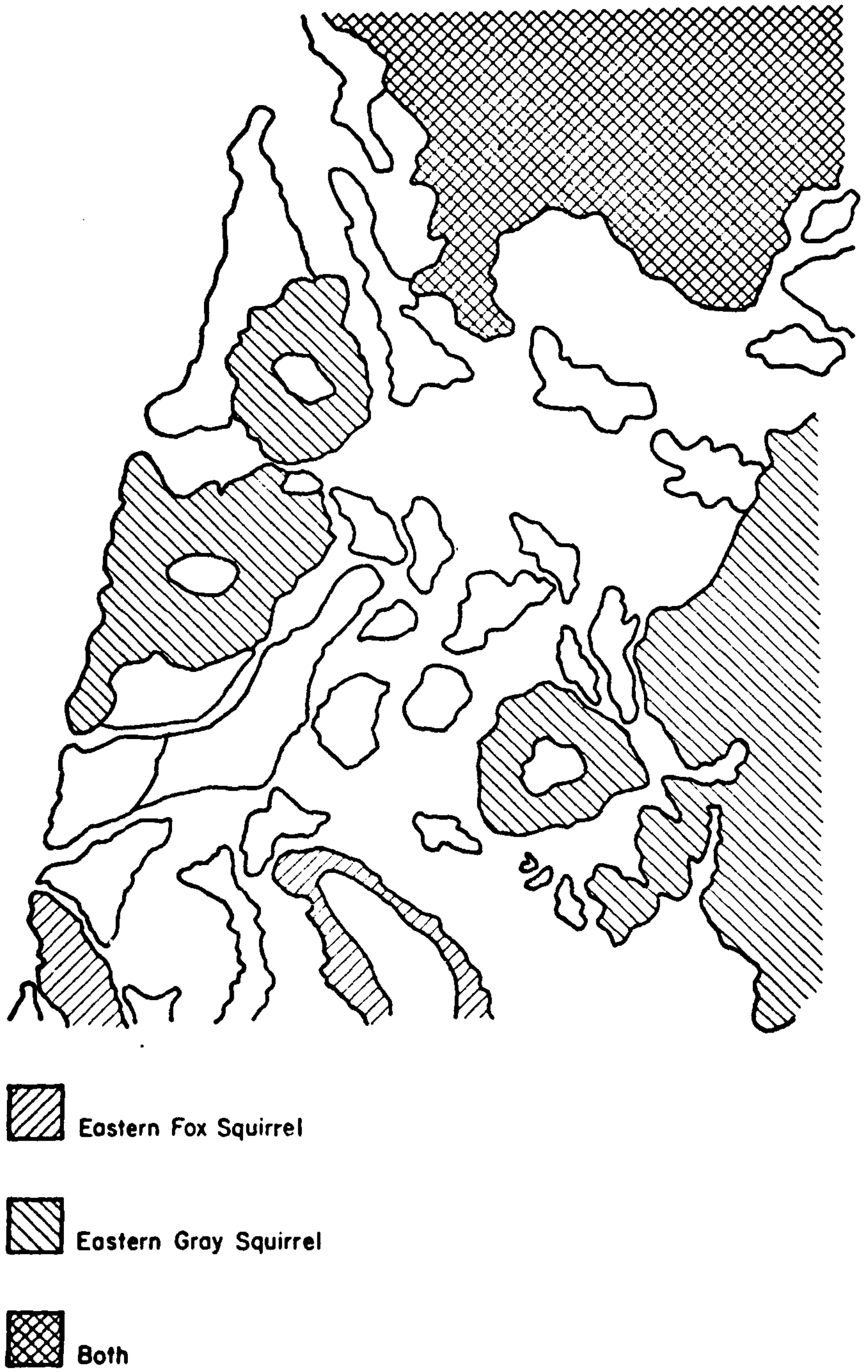

Figure 9. Habitat areas -- squirrel.

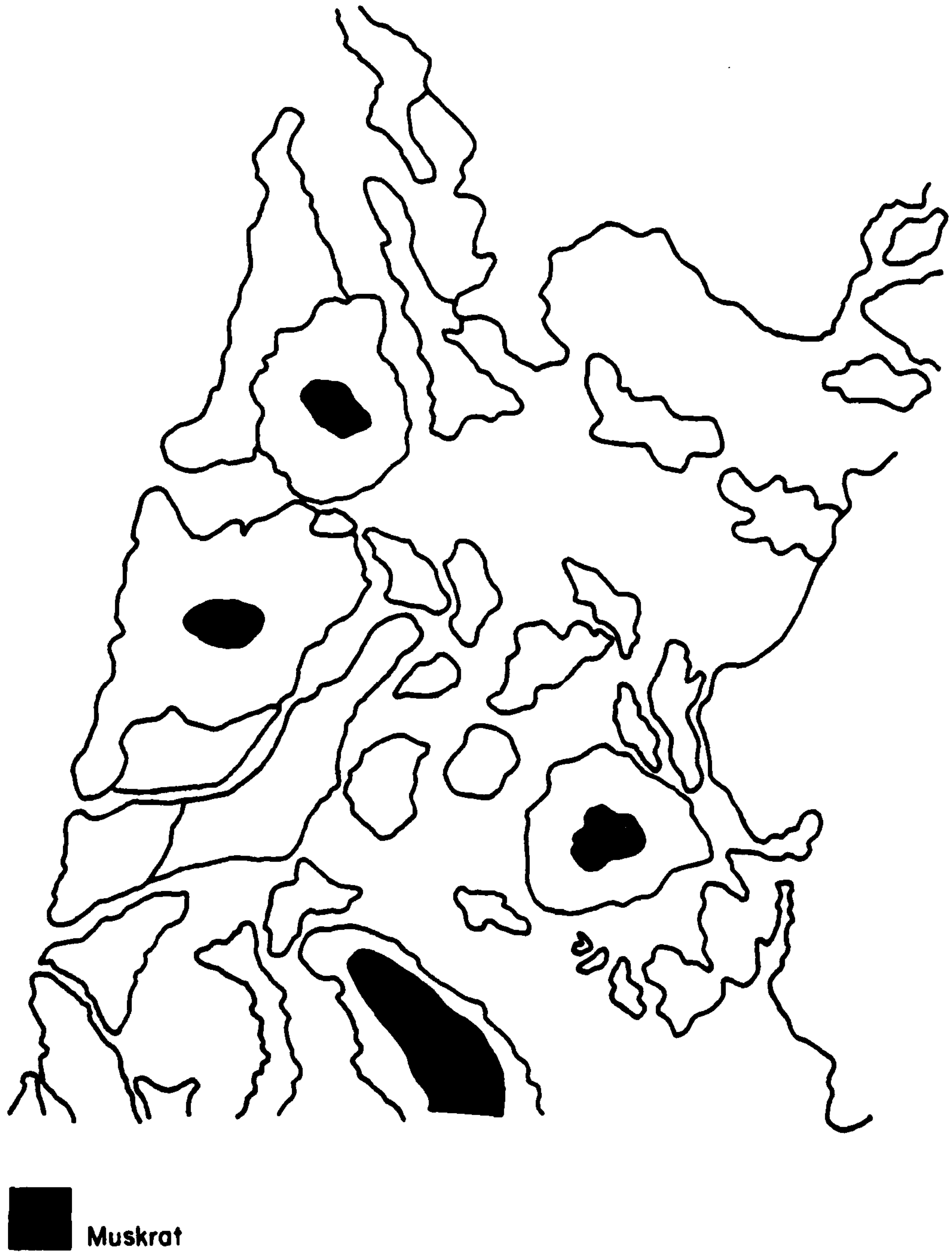

Figure 10. Habitat areas -- muskrat.

1.	Wood Duck	AY	18.	Bald Eagle	W
2.	Turkey	AY	19.	Peregrine Falcon	W
3.	Ruffed Grouse	AY	20.	Canada Goose	M
4.	Bobwhite	AY	21.	Blue Goose	M
5.	Mourning Dove	AY	22.	Snow Goose	M
6.	Pileated Woodpecker	AY	23.	Pintail	M
7.	Common Crow	AY	24.	Gadwall	M
8.	Hooded Merganser	B	25.	American Widgeon	M
9.	American Coot	B	26.	Shoveler	M
10.	American Woodcock	B	27.	Blue-winged Teal	M
11.	Mallard	W	28.	Green-winged Teal	M
12.	Black Duck	W	29.	Red Head	M
13.	Ring-necked Duck	W	30.	Canvasback	M
14.	Common Goldeneye	W	31.	Greater Scaup	M
15.	Bufflehead	W	32.	Lesser Scaup	M
16.	Common Merganser	W	33.	Ruddy Duck	M
17.	Red-breasted Merganser	W			

Figure 11. Critical bird species at Fort Knox.

Other Birds. These species should be organized by habitat; no mapping is necessary at this stage. Each species should be cross-referenced -- as were mammals in Table 3 -- with the various types of vegetational characteristics of the installation. This can be done by first completing Table 2 for birds. In addition to the information presented in Table 2, the residency for each species should be indicated as it was with the game, rare, endangered, and threatened species.

Other Animals

All other animals (reptiles, amphibians, insects, other invertebrates) should follow the same format as outlined for mammals. Most groups in this category do not require extensive mapping or documentation (for the purpose of this report) since, except for insects, they do not contribute greatly to the trophic structure of terrestrial ecosystems. Furthermore, other groups previously dealt with are equally indicative of environmental and/or habitat conditions. Nonetheless, it should be noted that these groups are important to communities in which they reside, and if lost or impacted, could disrupt the community and trophic structure. For example, the impact of insects is important because they alone consume more vegetation than all other organisms.

3 STAGE II. VERIFICATION OF TERRESTRIAL BIOTA

The results of Stage I should yield a composite picture of the potential biota and habitat of the installation. The material gathered should be more accurate and reliable than existing information unless that information was obtained through actual field investigations.

Stage II, which is designed to verify the information gathered in Stage I, entails some field work. If Stage I indicates that a specific area is a hardwood, upland forest with a 75 to 50 percent closed canopy, a 25 to 0 percent shrub crown, an absent herb cover, and is inhabited by various animals, Stage II should verify such information. The vegetation information and the presence of large mammals, birds, some small mammals (squirrels, chipmunks, rabbits, etc.), some reptiles, and some amphibians can be verified by "cruising." Cruising requires making observations while taking a brief walk through the area. Verification of other parameters might involve a "one shot" collection of floral and faunal organisms. If such specimens are collected, it may be advisable to preserve these organisms for future reference or as voucher specimens. The results of Stage II yield a product that both verifies the types of habitat on that installation, and identifies, by habitat, the species of organisms existing on that installation. It would be easy to determine, for example, how many acres of forest edge exist, how many acres of suitable deer habitat, or how many acres of Redwinged Blackbird habitat are available.

Since most of this field work consists of "cruising" and spot checking information, it should not be necessary to visit all portions of the installation during this stage. Once several areas of each type of habitat have been checked for accuracy of those plant and animal parameters previously mapped, it can be assumed that Stage I resulted in a reasonably accurate characterization of similar habitats. The only exception to this assumption is if rare, endangered, or threatened species are discovered during the verification process, then all similar areas should be examined for the presence of such species.

Biotic parameters can be verified simultaneously for all plants and animals to reduce the effort required to complete Stage II. The following are suggested procedures for the verification process.

Species Familiarization

The individual(s) conducting the field investigation should become familiar with species that may be present on the installation. Before investigators go to the field, reference materials including items such as Peterson Field Guide Series or Golden Guide Series should be consulted (these and other references are listed in Appendix A). Equipment necessary is:

1. Mouse traps, rolled oats, peanut butter.

2. Binoculars.

3. Various sizes of sweep nets.

4. Plastic bags (for plants and dead animals); cloth bags for live animals); jars with a preservative, either alcohol or formaldehyde (for invertebrates).

5. Pruning shears.

6. Trowel.

7. Light traps.

8. Fly paper.

Site Selection

The site to be surveyed should be chosen from the maps previously completed on potential habitat and biota. Initially, such an area should be one whose habitat type is one of the most common on the installation.

Field Survey

Boundary Verification

The habitat of the site should be recognizable, and investigators should drive along or walk the boundary of the habitat. The boundary, as it actually appears in the field, should be compared to that determined by use of topographic maps and aerial photographs in Stage I. Any significant deviations from the mapped areas should be corrected.

Survey Transect Determination

Personnel can verify biotic parameters by walking along line transects plotted through the area. Transects should be determined with the aid of a compass because no transects should cross each other. The number of transects that should be surveyed per unit area can be determined by the following methods (see Figure 12):

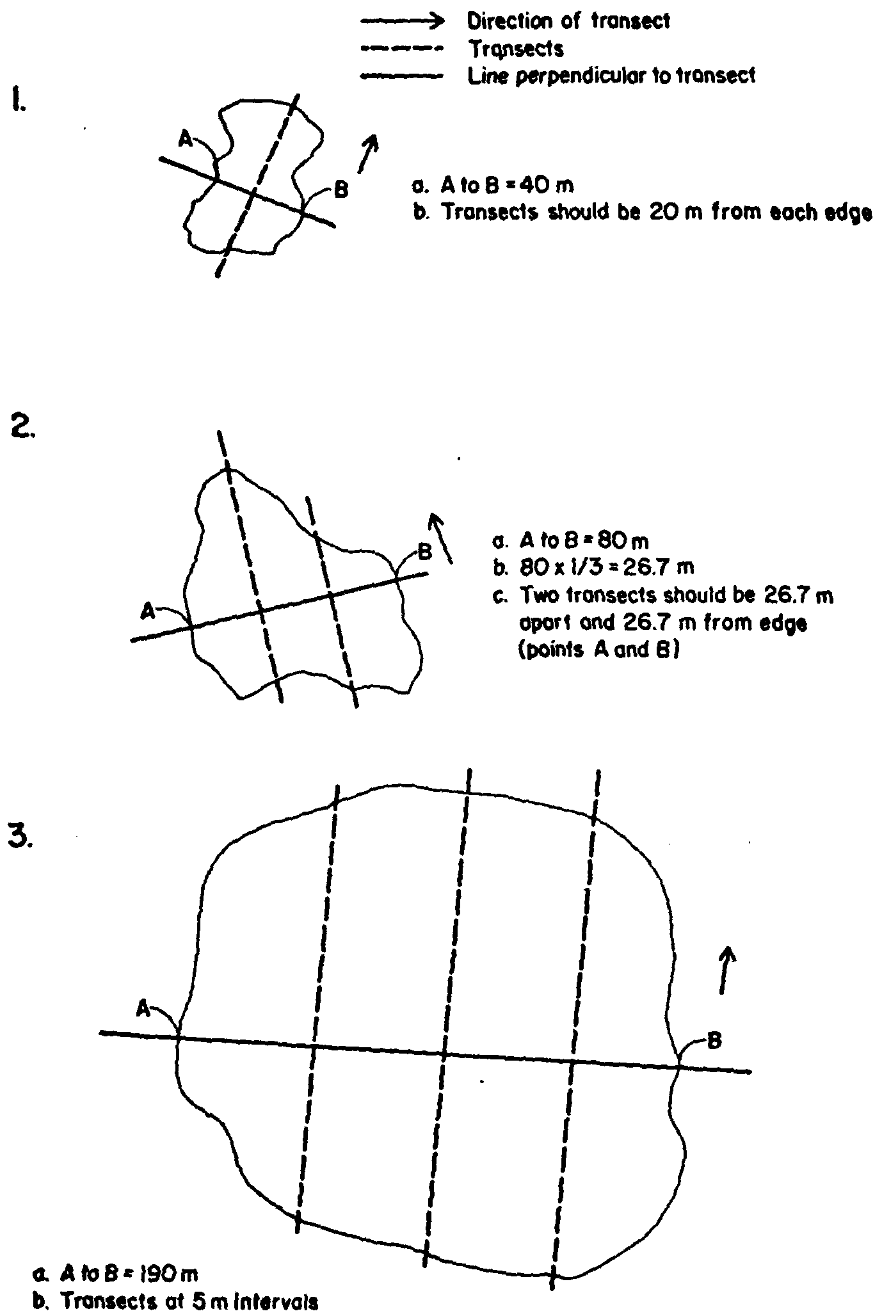

Figure 12. Survey transect determination.

1. Determine the direction of the transects. It is irrelevant whether the long or short axis is used to initiate the transects.

2. Estimate the length of the longest line that could be drawn perpendicular to the transects and still remain inside the area.

3. If the line is:

a. 50 m or less, use one transect through the center of the area (plot 1, Figure 12).

b. 50 to 100 m, use two transects at intervals of one-third the length of the line. For example, if the line is 75 m long, the first transect should be 25 m from one edge, and the second transect should be 25 m from the first and 25 from the opposite edge (plot 2, Figure 12).

c. Over 100 m, use a minimum of two transects, and transects can be set at up to 50-m intervals (plot 3, Figure 12).

Biotic and Habitat Verification

The parameters discussed below should be estimated for each transect. Upon completion of all transects, the information should be compiled and summarized. This information should then be compared with that obtained in Stage I and a more accurate characterization formulated.

1. Vegetation.

a. Trees.

(1) Tree Types: percentage of evergreen and hardwood.

(2) Canopy Closure: percentages.

(3) Aquatic Relationship: upland, bottomland, riparian, marsh/swamp, arid/semi-arid.

(4) Tree Species: record recognizable species and obtain samples of those that are unidentifiable. Samples should be taken by clipping a branch that has a terminal bud and several leaves.

b. Shrubs.

(1) Shrub Types: percentage of evergreen and deciduous.

(2) Crown Cover: percentage.

(3) Shrub Species: record recognizable species and obtain samples of those that are not. Samples should be taken by clipping a branch that has a terminal bud, several leaves, and a flower and/or fruiting body, if available.

c. Herbs.

(1) Herb Types: percentage of monocots (grasses) and dicots (broad-leaf).

(2) Ground Cover: percentage.

(3) Matting: approximate thickness.

(4) Herb Species: record recognizable species and obtain samples of those that are not. Samples should be taken by collecting the entire plant including the root system and flower or fruiting body, if available.

d. Algae, Fungi, and Lichens: record recognizable species and obtain samples of those that are not. Samples should be taken by collecting the entire plant.

e. Rare, Endangered, or Threatened Plant Species: record those species present and plot their approximate location and numbers of individuals on overlays. Do not collect samples, clippings, or disturb the plant in any way.

2. Animals.

a. Mammals.

(1) Visual Sighting Along Transect: record all species that are recognizable.

(2) Tracks.

(3) Scat (droppings).

(4) Collection: it is necessary to collect small mammals because the secretive habitats of most rodents, shrews, moles, and bats do not allow visual identification. About 25 traps per hectare (2.47 acres) should be used, and traps should be flagged and placed near the transect line so that they can be found easily. Snap traps baited with a mixture of rolled oats and peanut butter can be used for the rodents and shrews. Mist nets and mole traps should be used for bats and moles. If gophers may be present, gopher traps will be required. All traps and nets should be set overnight and the specimens collected the following morning. Mist nets should be set at dusk and recovered shortly before dawn so as not to collect birds.

b. Birds.

(1) Visual Identification.

(2) Vocal Identification.

(3) Other Signs: some birds may be identified on the basis of tracks (turkey, pheasant). Owl pellets should be looked for and be examined by teasing them apart and looking for identifiable animal remains. Some field guides can aid in identification, or the remains can be sent to the museums or specialists listed in Appendix B.

c. Reptiles and Amphibians.

(1) Visual Identification.

(2) Collection: sweep nets can be used to collect specimens.

d. Insects and Other Invertebrates.

(1) Visual Identification When Possible.

(2) Collection: sweep nets, light traps, fly paper, litter samples can be used. Rocks, logs, and other debris can be turned over.

e. Rare, Endangered, or Threatened Animal Species: these animals should not be disturbed but should be identified and their approximate locations plotted on overlays. Numbers of individuals and precise habitat should be recorded.

Specimen Collection

1. Care should be taken that all Federal, State, and local regulations are followed. Permits may be necessary for collecting some groups of organisms.

2. Identify as many specimens as possible by using guides in the literature. This identification will be useful in later surveys.

3. Submit unidentified specimens to specialists for identification. Sources of specialists are academic institutions and various museums (Appendix B).

4. Maintain a reference collection to eliminate the need of outside expertise at a later date. Most field guides include sections on methods of collection and preservation (see Appendix A).

Other Methods of Verification

1. Special trips to the field need not be made to complete most of Stage II. An investigator could gather information, for example, while traveling around the installation on other duties.

2. Groups such as the Audubon Society, Boy Scouts, and Girl Scouts may be willing to aid in this stage if given adequate guidance.

3. Academic institutions may be willing to help or conduct the study for a fee.

4. Information may be checked against that available in installation files from any previous surveys or preparation of EA or EIS.

4 STAGE III. QUANTIFICATION OF TERRESTRIAL BIOTA

Stage I provided rough estimates of the quantity of various habitats, their locations on the installation, and the potential species of plants and animals in each habitat. Stage II verified the information obtained during the first state and also presented information on relative population levels. The sampling techniques described in Stage II are designed to discern population diversity and place less emphasis on density.

Stage III involves the explicit documentation of population densities and other ecological parameters of the various organisms on the installation. Therefore, Stage III provides direct quantification of the amount of biota on the installation. This quantification is done by calculating the biomass or number of individuals present in a unit area of habitat. For example, if an installation contains 100 acres of forest edge, which in turn supports one deer per 4 acres, the result would be 25 deer inhabiting forest edge. When deer populations in other habitats are determined, the size of the deer herd can be approximated. In preparing an EA/EIS, this information would be valuable because if the amount of each type of deer habitat to be impacted is determined, then the impact on the total deer herd also can be judged.

Site Selection

An area should be chosen for survey from maps completed in Stages I and II on potential habitat and biota. It may be desirable to choose several areas of different potential to be surveyed simultaneously because examination of habitats (plants, birds, mammals, etc.) can be conducted in several areas without difficulty. Initially, such areas should be those whose habitat types are the most common on the installation. This allows maximum use of available funds and maximum benefit per unit of effort -- a critical point since field surveys are generally the most expensive item of environmental studies.

Vegetation

All vascular vegetation should be sampled in each basic type of habitat noted in Stage II. Vascular vegetation is divided into two working units: (1) woody plants greater than 2 m in height, and (2) herbaceous and woody plants less than 2 m in height.

Sample Point(s) Determination

Most vegetation sampling is conducted at points along transects, which need to be randomly determined as in Stage II. The number of sampling points required is based on the approximate acreage to be included in the study site. It is necessary to take at least 10 (20 is preferable) samples per unit, regardless of size. The following guide should be used for determining the number of sample points:

1. 0 to 40 acres (0 to 16 hectares) = one point per acre (0.5 hectare).

2. 41 to 80 acres (16 to 32 hectares) = one point per 2 acres (1 hectare).

3. 81 to 200 acres (32 to 80 hectares) = one point per 4 acres (1.6 hectares).

4. Over 200 acres (80 hectares) = one point per 10 acres (4 hectares).

Woody Vegetation Greater Than 2 m in Height

The prism method of forest sampling is the best available because of its accuracy, ease of use, reduced field time, and reduced manpower expenditure. Although techniques for using this method are discussed in Appendix C, several points can be made here to supplement that information.

1. Transects along which sample points are to be selected should be chosen randomly.

2. Samples should be taken so that trees counted at one sampling point are not counted with those of a nearby point. This problem can be solved by using a different size (diopter) prism or by separating sample points and/or transects by a greater distance.

3. Data should be taken as in the following example:

The forest to be surveyed is approximately 63 acres in size; therefore, investigators will have to take 65 ÷ 2 = 32.5 or 33 samples. The transect is selected as a random compass direction and 25 m chosen to separate sample points. Table 4 gives sample data on the number of each of 14 species of trees at the 33 separate sampling points.

4. Calculation following the guidelines in Appendix C yields the following results:

a. 33 points, total count 141, prism factor 27.62.

b. 141 = 4.273 X 27.62 = 118 sq ft (12 m^2) of basal area per acre (0.5 hectare).

c. Results should be tabulated as in Table 5.

Table 4

Trees' Basal Area

Sample Point	Species 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Totals
1	1		2							1					4
2		1					1		2			1			5
3						1					2				3
4			2	1											3
5					3				2						5
6	1					1								1	3
7		1		1					1				1		4
8	2		1			2									5
9		1			2			1							4
10										1	1	1	1		4
11				2				2	1						5
12		2					2							1	5
13	1		2			1									4
14					1						2		2		5
15									1			1		2	4
16							2			2	1				5
17	2	1	1												4
18		1	2	1											4
19			2	1	1	1									5
20							4								4
21									1		1	1		1	4
22	1	2				1									4
23		1					2				1		1		5
24				1						1				2	4
25	2				1			1							4
26		1			2		3								6
27								3		2					5
28		1													1
29			2			1		1		1			1		6
30	2				2										4
31	1		1		1			1							4
32		2								2				1	5
33			1		1		1					1			4
Totals	13	14	16	7	14	8	15	9	8	10	8	5	6	8	141

Table 5

Basal Area Results

Species	Total Count	Average Count	Basal Area/Acre (0.5 Hectare)
1	13	0.394	10.88
2	14	0.424	11.71
3	16	0.485	13.40
4	7	0.212	5.56
5	14	0.424	11.71
6	8	0.242	6.68
7	15	0.455	12.57
8	9	0.273	7.54
9	8	0.242	6.68
10	10	0.303	8.37
11	8	0.242	6.68
12	5	0.152	4.20
13	6	0.182	5.03
14	8	0.242	6.68

Vegetation Less Than 2 m in Height

A circle whose radius is 1/1000 of an acre (44.68 in. or 113.5 cm) should be plotted at each sampling point used for trees. All vegetation within this area must be identified, and an estimate of cover diameter, the percentage of cover of the plot, and the number of stems within the plot must be recorded (Table 6). The results should be tabulated in Table 7. Appendix D outlines additional methods of vegetation sampling.

Mammals

Although game species and furbearers such as deer, rabbits, and tree squirrels may be of more interest to the general public, small mammals -- primarily mice, rats, and shrews -- yield more statistically significant data. These mammals are the easiest to collect and allow for a study of short duration. Their relatively small home ranges and high densities of individuals permit such studies to be conducted on small areas and uniform habitat.

There are two generally accepted methods of studying the population densities of small mammals. One involves permanently removing the animals from the site (capture-removal) and the other does not (capture-recapture). Considerable controversy exists over which of these methods is more accurate, and over whether the advantages or disadvantages of one sufficiently outweigh those of the other.

Table 6

Vegetation Less Than 2 Meters in Height -- Raw Data

Species (crown diameter/cover %/number of stem)

Sample Points	1	2	3	4	5	6	7	8	9	10	11
1	9/60/4	9/20/7	8/50/3	.	.	.					
2											
3											
4											
5											
5											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
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20											
21											
22											
23											
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
Totals											

Table 7

Vegetation Less Than 2 Meters in Height -- Results

Species	Cover	Frequency	Density
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
.			
.			
.			
.			
.			
N			

Cover = average % of sample plot crown cover
Frequency = % of occurrence in sample plot
Density = average number of stems per sample plot

Capture-removal allows for quicker analysis of population densities, but in turn results in less data, loss of the animals to the population, and a slightly reduced level of accuracy. However, capture-recapture will be explained here since it can provide more information than capture-removal and does minimal damage to existing populations.

The site chosen for capture-recapture should have at least a 1-hectare study grid with a 25-m buffer area surrounding the grid in which the habitat is similar to the study grid. This will reduce the probability of immigration and emigration of small mammals. The area of the grids should be inspected for the presence of large mammals (domestic and endemic) that might disturb the study by eating the bait, eating the specimen, or otherwise reducing the accuracy of the data collected. The area should be inspected for the relative population densities of insects, particularly ants, that may remove bait, trip traps, or damage specimens. If there are many ants, alternate methods of trapping and the timing of running the traps can be implemented (see Appendix D). The following paragraphs provide additional details on using the capture-recapture method.

Equipment

1. Folding live traps per grid: 121.

2. Flags on wire per grid: 121.

3. Peanut butter and oatmeal or cracked corn.

4. Metric scales in 1-gram units.

5. Scissors or toenail clippers.

6. Rapidiograph and permanent ink.

7. Data cards: 5 in. x 8 in. (Figure 13).

8. Cloth sack, sock, or stocking.

9. Bulk cotton: enough to supply nest material in traps.

10. Leather gloves: usually not necessary if handler is experienced.

11. Quart jars with alcohol or formaldehyde to preserve those few specimens that die in traps or during handling.

Clip Number________	Recapture Yes No
Species________	Data________
Sex________	Weight________
Grid________	Grid Coordinates_____
Reproductive Condition________	
Weather Conditions________	

Figure 13. Data card.

Methods

For each habitat, a 100-m by 100-m test grid and control grid should be used. The grid need not be square but must total 10 000 m^2; see Appendix G for an example of such a grid. The grid should be set up with the flags placed at 10-m intervals, and each flag should be labeled with its particular grid coordinates (for example, A1 or B3 in the grid from Appendix G); this will allow ready identification of grid coordinates during the actual survey period. A trap should be set within a meter of each flag. Each grid should be run in the mornings to reduce the animals' exposure.

When running each grid, all information on the data card should be completed. Assign a number to the captured specimen, and clip its toes as described below so it can be identified by that number. Since animals have four toes on a paw, for this identification system each toe has the following number:

<u>Left Front Paw</u>	<u>Right Front Paw</u>
1, 2, 4, 7	10, 20, 40, 70
<u>Left Rear Paw</u>	<u>Right Rear Paw</u>
100, 200, 400, 700	1000, 2000, 4000, 7000

Thus, specimen number four would have only the "four" toe on the left front paw clipped; specimen number nine would have the seven and two toes clipped; specimen 563 would have the 400 and 100, 40 and 20, and two and one toes clipped.

Toes should be clipped cleanly at the base; this should be done consistently to preclude misidentification at a later date due to natural injury. Furthermore, even though an animal has been collected previously, all information should be recorded. This will help verify identification as to species and sex, and will produce data on growth rates and changes in reproductive condition. After the animal's toes are clipped and all pertinent data are recorded, the animal can be released.

Data Management

Cards should be filled out for each individual for each time it is captured. Cards should be maintained by species and by number (toe clip number) within each species.

Analysis of Data

Population Density in Number of Each Species per Hectare (10 000 m^2). A table similar to Table 8 should be formulated for each species on each grid. Once the estimated population has leveled off (at 145 in Table 8, for example), the results tabulated after this point should be averaged. Since the grid size is 1 hectare, the results will be in individuals per hectare.

Biomass per Hectare for a Species. The weight of all individuals of each species for each grid should be averaged.

This average weight should then be multiplied by the estimated population figure determined previously. For example, the population density in Table 8 was 148.9 individuals per hectare. If the average weight was 26.8 g, then 148.9 X 26.8 = 3990.52 g/hectare.

Home Range Size. This portion of the analysis is based on only those individuals that were recaptured. A card showing the grid coordinates should be produced for each individual, with all points marked where the individual was recaptured. In Appendix G, for instance, three recapture points are indicated for specimen 32, three for specimen 81, and so on.

Table 8

The Schnabel Method of Estimating Populations*

P Period (date)	A Number Trapped	B Marked Number Marked	Marked Animals in Areas	(A)x(B)	(A)x(B) Sum	Recaptures	C Sum of Recaptures	$\frac{(A)x(B)}{(C)}$ Estimated Population
1	4	4	--	00	0	--	--	--
2	4	4	4	16	16	0	0	--
3	2	2	3	16	32	0	--	--
4	6	6	10	60	92	0	--	--
5	10	7	16	160	252	3	3	--
6	4	4	23	92	344	0	3	--
7	8	6	27	216	560	2	5	--
8	4	2	33	132	692	2	7	--
9	5	4	35	175	867	1	8	--
10	7	6	39	273	1140	1	9	--
11	7	6	45	315	1455	1	10	145
12	9	7	51	459	1914	2	12	159
13	6	3	58	348	2262	3	15	150
14	10	6	61	610	2872	4	19	151
15	8	5	67	536	3408	3	22	154
16	6	1	72	432	3480	5	27	143
17	4	2	73	292	4132	2	29	142
18	12	7	75	900	5032	5	34	148
19	8	4	82	656	5688	4	38	149

* Table B-8, "The Schnabel Method of Estimating Populations," p 718 in Ecology and Field Biology, Second Edition by Robert Leo Smith.

To determine the home range of each individual, the areas should be circled -- as in Appendix G -- by using the median between two grid coordinates as the average distance an animal would travel toward the next station. The area within the enclosed area is measured using planimetry or the quadrat method, for example. Then average home range for every species is determined by adding the area of home range for individuals of the species and dividing that total by the number of individuals. Care must be taken that the home ranges for the sexes are determined separately since males usually have a significantly larger home range.

Breeding Condition. The number of pregnant females, parous females, lactating females, nonreproductive females, scrotal males, and nonscrotal males of each species for each grid should be determined along with sex ratios.

Results

1. The information for each of the four points discussed in *Analysis of Data* should be recorded and organized so that it is easily retrievable -- whether by card file or computerized system.

2. Basic habitats on the installation should be compared, taking into account the four points treated under *Analysis of Data*. These comparisons are to produce concise, written evaluations of the habitats -- evaluations that should be readily available for use by those making decisions on the environmental impact of U.S. Government actions.

Birds

Birds, being both highly mobile and highly territorial, are very responsive to habitat changes. The major problem in studying bird populations, is the identification of species. Studies on birds must usually be conducted without handling the specimens, which must be identified from a distance by sight or sound. The expertise needed to do this is extensive, and a considerable amount of previous field experience is required, usually several years or more. A second problem is the timing of the survey. The survey must be conducted during the breeding season, when territories are defended. Population estimates are most feasible at this time because birds are both quite vocal -- and thus easily located and identified by their calls -- and active, making visual identification easier than at other times. The last problem is that sites must be relatively large (10 to 25 hectares) in order to obtain significant amounts of data.

Two techniques -- actually variations on one method -- are commonly used for studying bird populations. The more accurate technique involves using mist nets to trap birds. The mist nets are set up within the study area, run every mid-morning, and not reset until late evening (after dark) so the birds will not be held in the nets overnight. Birds removed from the nets are identified and banded with a series of variously colored leg bands so that the individuals can be positively indentified in the field with the aid of binoculars. Paint is sometimes put on the feathers instead of, or in addition to banding.

How can leg banding aid the accuracy of the data? If, for instance, each individual could be identified in the example described in Appendix H, a number of questions could be answered. Were the individual Cardinals, Blue Jays, and Carolina Wrens recorded near the periphery of their territories residents? Was the transient Blue Jay the male from one of the territories? Were some of the transient Redwinged Blackbirds and Grackles actually nonbreeding residents? Such information clearly could add to the data's specificity.

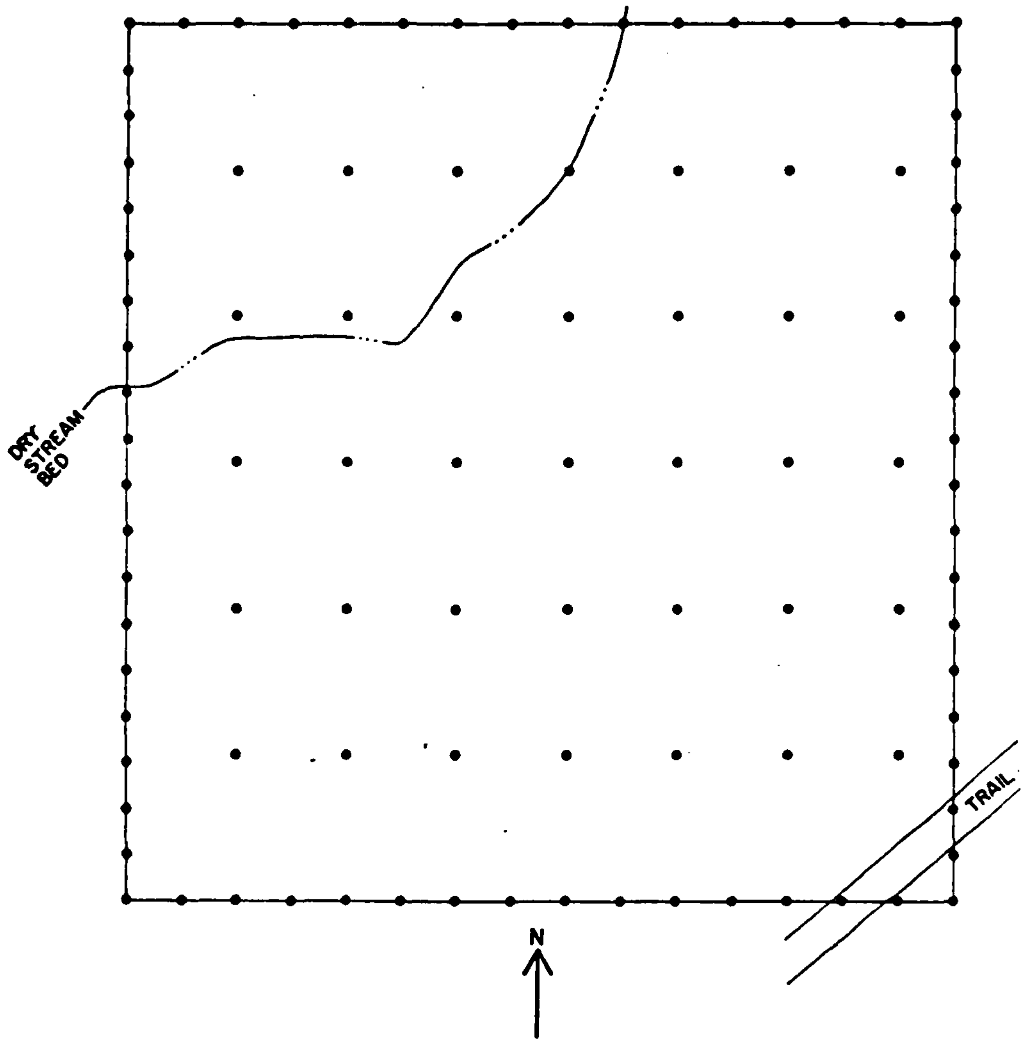
Trapping, collecting, or any other handling of migratory birds requires both State and Federal permits. It should be pointed out that these permits are usually very difficult to obtain, although this difficulty may be lessened because this study is essential in producing EA and EIS, and because a Governmental agency is conducting the study. Banding is not absolutely necessary, however; and the rest of this discussion deals with the technique that does not require permits and does not include banding the birds or any other handling procedures.

This technique requires sites that are a minimum of 10 hectares (24.7 acres). The maximum size the grids could be is 20 hectares (approximately 50 acres) in forested areas, and 30 hectares (approximately 75 acres) in open fields when only one person will be conducting the observations.

Sites may be flagged at even intervals along the periphery of the grid. Colored flagging should be used so that the observer can determine a specific location on the grid at a glance. The interior of the grids should be similarly flagged. A scale drawing of each grid should be made (Figure 14) with the flagging, compass direction, and other major features -- such as roads, trails, streams, and topography -- properly placed. Copies of this map should be made so that one can be used for each period of field observation and one can be used to compile observations on each species separately at the end of the study.

The field observations should ideally be conducted during five or six survey periods of 5 days each. For the central United States the intervals are as follows:

Number of Survey Periods	Month
1	late April
1	mid May
2 or 3	June
1	mid July



Grid:
Date:
Weather:
Time: In Out
Total Hours:

Figure 14. Grid for field observations.

Studies in the southern part of the United States should be conducted about a week earlier than this guide suggests, and in the northern part about a week later than the guide suggests. This estimated variation probably would be sufficient, although the timing should be more accurately determined before beginning the field expedition by reviewing the literature on breeding activity in that portion of the United States. Each survey period should include a minimum of five repetitions of observations per grid, although 10 repetitions is preferable.

During each period all sites should be surveyed. The best time for surveys is in the early morning from daybreak until about 4 hours later; this is when most species are active and defending their territories. A secondary observation period exists for approximately 4 hours before nightfall. Birds are less active during this period than during the early morning, but they are active enough so that data can be collected. Since all areas cannot be surveyed simultaneously, it is best to alternate by studying one grid in the morning and another grid in the late afternoon during one day and then reversing observation periods the next day.

Day-to-day field observations should be conducted using the following guidelines. Each day's observations should be recorded on the map of the grid like that in Appendix H. The time of the observations and the total hours should be recorded along with the weather conditions. During the observations, the grids should be traversed at 100-ft (30-m) intervals, and the following information on each bird seen should be recorded on the map:

1. Species.

2. Sex.

3. Age: adult or young.

4. Behavior: feeding, roosting, flying, vocalizing, territorial dispute, etc.

5. If individual is moving, both direction and distance of flight should be recorded.

6. Active nests should be recorded.

7. All locations plotted on the map should be recorded as precisely as possible.

If time permits during the course of the field observations, investigators should try to force male birds off their territory. This can be done by walking towards the bird until it takes flight and finally doubles back. The point at which it doubles back is generally assumed to represent the border of its territory.

Upon completion of all survey periods, a composite map of each different species should be made. By examining the distribution of observation points, it should then be determined if individuals were maintaining a defended territory on the grid, or if they were unmated individuals or transients. The number of individuals of each species then can be determined by examining the number of mated pairs, number of territories being defended, or number of active nests. Appendix H describes how field observations on birds should be recorded and analyzed.

5 CONCLUSIONS AND RECOMMENDATIONS

The guidelines in this document will enable installations to compile and maintain information on terrestrial biota -- information needed to perform environmental assessments/environmental impact analyses. Since technician-level personnel at the installation, rather than consultants, can collect data over a period of time, the procedures are economical, and in addition provide detailed information on terrestrial ecosystems. Similar guidelines should be prepared for aquatic ecosystems and other specific ecological topics.

APPENDIX A:

SELECTED LITERATURE REFERENCES

This appendix contains approximately 1300 literature citations.

APPENDIX A CONTENTS

APPENDIX A CONTENTS (Cont'd)

1. Ecological Survey Techniques

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Utah

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Vermont

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Virginia

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APPENDIX B:

LIST OF MUSEUMS AND SPECIALISTS

Alabama

1. Alabama Department of Conservation and Natural Resources
   Game and Fish Division
   64 Union Street
   Montgomery, Alabama 36104

2. University of Alabama
   Museum of Natural History
   University, Alabama 34586

3. University of South Alabama
   Natural History Collection
   Mobile, Alabama 36688

Alaska

1. Alaska Department of Fish and Game
   Division of Game
   1300 College Road
   Fairbanks, Alaska 99701

2. Naval Arctic Research Laboratory
   Barrow, Alaska 99723

3. University of Alaska Museum
   Fairbanks, Alaska 99701

Arizona

1. Department of Zoology
   Arizona State University
   Tempe, Arizona 85281

2. Grand Canyon National Park
   Box 129
   Grand Canyon, Arizona 86023

4. Northern Arizona University
   Museum of Vertebrates
   Box 5640
   Flagstaff, Arizona 86001

5. Southwestern Research Station
   Portal, Arizona 85632

6. Department of Biological Sciences
   University of Arizona
   Tuscon, Arizona 85721

Arkansas

1. Division of Biological Sciences
   Arkansas State University
   State University, Arkansas 72467

2. Zoology Department
   University of Arkansas
   Fayetteville, Arkansas 72701

3. Arkansas Game and Fish Commission
   Game and Fish Building
   Little Rock, Arkansas 72201

California

1. California Academy of Sciences
   Golden Gate Park
   San Francisco, California 94118

2. San Diego Natural History Museum
   Balboa Park
   P.O. Box 1390
   San Diego, California 92112

3. United States Forest Service, San Joaquin Experimental Range
   Coarsegold, California 93614

4. Museum of Vertebrate Zoology
   University of California
   Berkeley, California 94720

5. Museum of Wildlife and Fisheries Biology
   University of California
   Davis, California 95616

6. Los Angeles County Museum
   Los Angeles, California

Colorado

1. University of Colorado Museum
   University of Colorado
   Boulder, Colorado 80302

2. U.S. Bureau of Sport Fisheries and Wildlife
Denver Collection of the Bird and Mammal Laboratories
Building 45
Federal Center
Denver, Colorado 80225

3. Department of Zoology and Entomology
Colorado State University
Fort Collins, Colorado 80521

4. Denver Museum of Natural History
City Park
Denver, Colorado 80205

Connecticut

1. Museum of Natural History
University of Connecticut
Storrs, Connecticut 06268

2. Peabody Museum of Natural History
Yale University
New Haven, Connecticut

Delaware

1. Delaware Museum of Natural History
P.O. Box 3937
Greenville, Delaware 19807

2. Department of Entomology and Applied Ecology
University of Delaware
Newark, Delaware 19711

District of Columbia

1. National Museum of Natural History
Smithsonian Institute
Washington, DC 20560

Florida

1. The Florida State Museum
University of Florida
Gainesville, Florida 32611

2. Archbold Biological Station
Rt. 2
Box 380
Lake Placid, Florida 33852

3. Biology Department
   University of South Florida
   Tampa, Florida 33620

4. Tall Timbers Research Station
   Rt. #1
   Box 160
   Tallahassee, Florida 32303

Georgia

1. Museum of Vertebrate Zoology
   University of Georgia
   Athens, Georgia 30602

Hawaii

1. Bernice P. Bishop Museum
   Box 6037
   Honolulu, Hawaii 96818

Idaho

1. Department of Biology
   Idaho State University
   Pocatello, Idaho 83201

Illinois

1. Field Museum of Natural History
   Chicago, Illinois 60605

2. Illinois Natural History Survey
   University of Illinois
   Urbana, Illinois 61801

3. Illinois State Museum
   Springfield, Illinois 62706

4. Museum of Natural History
   University of Illinois
   Urbana, Illinois 61801

5. Cooperative Wildlife Research Laboratory
   Southern Illinois University
   Carbondale, Illinois

Indiana

1. Joseph Moore Museum
   Earlham College
   Richmond, Indiana 47374

2. Wildlife Laboratory Collection
   Department of Forestry and Conservation
   Purdue University
   Lafayette, Indiana 47907

3. Department of Life Sciences
   Indiana State University
   Terre Haute, Indiana 47800

Iowa

1. Museum of Zoology
   Iowa State University
   Ames, Iowa 50010

2. Museum of Natural History
   University of Iowa
   Iowa City, Iowa 52240

Kansas

1. Museum of the High Plains
   Fort Hays Kansas State College
   Hays, Kansas 67601

2. Museum of Natural History
   University of Kansas
   Lawrence, Kansas 66045

Kentucky

1. School of Biology
   University of Kentucky
   Lexington, Kentucky 40506

Louisiana

1. Museum of Zoology
   Louisiana State University
   Baton Rouge, Louisiana 70803

2. Systematic and Environmental Biology Laboratory
   Herbert Center
   Riverside Research Laboratories
   Route 1
   Box 46-B
   Belle Chasse, Louisiana 70037

Maine

1. School of Forest Resources
   University of Maine
   Orono, Maine 04473

Massachusetts

1. Museum of Comparative Zoology
   Harvard University
   Oxford Street
   Cambridge, Massachusetts 02138

2. Department of Forestry and Wildlife Management
   University of Massachusetts
   Amherst, Massachusetts 01002

3. Museum of Zoology
   University of Massachusetts
   Amherst, Massachusetts 01002

Michigan

1. The Museum
   Michigan State University
   East Lansing, Michigan 48823

2. Museum of Zoology
   University of Michigan
   Ann Arbor, Michigan 48104

3. Museum of Natural History
   Wayne State University
   Detroit, Michigan 48202

Minnesota

1. The Science Museum of Minnesota
   30 E. Tenth
   St. Paul, Minnesota 55101

2. Department of Entomology, Fisheries, and Wildlife
   University of Minnesota
   St. Paul, Minnesota 55108

3. James Ford Bell Museum of Natural History
University of Minnesota
Minneapolis, Minnesota 55455

Mississippi

1. The Fannye A. Cook Memorial
Mississippi Museum of Natural Science
Division of Game and Fish Commission
111 N. Jefferson Street
Jackson, Mississippi 39202

Missouri

1. Department of Fisheries and Wildlife
University of Missouri
Columbia, Missouri 65201

Montana

1. Wildlife Laboratory
Department of Fish and Game
Montana State University
Bozeman, Montana 59715

2. Department of Zoology
University of Montana
Missoula, Montana 59801

Nebraska

1. Vertebrate Museum
Kearney State College
Kearney, Nebraska 68847

2. State Museum
14th and U Street
University of Nebraska
Lincoln, Nebraska 68508

Nevada

1. Nevada State Museum
600 N. Carson Street
Carson City, Nevada 89701

2. Department of Biological Sciences
University of Nevada, Las Vegas
Las Vegas, Nevada 89154

New Hampshire

1. Dartmouth College Museum
   Hanover, New Hampshire 03755

New Jersey

1. Museum of Natural History
   Princeton University
   Princeton, New Jersey 08540

New Mexico

1. Natural History Museum
   Eastern New Mexico University
   Portales, New Mexico 88130

2. Department of Biology
   New Mexico State University
   Las Cruces, New Mexico 88003

3. Museum of Southwestern Biology
   University of New Mexico
   Albuquerque, New Mexico 87106

New York

1. American Museum of Natural History
   Central Park West at 79th Street
   New York, New York 10024

2. Section of Ecology and Systematics
   Langmuir Laboratory
   Cornell University
   Ithaca, New York 14850

3. New York State Museum and Science Service
   Albany, New York 12224

4. College of Environmental Science and Forestry
   State University of New York
   Syracuse, New York 13210

5. Wildlife Research Laboratory
   New York State Department of Environmental Conservation
   Delmar, New York 12054

North Carolina

1. North Carolina State Museum
   P.O. Box 27647
   Raleigh, North Carolina 27611

2. Department of Zoology
   North Carolina State University
   Raleigh, North Carolina 27607

North Dakota

1. Department of Biology
   University of North Dakota
   Grand Forks, North Dakota 58201

Ohio

1. Cleveland Museum of Natural History
   Wade Oval
   University Circle
   Cleveland, Ohio 44106

2. Museum of Zoology
   Ohio State University
   Columbus, Ohio 43210

Oklahoma

1. Museum of Natural and Cultural History
   Oklahoma State University
   Stillwater, Oklahoma 74074

2. Stovall Museum of Science and History
   University of Oklahoma
   Norman, Oklahoma 73069

Oregon

1. Museum of Natural History
   Oregon State University
   Corvallis, Oregon 97331

2. Museum of Natural History
   University of Oregon
   Eugene, Oregon 97403

Pennsylvania

1. Carnegie Museum of Natural History
   4400 Forbes Avenue
   Pittsburgh, Pennsylvania 15213

2. Forest Resources Laboratory
   Pennsylvania State University
   University Park, Pennsylvania 16802

3. Philadelphia Academy of Natural Sciences
   19th and the Parkway
   Philadelphia, Pennsylvania 19103

Puerto Rico

1. Department of Biology
   University of Puerto Rico
   Mayaquez, Puerto Rico 00708

South Carolina

1. Charleston Museum
   121 Rutledge Avenue
   Charleston, South Carolina 29401

South Dakota

1. Entomology - Zoology Department
   South Dakota State University
   Brookings, South Dakota 57006

Tennessee

1. Biology Department
   Memphis State University
   Memphis, Tennessee 38111

Texas

1. Dallas Museum of Natural History
   P.O. Box 26193
   Fair Park Station
   Dallas, Texas 75226

2. Fort Worth Museum of Science and History
   1501 Montgomery Street
   Fort Worth, Texas 76107

3. Texas Cooperative Wildlife Collections
   Texas A&M University
   College Station, Texas 77843

4. Texas Natural History Collection
   Texas Memorial Museum
   University of Texas
   Austin, Texas 78705

5. The Museum
   Texas Tech University
   Lubbock, Texas 79409

6. Museum of Arid Land Biology
   University of Texas at El Paso
   El Paso, Texas 79968

<u>Utah</u>

1. Life Sciences Museum
   Brigham Young University
   Provo, Utah 84602

2. Department of Biology
   University of Utah
   Salt Lake City, Utah 84112

<u>Vermont</u>

1. Department of Zoology
   University of Vermont
   Burlington, Vermont 05401

<u>Virginia</u>

1. Center for Systematics Collections
   Virginia Polytechnic Institute and State University
   Blacksburg, Virginia 24061

<u>Washington</u>

1. Puget Sound Museum of Natural History
   University of Puget Sound
   Tacoma, Washington 98416

2. Thomas Burkes Memorial Washington State Museum
   University of Washington
   Seattle, Washington 98195

3. Department of Biology
   Walla Walla College
   College Place, Washington 99324

4. Charles R. Conner Museum
   Washington State University
   Pullman, Washington 99163

West Virginia

1. Conservation Commission for West Virginia
   Marshall University
   Huntington, West Virginia 25701

Wisconsin

1. Milwaukee Public Museum
   800 West Wells
   Milwaukee, Wisconsin 53233

2. Zoological Museum
   Noland Zoology Building
   University of Wisconsin
   Madison, Wisconsin 53706

3. The Museum of Natural History
   University of Wisconsin
   Stevens Point, Wisconsin 54481

Wyoming

1. The Museum of Zoology
   University of Wyoming
   Laramie, Wyoming 82071

APPENDIX C:

PRISM METHOD OF FOREST SAMPLING

The following is from a paper by John F. Bell and Lucien B. Alexander, "Application of the Variable Plot Method of Sampling Forest Stands," Oregon State Board of Forestry, Salem, Oregon (1957), 22 pp.

INTRODUCTION

The variable plot method of sampling a forest stand was developed in Europe by Walter Bitterlich (1). It was introduced to American foresters by Dr. L. R. Grosenbaugh (2) in 1952.

Although several papers have been written covering the principle of the variable plot method of sampling a forest stand, little has been written about its field application. This paper is designed for the practicing forester who is interested primarily in the use of the technique for cruising and other inventory work.

Determination of the ratio of basal area or volume to land area with the fixed plot size method of sampling, requires that trees inside the plot boundary be measured and tallied and those outside ignored. The variable plot method in actuality is merely another way of determining which trees to measure and tally. Those trees which are large enough to subtend a predetermined angle are tallied and used to determine the ratio of basal area or volume to land area, while those too small or too far away are ignored.

The variable plot method is a simpler, more rapid method of determining basal area and volume per acre than the conventional plot or strip methods. It reduces the personal error involved since the need to measure plot radii or strip width is eliminated and accurate diameter measurements are not necessary. The variable plot method reduces total field cruising time by approximately one third. The probability that any tree will be sampled is proportional to its basal area. Thus, a greater proportion of cruising time is spent on the larger trees. Since there is a saving in field cruising time and since more time is spent on the larger trees, the accuracy of defect and grade determinations is increased.

The reader will find in the appendix an abstract on the theory of the variable plot method of sampling a forest stand.

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(1) Bitterlich, W. Die Winkelzahlprobe. Allgemeine Forst - und Holzwirtschaftliche Zeitung 59(1/2): 4-5. 1948.

(2) Grosenbaugh, L. R. Plotless Timber Estimates - New, Fast, Easy. Journal of Forestry 50: 32-37. 1952.

THE WEDGE PRISM

The wedge prism is a precise optical instrument which bends light rays establishing the reference or critical angle. Wedge prisms ground to specifications, as developed by the consulting firm of Mason, Bruce and Girard, can be purchased through Bausch and Lomb, 7 Northwest 9th Avenue, Portland, Oregon, or through Kollmorgan Optical Corporation, Northampton, Massachusetts. The former company does not produce prisms which can be interchanged without a change in basal area factors. Their prisms cost about $2.50 each. The latter company produces prisms with exact factors such as 20, 25, or 30, but the prisms are $15.00 each and must be purchased in quantities.

FUNCTIONS OF WEDGE

What Prism Diopter to Use

One prism diopter is equal to a right angle displacement of one unit per 100 equal units distance. The general rule to follow is to select a prism diopter that will give an average tree count of four to six trees per observation point. It is best to employ the same diopter in any one given stand. The smaller the trees, the lower the diopter. The larger the trees, the higher the diopter. The more open the stand, the smaller the diopter. The more dense the stand, the larger the diopter. A compromise between size and density, with size the dominant factor, determines the diopter to use.

Listed below are some examples for the Pacific Northwest:

2-3 Diopter - small immature stands

4 Diopter - large immature Douglas fir stands and selectively cut Ponderosa Pine.

5 Diopter - second growth Douglas fir sawtimber and uncut Ponderosa Pine.

6 Diopter - old growth Douglas fir or Cascade Mountain mixed sawtimber.

8 Diopter - dense old growth Douglas fir, Redwood, or other very large sawtimber.

The Wedge Prism Basal Area Factor

The wedge prism would be of little use to the forester in determining stocking density or in the estimation of volume without the basal area factor. This factor, when multiplied by the average number of trees per observation point, will result in square feet per acre occupied by tree stems.

Determination of the Basal Area Factor

The basic method followed in determining a basal area factor is relatively simple. Place a rectangular target of any convenient width (1'-2'-3') on a vertical surface. The wedge is first moved away from the target until the target image is completely displaced so that one side of the image as seen over the prism is aligned with the other side as seen through the prism. The distance at which this occurs is measured in feet. Next the wedge is moved toward the target until the displacement occurs again. Again the distance is measured.

An average distance calculated from six such trials is placed in the Basal Area Factor formula.

$$\text{B.A.F.} = \frac{43{,}560}{1+4\left(\frac{d}{w}\right)^2}$$

Where d is distance to target in feet, w is the width of target in feet.

A question that may arise is, how much can the measured distance from target to wedge be in error and still be within reasonable limits of giving a good answer?

(It should be noted that a given per cent error in the basal area factor will produce the same per cent error either in basal area calculations or in cruise volume calculations.)

The following table shows how much this distance (an average for six trials) may vary for a one and two per cent error in the basal area factor using various diopter wedges with a one-foot target.

DISTANCE ALLOWANCE IN CALIBRATING

Diopter	B.A.Factor within ± 1% limits		B.A.Factor within ± 2% limits	
	* ± ft. for ± 1%	Total Distance Allowance	* ± ft. for ± 1%	Total Distance Allowance
4.0	.13 -	.25 +	.25 +	.50 +
5.0	.10 +	.20 +	.20 +	.40 +
6.0	.08 +	.17 -	.17 -	.34 -
8.0	.06 +	.12 +	.12 +	.25 -

* ± feet allowance from exact distance from wedge to target center.

Example: An exact 4.0 diopter wedge is to be given a basal area factor. The range is set up and the previously described procedure followed. The true distance, by formula, from wedge to target is 25.00' when a one foot target is used. The average of, for example, six trials is 25.105' with a calculated basal area factor of 17.272. The correct factor of 17.417 varies 0.83% from the calculated factor of 17.272. Thus, any cruise made with the wedge marked as having a basal area factor of 17.272 will be 0.83% low when the volume calculations are made.

FIELD PROCEDURE USING THE WEDGE PRISM FOR BASAL AREA DETERMINATION

How to Establish the Sample Point

A series of sample points is established on the ground in the same manner as the center points of fixed-radius sample plots. Either full points (360 degrees) or half points (180 degrees) may be taken.

The half point is established as follows:

1. The point is established in the normal manner.

2. From the point, the compassman faces downhill regardless of the direction of the cruise line. (Whenever the crew consists of two or more men the compassman selects the half point to eliminate any bias that might be introduced if the cruiser established the point.)

3. He next picks a reference tree on his left that is on contour with the point. A stake may be set if a reference tree is not available. When it is desired that the point can be reestablished at a later date, the tree is blazed and marked with a 2.

4. The half point is established from the reference tree by extending an imaginary line across the plot center. All the trees on the downhill side of this line are potential "in" trees.

Normally a wedge of one diopter lower is used when half points are taken.

How to Determine Whether a Tree is "in" or "out"

From the sample point the surrounding trees are observed both through and over the wedge prism. The prism bends the rays of light passing through it by a fixed angle so that the transmitted image of the tree is laterally displaced. If the edge of the direct and transmitted images overlap, the tree is considered "in" and it is counted. Figure C1 shows the diagram of an "in", "out", and "borderline" tree. Alternate "borderline" trees may be counted as being "in" or each "borderline" tree may be counted as a half tree. The distance between the eye and the prism does not affect the angular displacement of the prism. However, it is very important to keep the prism over the sample point. The cruiser sights on the tree at the point on the tree where his basic volume table diameters are indicated. Usually, that point is D.B.H. There are advantages to using a point higher on the tree; however, the basic volume table must then be adjusted to give diameters at that new point. The face of the prism should be at right angles to the line of sight and when this condition exists the lateral displacement of the image is minimum. The bottom edge should be horizontal on level ground. To correct for slope, the prism is rotated at exactly the same angle as the slope, but in a plane which is at right angles to the line of sight. Both the slope angle from eye to tree and the amount in which the wedge prism is rotated to correct for slope must be equal. An abney can be used to measure the amount of slope and then used to rotate the wedge to the same angle with the line of sight. Figure C2 shows the correct way to employ the abney and the wedge prism. Note that the line of sight is perpendicular to the face of the wedge prism.

The following are some pointers on determining whether a tree is "in" or "out":

1. For hidden trees the observation center may be moved away from the actual point as long as the distance from the point to the tree in question is maintained. By moving the observation center, it is often possible to get to one side of brush that is obstructing the view. It is necessary to move the center when a possible "in" tree is directly behind another tree.

2. For a leaning tree, rotate the wedge prism so that its vertical axis corresponds with the center of the stem of the tree.

3. Occasionally the displaced image of one tree will overlap an adjacent tree giving the appearance that it should be counted when actually it is "out". This can be avoided by careful observation of the trees involved to see whether the displaced image belongs to the tree that is overlapped. In some instances, having the compassman stand beside the closer tree will facilitate making the distinction.

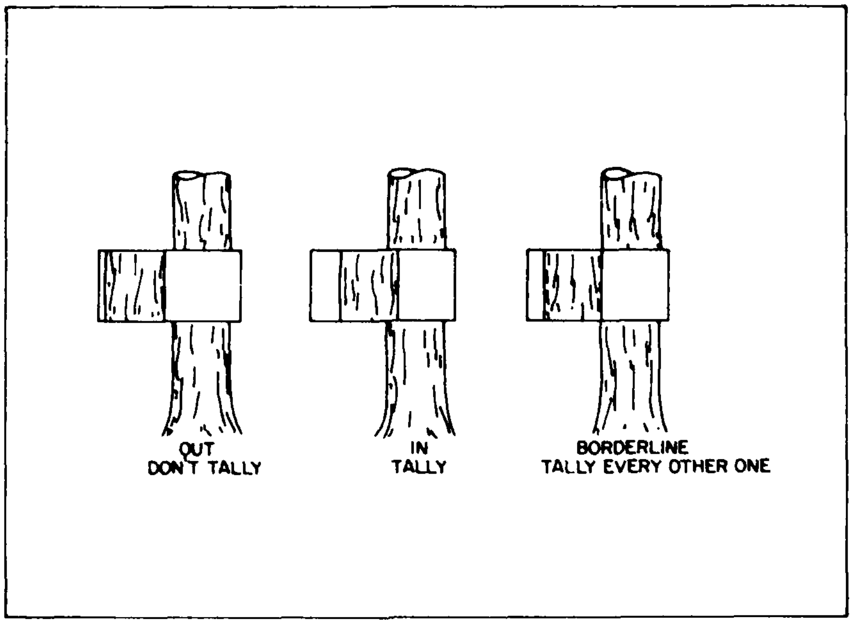

Figure C1. "In," "out," and "borderline" trees.

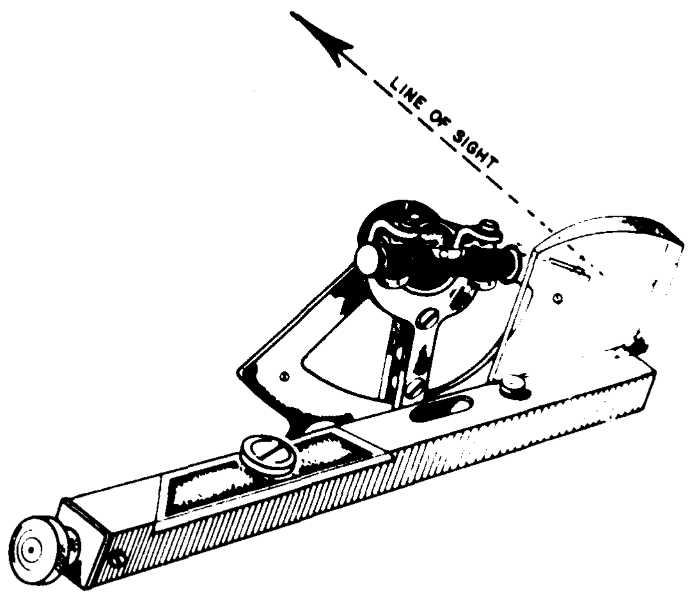

Figure C2. The correct way to employ the abney and the wedge prism.

4. In rare cases it may be necessary to remove some of the brush that is obstructing the view. The use of half points helps to eliminate the brush problem.

5. Normally the prism is held so that the image is displaced to the left. Reversing the prism so that the image is displaced to the right will aid in determining whether a tree is "in" or "out".

6. Another method of determining whether a tree is "in" or "out" is through the use of a plot radius factor. The distance from the point of observation to a tree that is just "in" is called the plot radius. The D.B.H. of any tree is directly proportionate to the plot radius. Thus, a plot radius factor can be computed for any wedge prism.* The D.B.H. in inches of any tree multiplied by the plot radius factor gives the plot radius in feet for a tree that is just "in". It is easily seen that there is a different plot radius for each different diameter. Thus, this method is often referred to as the variable plot radius method. The plot radius factor is particularly useful as a training aid.

How to Determine Basal Area per Acre

The average tree count per plot multiplied by the wedge prism factor gives basal area per acre.

Example: 21 points are taken which have a total tree count of 87. A wedge prism with a factor of 27.62 was used.

Average tree count = $\frac{87}{21}$ = 4.143 (normally carried out to three decimal places)

4.143 x 27.62 = 114.4 square feet of basal area per acre.

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*The plot radius factor is computed from the following formula:

$\sqrt{\frac{43{,}560 - \text{B.A.F.}}{4\ \text{B.A.F.}}} \div 12$ where B.A.F. = Basal Area Factor

The plot radius factor may also be computed from the following formula (for any given wedge prism):

$\frac{d}{12w}$ where d = distance to target in feet
w = width of target in feet

APPENDIX D:

ALTERNATE SAMPLING METHODS

The following discussion presents alternatives to the methods described in Chapter 4 for sampling vegetation, mammals, and birds.

Vegetation

Equipment and Materials

1. Chaining Pins.

2. Tree Measurements: measuring stick, distance tapes, diameter tapes, compass, Biltmore sticks.

3. Sapling and Shrub Measurements: measured tapes.

4. Forage Production Measurements: clippers, paper bags, triple-beam balance, drying oven, long-handled pruner, calibrated sticks.

Choice of Area

General Location. The general location of a transverse line and its individual plots depends on the objectives of the data to be secured. In all instances the reasons for choosing the general location and the placement of the transverse line should be recorded.

The general location of each transverse line should be shown on a USGS map or copy (or equivalent on larger scale) so that this location can be approximated at a later date.

Specific Transverse Line and Plot Location. A specific starting point, compass direction(s), distance between plots, and number of plots for each transverse line must be established in advance of field work. All this information for each transverse line should be recorded. The first plot must be at least 50 yds (paces) (46 m) along the transverse line to avoid biased choice of plot locations.

The compass direction of the transverse line should be established for at least 25 yds (paces) (23 m) beyond the location of a plot so that the center of the plot can be established by measure (yards) or footfall (paces) rather than by some arbitrary decision. Finally, the center of each plot must be marked by a stake.

Vegetation Categories

1. Trees: over 4 in. (8 cm) diameter at breast height (dbh, 4 1/2 ft [1.4 m] above ground).

2. Saplings: 1 to 4 in. (3 to 8 cm) dbh.

3. Seedlings and herbaceous vegetation: under 1 in. (3 cm) dbh.

Tree Measurements. At each point, four trees are selected according to the point-quarter method (Curtis and Cottam, Plant Ecology Workbook, 1962, see Appendix A). Compass lines north-south and east-west are used as axes. The closest tree to the point in each quadrant is included in the sample.

The data to be recorded for each tree are:

1. Species.

2. Distance from the point to the center of the tree.

3. Dbh: use diameter tape.

4. Height to the top of the crown: use Biltmore stick. A Biltmore stick works by the principle of similar triangles. The investigator, standing at one chain (66 ft [20 m]) from the tree, holds the stick vertically at 15 in. (64 cm) from the eye. When the bottom of the stick is aligned with the base of the tree, other height measurements may be read. Avoid standing downhill from the tree when making height measurements (Figure D1).

5. Height to the bottom of the crown: use Biltmore stick.

6. Crown radius: three rays are projected from the center of the tree at 120 degrees from each other. A chaining pin is placed where a vertical line tangent to the crown intersects each ray. The average of the three pin-to-tree measurements is taken as the crown radius (Figure D2).

$$\text{Crown radius} = \frac{QA + OB + OC}{3} \qquad \text{[Eq D1]}$$

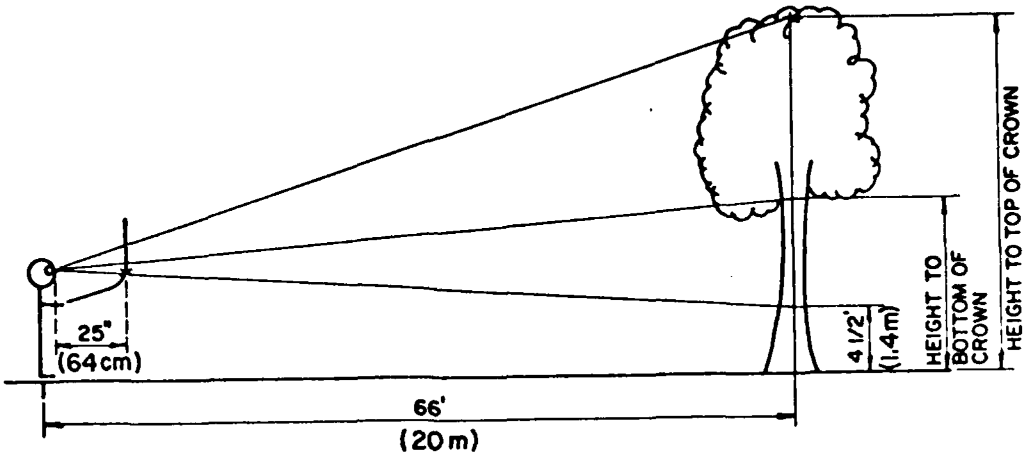

Figure D1. Use of the Biltmore stick for making tree height measurements.

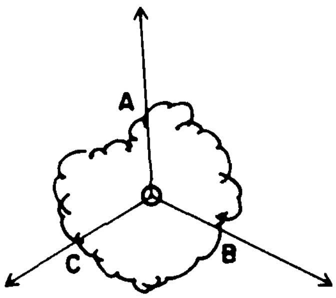

Figure D2. Determining crown radius for trees.

Note: Trees with multiple trunks are considered a single tree if the trunks are connected above ground. The dbh recorded (d_0) is calculated as the diameter of a single trunk having the same basal area as the sample tree (e.g., if the sample tree has two trunks with diameters d_1 and d_2, $d_0 = d_1 2 + d_2 2$).

Sapling Measurements. All saplings within 11.8 ft (3.6 m) from the point are included in the sample and tallied according to species (a radius of 11.8 [3.6 m] defines a 1/100 acre, with the same measurements taken as for trees.

Seedling and Herbaceous Vegetation Measurements. All seedlings and herbaceous vegetation within 3.7 ft (1 m) from the point (a 1/1000 acre plot) are included in the sample and tallied according to species.

A plot is established centered on the plot stake. All herbaceous and seedling vegetation is clipped at ground level from this 1-m-square plot, placed in a bag, and saved.

Calculations (Calculated by Species and Then Totaled If Identification Is Possible)

1. Trees.

a. Individuals per hectare = [Eq D2]

$$\frac{10\ 000\ m^2/\text{hectare}}{(\text{average distance trees [m]}^2)}$$

b. Basal area per hectare = [Eq D3]

$$\frac{10\ 000\ m^2/\text{hectare}}{(\text{average basal area per tree [m]}^2)}$$

2. Saplings.

a. Individuals per hectare = [Eq D4]

average number of individuals per point X 100 X 2.47

b. Basal area per hectare = [Eq D5]

average basal area per point X 100 X 2.47

3. Seedlings and Herbaceous Vegetation.

a. All clipped vegetation should be dried 48 hours at $55^{o}C$.

b. Biomass per hectare = [Eq D6]

average dry weight per point X 1000 X 2.47

Mammals

The following two methods of analysis can be implemented at the Stage II or III level, but supply less information than the capture-recapture method described in the main text; however, they are less complex, require less field time, and are less expensive. The final decisions on investments in manpower and finances, and on the level of accuracy desired will have to be made before using any of the guidelines in this report.

Capture-Removal Method

Equipment for this procedure is as follows:

1. Rat traps: 6 dozen

2. Mouse traps: 26 dozen

3. Oatmeal and peanut butter

4. Staked flags: 12 dozen.

The traps must be placed in a grid system enclosing 1 hectare (2.47 acres), with each set of traps 10 m apart (Figure D3). The traps are baited with a rolled oats and peanut butter mixture. The traps are set for five consecutive nights with the captured animals removed each morning and the traps rebaited. This method is generally more successful if the trap points are prebaited for 3 days prior to setting the traps. All captured individuals are identified; and sex, reproductive condition, and age (young or adult) are recorded. Trapping is done for only 5 nights, because animals outside the area will begin to move into the population vacuum created by the removal of resident individuals.

The population is determined by graphing the daily catch against the accumulated catch and drawing or calculating a regression line to determine the population (Figure D4).

Transect Method

Using the same equipment as for the capture-removal method, the traps are set in a straight line at a predetermined distance (every 3 or 4 steps, or other distance). The catch for this area is calculated as number caught per number of traps set times 100.

Birds.

The articles in Appendices E and F outline two alternative methods of censusing bird populations. These techniques are being investigated by CERL for further use by scientists and have not yet been thoroughly tested; but it would appear at this time that they will be found valid, because scientists are using them with reasonable success.

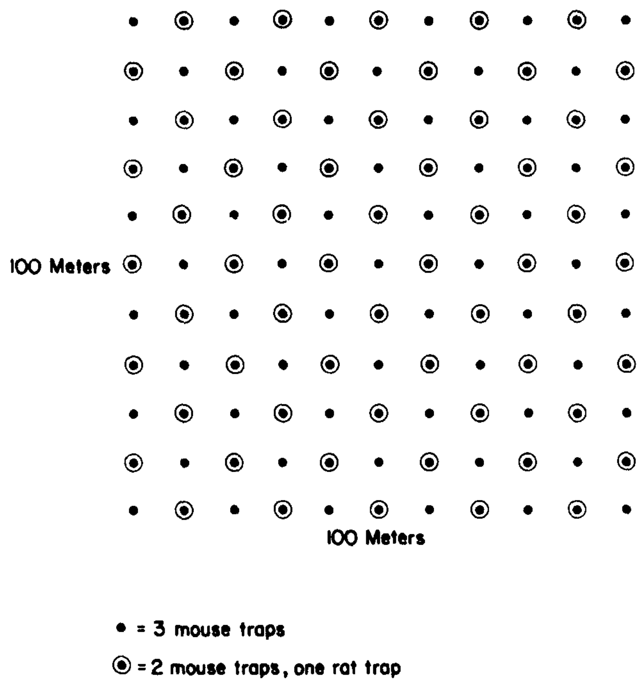

Figure D3. Grid system for traps.

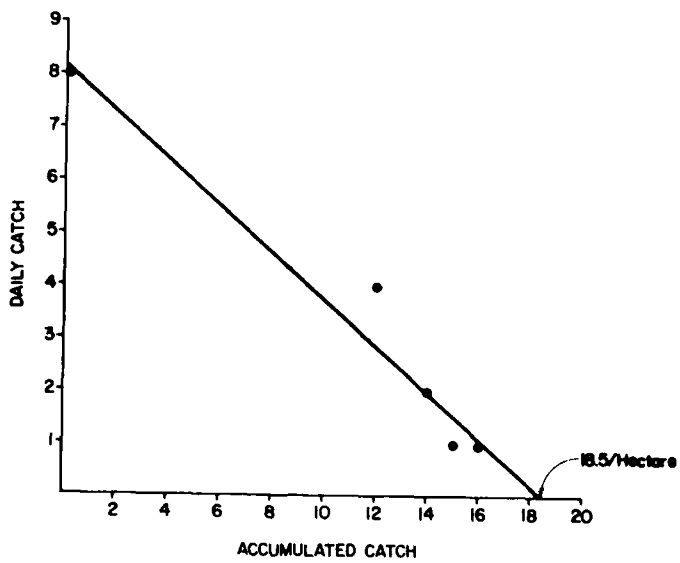

Figure D4. Mammal population.

APPENDIX E:

ANALYZING BIRD TRANSECT COUNTS

The following is a paper by Martha Hatch Balph, L. Charles Stoddart, and David F. Balph, "A Simple Technique for Analyzing Bird Transect Counts," The Auk, Vol 94, No. 3 (July 1977), pp 606-607.

A simple technique for analyzing bird transect counts.—Natural resource inventories commonly call for density estimates of all bird species in an area throughout the year. Transect methods (reviewed by Eberhardt 1968, J. Wildl. Mgmt. 32: 82 and by Emlen 1971, Auk 88: 323) are perhaps the most appropriate means for making such estimates. This paper describes a simple method of analyzing transect counts used by Balph and Balph (MS) to estimate bird densities by species at 2-month intervals through 1 year on a limited budget.

Data for analysis were collected on line transects in each of several vegetation types near an arid-lands river in eastern Utah. Information recorded included the identities of birds seen on transects and the lateral distance from the transect line to the point of first signting. Lateral distances were grouped into the following meter intervals: 0–5, 6–10, 11–15, 16–20, 21–25, 26–30, 31–40, 41–50, 51–75, 76–100, and >100. The first interval (0–5 m) was judged to be wide enough to obtain a good sample, yet narrow enough to assume reasonably that all birds within the corridor would be seen. Variability was measured by comparing day-to-day counts made on the transects.

Data were used to maximize the density estimate for each species seen during a given transect walk. The procedure is illustrated using hypothetical data presented in Table 1. The largest number of individuals of species A (i.e. 7) occurs in the first (i.e. 0–5 m) interval. Given a transect 2,000 m in length, 7 individuals of species A are estimated to be present in a $5 \times 2{,}000$ m area doubled to include both sides of the transect—a corridor of 20,000 m^2. Expressed in number of birds per km^2, the density of species A is 350. For species B, the density estimate is maximized by averaging the values in the first two intervals, which gives 1.5 birds per

TABLE 1

HYPOTHETICAL DISTRIBUTION OF INDIVIDUALS OF SEVERAL BIRD SPECIES SEEN AT VARIOUS LATERAL DISTANCES FROM A TRANSECT LINE

	Distance from transect line (m)					
Species	0–5	6–10	11–15	16–20	21–25	26–30
A	7	5	2	2	0	1
B	1	2	0	1	0	0
C	0	0	0	0	1	0

20,000 m^2 or 75 per km^2. For species C, the estimated density is 0.2 birds per 20,000 m^2 or 10 per km^2. A generalized equation for this procedure is:

$$D = \frac{n}{l \times d \times 2} \times \frac{10^6\text{m}^2}{\text{km}^2},$$

where D = density of birds (number per km^2), n = number of birds observed between transect line and outside edge of last interval used in density estimate, l = length of transect in meters, d = number of meters from transect line to outside edge of last interval used in density estimate, and where the last interval used is that which gives the largest mean number of birds per meter of lateral distance.

This method of analyzing transect counts emphasizes the use of data obtained in the first interval from the transect line. Sightings outside of the first interval are of interest only when, due to small sample size, the number of individuals is largest in an interval other than the first. The logical and mathematical basis for this approach is given by Stoddart (Gross, Stoddart, and Wagner 1974, Wildl. Monogr. 40). No attempt is made to establish a species specific "sighting probability" (Eberhardt ibid.) or "coefficient of detectability" (Emlen ibid.), because few species occur with sufficient frequency to do so feasibly.

There may be some problems in treating the data in the manner described. The procedure assumes that the numbers of birds seen in the intervals used in the density estimate represent the actual numbers of birds present in those intervals. Since in most cases a progressively smaller proportion of the individuals present are likely to be seen at increasing distances from the transect line, the use of data from intervals other than the first to maximize the density of a particular species may result in an underestimated density figure for that species. However, we believe that the technique described is an adequate solution to the problem of making density estimates for all bird species encountered along a transect.

This paper is an outgrowth of work supported in part by the White River Oil Shale Project and ERDA contract no. E(11-1)-1329.—MARTHA HATCH BALPH, L. CHARLES STODDART, AND DAVID F. BALPH, *Department of Wildlife Science, UMC 52, Utah State University, Logan, Utah 84322.* Accepted 1 Dec. 76. (This paper was subsidized by the authors.)

APPENDIX F:

ESTIMATING BREEDING SEASON BIRD DENSITIES

The following is a paper by John T. Emlen, "Estimating Breeding Season Bird Densities From Transect Counts," The Auk, Vol 94, No. 3 (July 1977), pp 455-468.

ESTIMATING BREEDING SEASON BIRD DENSITIES FROM TRANSECT COUNTS

JOHN T. EMLEN

ABSTRACT.—In this paper I propose that for each species in an area the number of birds detected along a transect trail can be translated into an estimate of absolute density (birds per unit of area) by counting all the detectable (cue-producing) birds in a trailside strip narrow enough to permit detection of all cues produced (the specific census strip), and adjusting this count for the undetectable (silent) birds in the strip by applying a locally and concurrently derived index of the frequency of cue production for the species. Cue frequency is apparently impossible to measure in nonbreeding birds, but if all cues (sightings, calls, etc.) are used, most of the birds in the strip presumably will be detected when the observer advances slowly enough to allow each bird a good chance to make its presence known. In the nonbreeding season the strip width is set for each species at the distance from the trail at which total cue detection starts to decline. In the breeding season cue frequency may be determined for song cues, and strip widths for each species set at a convenient distance within the relatively great distance at which song detection starts to decline. Values obtained by these transect procedures reflect the density of each species at the time the traverse is run; a series of traverses may be made to provide mean values for selected periods through the season.

The method is similar to that described in an earlier paper. New or modified procedures are described for recording detections, establishing specific strip widths, bypassing the calculation of "coefficients of detectability," estimating distances in the field, determining an optimum rate of progress, and measuring the frequency of singing in a representative sample of the population.

Problems of converting adjusted transect counts of singing males to total population density and of applying a combination of all-cue and song-cue procedures to mixed populations of breeding and nonbreeding species are discussed.

A comparison of transect and plot map census methods is presented. In the transect method density estimates are of birds present at a particular time rather than of birds wholly or partially resident at one time or another during a season. The sampling quadrats of transect censuses are elongate rectangles spanning extensive tracts of habitat rather than truncated blocks of representative habitat. The transect method is applicable at any season while the plot map method can be used only during the breeding season when birds are singing on territories. Problems of reliability in the plot map method stemming from individual movements during a survey period and from questions on how to interpret clusters of observation points on territory maps and how to evaluate boundary line territories are replaced in the transect method by problems of accuracy in assuming complete coverage in the all-cue operations and in assigning birds as inside or outside the lateral boundary lines of the census strips. More area can be covered per unit of time in the transect than in the mapping method.—*Department of Zoology, The University of Wisconsin, Madison, Wisconsin 53706.* Accepted 3 November 1975.

THE PROBLEM AND THE MODEL

THE principal access to absolute density values (birds per unit of area) for land birds has been the spot-map method (Williams 1936, Robbins 1970). While reasonably satisfactory for many purposes, spot-mapping procedures are applicable only during the breeding season and on fairly small tracts. Success in estimating absolute densities in large areas has recently been achieved by coordinating absolute data from small mapped plots with relative data from extensive transect counts (Enemar and Sjostrand 1967, 1970), and in 1971 I described a method for translating counts of bird detections along a transect route to absolute density values by applying correction factors for each species based on the distribution of detection points laterally from the transect trail (Emlen 1971). Järvinen and Väisänen (1975) also used the principle of declining detectability with distance, applying three theoretical regression curves to the extensive narrow and broad belt census data of Merikallio (1946, 1958) and others on Finnish bird populations.

There is no test of accuracy for my 1971 distance attenuation method, but results appear to be reasonably satisfactory in the nonbreeding season when most birds close to the trailside provide sound or visual cues as the observer passes. It is quite unsatisfactory during the breeding season, however, when many individuals, notably nesting females, remain silent and essentially undetectable even at close range. This paper is concerned primarily with breeding season census problems but reviews various aspects of nonbreeding season transect procedures.

The relation between the number of cues tallied along a transect trail and the absolute density of birds that number represents appears to rest on two variables, both of which can be controlled or measured in many situations: (1) cue attenuation with lateral distance from the trail and (2) the frequency with which birds produce visual or auditory cues detectable by an observer at any range. This paper reexamines and revises the procedures for attenuation control described in my 1971 paper, outlines procedures for measuring cue frequency, and discusses methods for coordinating the two procedures in various situations. It also compares the characteristics, applicability, basic assumptions, advantages, and weaknesses of the transect and the traditional plot-map census methods. The appendix presents some results of preliminary field tests made in Wisconsin using the two methods.

Cue attenuation.—My basic procedure for controlling the attenuation of sound cues and visual cues with distance is to determine for each species the strip width along the trail within which a fully alert observer will detect essentially all cues that are produced. In my 1971 paper I projected the density within this strip to an outer boundary line and used the ratio of the actual count inside that boundary line to the projected total over many miles of transect as a coefficient of detectability for the species. The count within the strip can be used directly as a specific census strip, and this procedure has the advantage of being locality and period specific. In either case distances perpendicular to the trail on either side are estimated for each bird as it is detected, and tallied as dots or other symbols on survey sheets in columns representing narrow strips of terrain paralleling the trail. The symbols in these columns are totaled for each species at the end of a survey or series of surveys, and the accumulated data are plotted as a regression curve with the transect trail serving as the base. Curves typically show fairly level basal plateaus out to from 30 to 200 feet (9–60 m), depending on the species, before declining rapidly or gradually to zero at the limits of detection

On the assumption that (1) I miss relatively few cues in the proximal strips immediately adjacent to the trail, and (2) the plateau form of the curve indicates that there is no appreciable additional loss in detection out to the inflection point of the curve, I adopt the inflection point or some convenient point within it on either side of the trail as marking the lateral boundaries of the specific census strip for the species. These lateral boundary lines and the ends of the transect route define the areal base for the density function as well as delimiting the area in which cues can be accepted for density determinations. Specific census strips are thus elongate quadrats within which cue detection approaches completeness. They must not be confused with the areas used in the flushing distance method of King (Leopold 1933, Hayne 1949) in which the estimated distances are along radii emanating forward and laterally from the advancing observer.

In addition to applying the specific census strip directly in place of the derived coefficient of detectability I have made several innovations or modifications of procedure since presenting the transect census model in 1971: (1) To meet the problem of obtaining adequate samples for an uncommon species I may arbitrarily group the available data with those for one or more common species displaying similar cue-attenuation characteristics to derive an approximate value.

(2) Where habitats occur in narrow linear shapes as along a riverbank, a roadway, or an urban city block, I adopt the natural boundary of the habitat to define the census strip except for species in which the specific strip is narrower than the habitat strip.

(3) Where birds are concentrated in flocks it is often difficult to tally each individual as a separate dot on the survey sheet. Under these conditions I estimate the flock size and treat it as a unit, apportioning the lateral distribution points according to my best estimate of the position and dispersion of the flock at the moment it was encountered.

(4) Where, as in the breeding season, the detectability of members of a population fluctuates rapidly and irregularly or varies strongly among individuals, I focus on one or a few of the most stable cue types, such as song, and base my specific strip boundaries and calculations of density exclusively on these. Data obtained by this procedure require special adjustments for cue frequency as described below.

Cue frequency.—Cue attenuation should theoretically be completely controlled by the procedures described in the previous section, the observer simply basing his density calculations for each species on the count obtained in the relatively narrow strip within which his tally of detectable cues approaches completeness. But, entirely aside from cue attenuation, individual birds may still be bypassed because they produce no detectable cues, either visible or audible, while the observer is within detection range. These momentarily undetectable birds cannot be counted directly, but their numbers can be computed if the frequency of cue production (the proportion of observer encounters in which the birds make their presence known by emitting detectable cues) is determined for a representative sample of the strip's population and interpreted as the proportion of detected individuals in the total population of the strip. Thus, in a hypothetical case, if 10 birds of a selected species are detected on a transect count run at a speed that gives the observer 6 min within the detection range of each bird, and it is independently determined that representative members of the population make themselves detectable in 50% of a series of 6 min test periods in which they are continuously within detection range, we can conclude that 10 additional birds were bypassed on the transect count and that the population in the strip is 10 detected plus 10 undetected birds = 20 birds.

The frequency of cue production is difficult to determine under most conditions because when an observer follows them persistantly, birds tend to alter their natural behavior in ways that make them less or more detectable. *Total* cue frequencies (using all visual and sound cues) are, in fact, essentially unattainable, but fortunately during much of the nonbreeding season most of the birds within the narrow specific strip seem to make their presence known if the observer advances slowly and restricts his counts to favorable early morning conditions (Emlen 1971).

Cue frequencies can apparently be estimated with reasonable accuracy during the breeding season if calculations are based exclusively on song. Representative territorial males may be selected as samples and watched continuously over extended periods (Enemar 1959). Or, as it is difficult to recognize truly representative birds, a series of territorial males may be visited repeatedly for shorter periods and their individual song frequencies averaged (Hickey 1943).

When cue frequencies are based exclusively on song cues, transect counts must, of course, also be restricted to songs. The tally will thus be smaller, but the much wider specific census strips that can be employed when only loud vocalizations are used in determining attenuation distances, and the longer bird-observer exposure times available for each territorial singer compensate for the omission of numerous nonsong cues from the calculations.

Density computation —When cue frequency cannot be measured, as when all cues are used during the nonbreeding season, density must be computed entirely from cue attenuation data. When indices on cue frequency are available, as for song in the breeding season, total density can be computed by multiplying the count of detected (cue-producing) birds in the census strip by the reciprocal of the locally determined cue frequency for the species.

The density values obtained by the specific strip census method, with or without application of cue-frequency data, apply to the population present in the strip at the time the traverse is run. Individual birds that drift back and forth across the boundary lines are included if they happen to be inside, excluded if they are outside when the observer passes. The effects of such transboundary movements will presumably balance out for common species on long traverses, and fluctuations in a stable population should be small in a series of standardized traverses over the same route. Variations in computed density will occur, however, with changes in weather and variations in field procedure such as rate of progress or time of day.

When procedures are standardized, density estimates for a series of specific strip traverses may be averaged to reduce errors caused by small sample sizes, or statistically analysed for information on the completeness of cue detection under various conditions. Palmgren (1930) discussed the averaging of transect-derived density values for an area, noting that in open (no strip boundary) transects or where wide fixed strips are used, the largest count for a species in a series of traverses will approach the actual population level more closely (be more complete) than the mean for the series. This principle applies in situations where the population being counted is assumed to be definitive and where variations in the count are due to variations in the completeness or efficiency of the counting; it does not apply to specific strip counts where the population being counted fluctuates as birds drift back and forth across the boundary line and where all counts are assumed to be essentially complete or at least representative of the birds present within the indicated boundaries when the count was made.

Field Procedures for the Nonbreeding Season

To estimate densities of nonsinging, nonterritorial populations along a transect route one should use all available cues and follow the procedures described above under cue attenuation. The values will theoretically be complete for all cue-producing (detectable) birds in the specific census strips. Silent and inactive (undetectable) birds will inevitably be bypassed, and no satisfactory technique has yet been devised for estimating them. In the absence of data on cue frequency, best guess adjustments (basal detectability adjustments) may be made for these undetected birds where best estimates are preferable to minimum estimates.

Field Procedures for Breeding Season Populations

To estimate breeding season densities by the specific strip method one should use only song cues and then adjust the tallies of singing males for the unrecorded non-singing males and females. This procedure calls for two separate operations in the field, (1) tallying all song detections and their lateral distances along the route, (2) determining indices of song frequency during the census period. Although these two operations are functionally distinct, the data for each may be collected concurrently along a transect route without prejudice to either set of data and without loss of time.

Counting singing males.—The field procedures for song transects are similar to those used in all-cue transects as described in my 1971 paper, but involve a number of special considerations as discussed below:

(1) *Record all detections.*—Although density calculations in this model are based entirely on song cues, all detected cues should be recorded. Song cues should be clearly differentiated from the others on the tally sheet by some distinctive symbol such as a small circle or the letter s.

(2) *Song strip boundaries.*—Because songs in most species can be heard at relatively great distances, the basal plateaus of lateral regression curves are much broader when based exclusively on song cues than when soft call notes and sightings are also included. Under these circumstances the problems of distance estimation and density calculation can be simplified by setting the boundary lines for the census strip at some convenient arbitrary distance well inside the limits of song detection set by sound attenuation. In the Wisconsin test study (see Appendix) I selected 200 feet on either side of the trail (a 400-foot strip) for most species and 100 feet (200-foot strip) for a few quiet-voiced species.

(3) *Distance estimates.*—As distances from the transect trail to unseen singing birds can rarely be measured, a subjective approach is necessary. Elaborate estimation techniques must be avoided, however, as they involve distractions that can affect the efficiency of distant song detection adversely (Merikallio 1946). Fortunately if a fixed distance well within the absolute limit of detection is set, as advocated in the preceding paragraph, the only critical decision to be made for each observation is relatively simple, whether or not the bird is inside or beyond that prescribed census strip boundary line when first detected. In most cases the correct answer is subjectively obvious, but there may be a good many borderline cases. In any event, every census-taker must face the subjectivity problem squarely and work out a system for himself in which he can test his performance level objectively at frequent intervals. I find that with practice I can almost invariably predict to within 10 or 15% the number of paces (3 feet) it will take me to reach a selected fixed object 200 feet away, the distance to the strip boundary line for most species in breeding season transects. This level of accuracy I am obliged to accept as the best I can do. In making these estimates for self-testing and in actual transect count situations, I find it helpful to cultivate and retain mental images of familiar settings with known dimensions, such as a room in my home, a tennis court base line, a fallen 100-foot tree, or a 100-yard race track straightaway.

To apply these acquired skills to an unseen songbird along a transect route one must first determine the approximate location of the source of the sound with reference to some conspicuous and fixed object in the habitat such as a distinctive tree trunk or a tall shrub, and then estimate the distance of that object from the trail when he is approximately opposite it. Both the locating and the estimating operations

TABLE 1

SOME COMPARISONS OF THE PLOT-MAP AND TRANSECT-STRIP CENSUS METHODS

Plot-map method	Transect-strip method
Objectives	
To estimate the number of birds resident during the breeding season.	To estimate the number of birds present during a single census operation.
Nature of the data	
Data units are the territories lying within or partially within (fractions) the plot boundaries.	Data units are the individual detections of birds as the observer moves along the route.
Each visit to the plot contributes data to a single census estimate for the season.	Each traverse of the route provides the complete record for a definitive estimate; the results of repeated traverses can be averaged.
Plots are usually truncated in shape.	Plots are elongate in shape (strips).
Applicability	
Limited to the season when birds are on territories.	Applicable at any season.
Plots must be replicated when objective is to characterize a region or vegetation type.	A long transect plot provides a representative sampling of a region or vegetation type.
Problems of procedure and interpretation	
(Repeated traverses over the same area will reduce errors of omission.)	In the absence of cue frequency data (non-breeding season) an unknown number of silent (no cue) birds within detection range (the specific strip) will be bypassed in the single traverse that constitutes a definitive transect census.
(No distance estimates are required.)	Lateral distance measurements to detection points are only rough subjective estimates.
Double recording of individuals is difficult to control unless neighboring males sing concurrently.	(Double recording is rarely a problem when following a straight transect course at more than 0.70 mph.)
Determination of territory boundaries on base maps may be difficult especially where territories are contiguous.	(Precise boundary determinations are not required.)
Determination of the fraction of boundary line territories lying within a plot requires knowledge of the transboundary extensions.	(No territory evaluations are required.)
Individual territorial birds may enter, leave or shift within a plot between spaced visits.	(Intervisit changes are minimal when intervals are short.)
Efficiency (hypothetical) in hours	
For a 24-acre plot (birds resident through the breeding season)	For a 24-acre (0.5 mi × 400 feet) strip segment (birds present during three 5-day periods)
Staking and mapping — 10 hr.	Mapping — 2 hr.
Vegetation survey — 4 hr.	Vegetation survey — 4 hr.
8 surveys × 2 hr. — 16 hr.	15 traverses × 0.6 hr. — 9 hr.
Total — 30 hr.	Total — 15 hr.

are best accomplished by moving along the trail and sighting towards the object or the sound source from several spaced points. A clearly visible and reasonably straight trail is important as a reference base for this operation. Major landmarks previously plotted to scale on a strip map of the route (see next subsection) greatly facilitate all distance estimates in the tract.

(4) *Rate of advance.*—The rate of progress along the trail and the distance ahead and to the rear within which songs should be recorded are critical insofar as they determine the length of time the observer is exposed to each bird on the census strip. A net walking speed of about 0.75 mph combined with a 200-foot limit for recording birds, fore and aft, allows 6 min for each bird. Where 200 feet is also used as the lateral distance to the strip boundary (see consideration 2 above), the observer is, in effect, concentrating his attention on the birds in a slowly advancing 400-foot square area in which he is centered.

TABLE 2

CENSUS DATA FOR A 48-ACRE STAND OF MIXED WOODLAND IN WISCONSIN[1]

	Total count per mile[2]	Width of specific strip[3]	Total count in specific strip[4]	Song count in 200-foot strip[5]	Song frequency[6]	Territories in 200-foot strip[7]
Mourning Dove (*Zenaida macroura*)	2.0	40 + 40	0.5	0.64	0.40	2.0
Yellow-billed Cuckoo (*Coccyzus americanus*)	0.1	200 + 200	0.2s	0.09	v[8]	-
Common Flicker (*Colaptes auratus*)	1.9	60 + 60	0.9	0.45	0.15	3.1
Red-bellied Woodpecker (*Melanerpes carolinus*)	0.4	100 + 100	0.2	—	-	0.5
Downy Woodpecker (*Picoides pubescens*)	2.2	100 + 100	1.3	—		4.0
Great Crested Flycatcher (*Myiarchus crinitus*)	0.6	200 + 200	0.2	—	-	0.4
Blue Jay (*Cyanocitta cristata*)	13.0	100 + 100	8.4	—	—	8.2
Black-capped Chickadee (*Parus atricapillus*)	16.2	60 + 60	10.4	—	—	8.8
White-breasted Nuthatch (*Sitta carolinensis*)	0.2	200 + 200	0.1	—	—	0.2
Red-breasted Nuthatch (*S. canadensis*)	1.1	100 + 100	0.9	—	—	1.0
House Wren (*Troglodytes aedon*)	3.1	200 + 200	3.8s	1.91	0.66	3.0
Gray Catbird (*Dumetella carolinensis*)	5.2	40 + 40	1.6	1.68	0.44	7.9
Brown Thrasher (*Toxostoma rufum*)	4.3	60 + 60	2.9	0.91	0.19	6.0
American Robin (*Turdus migratorius*)	6.3	40 + 40	3.3	0.91	0.13	8.1
Wood Thrush (*Hylocichla mustelina*)	3.0	200 + 200	3.5s	1.77	0.52	3.6
Cedar Waxwing (*Bombycilla cedrorum*)	0.6	50 + 50	0.6	—	—	1.0
European Starling (*Sturnus vulgaris*)	0.3	100 + 100	0.2	-	v	—
Common Yellowthroat (*Geothlypis trichas*)	0.6	200 + 200	0.6s	0.32	0.27	1.0
Red-winged Blackbird (*Agelaius phoeniceus*)	0.4	200 + 200	0.5s	0.23	0.60	—
Northern Oriole (*Icterus galbula*)	0.3	100 + 100	0.3	0.09	0.10	0.8
Common Grackle (*Quiscalus quiscula*)	7.7	40 + 40	4.2	—	v	—
Brown-headed Cowbird (*Molothrus ater*)	4.7	50 + 50	2.2	1.95	0.51	3.5
Cardinal (*Cardinalis cardinalis*)	6.4	60 + 60	3.0	2.91	0.59	7.0
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	2.4	50 + 50	0.8	0.86	0.28	4.2
Indigo Bunting (*Passerina cyanea*)	0.8	200 + 200	0.8s	0.41	0.53	0.9

[1] Twenty traverses along a 1.10-mile transect route through a 48-acre stand in Madison, 18 June to 7 July 1974.
[2] All birds detected by sightings, calls or songs, per mile.
[3] Distance between inflection points for the species on each side of trail, in feet.
[4] All birds detected by sightings, calls or songs within the specific strip, or songs detected (indicated by s) × 2, whichever is larger.
[5] All males detected by song within 200 feet (100 feet for Catbird), per mile.
[6] Proportion of 6-min. territory crossings in which the resident bird sang.
[7] Sum of whole or fractional territories as determined by clusters of points representing song sites within 200 feet of trail on date when the species population was at maximum.
[8] v = nonresident vagrants.

TABLE 2—*Continued*

	Total count per mile[2]	Width of specific strip[3]	Total count in specific strip[4]	Song count in 200-foot strip[5]	Song frequency[6]	Territories in 200-foot strip[7]
American Goldfinch (*Spinus tristis*)	1.0	50 + 50	0.5	0.18	0.25	0.9
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	3.1	50 + 50	1.0	1.73	0.72	0.8
Field Sparrow (*Spizella pusilla*)	2.6	200 + 200	2.7	1.36	0.60	2.8
Song Sparrow (*Melospiza melodia*)	0.4	200 + 200	0.4s	0.14	0.75	0.3

(5) *Number of traverses.*—Because the calculated values obtained in these transect censuses apply to the number of birds in the strip at the moment of counting, traverses over a route may be repeated and averaged. To avoid complications related to seasonal or breeding cycle changes, such traverse replications should be made within a limited period, ideally on successive days. For reasons explained in the next subsection, the number of replications in a series is limited to about 5 when song frequency measurements are involved. Double (10) or triple (15) series may, of course, be used. Where a composite record for an entire breeding season is desired, as in traditional spot-mapping censuses, several series of counts will be needed, perhaps one 5-day series every 2 weeks.

Determining song frequencies.—The conversion of transect counts of singing males to population densities requires measures of mean song frequency for the area and season in which the counts were made. A series of observation periods at territories located along the census route can provide a record of the mean incidence of singing by their resident occupants. This operation can be coordinated with the transect count operation to provide song incidence records efficiently for the same population and periods as those covered by the count.

A simple strip map of the route (scale about 1:2400) showing prominent landmarks to 200 feet laterally should be prepared at the start. I carry a set of such strip maps, one for each resident species, on my clipboard beneath the census tally sheet for the day. On these maps I plot the position of each detection point as a colored symbol and draw lines to indicate a bird's movements from perch to perch. I use a different color on the maps for each traverse, and as I can clearly discriminate only five colors of small dots on a map, I set five as the number of traverses in a series. Each map thus provides the complete record for a species over a series of 5 traverses. Obvious clusters of differently colored symbols and lines delineate the territories of localized males on these maps, and song frequencies can be read directly as the number of color-distinct song symbols in a cluster (from 0 to 5) divided by the number of visits or checks of the territory in a series—always five. In this system a species with six recognizable territories along a strip provides a sample size of 6 × 5 = 30 song checks. Mean frequency values obtained in this way will be too high if the count of territories is incomplete because of the presence of nonsinging males (zero frequency) that fail to reveal themselves by any cue during the five visits to their territory, or that are detected by nonsong cues only once or twice and classed as nonterritorial birds.

The additional time needed for the double entry of detections in this coordinated transect-song check procedure is negligible, and the attention needed for carefully

TABLE 3

THREE DENSITY ESTIMATES (BIRDS PER 100 ACRES) BASED ON THE CENSUS DATA PRESENTED IN TABLE 2[1]

	Transect method		
	Based on all detected cues[2]	Based on song cues and adjusted for song frequency[3]	Plot-map method[4]
Mourning Dove	4.8	6.6	7.5
Yellow-billed Cuckoo	0.4	v	v
Common Flicker	6.0	12.4	11.7
Red-bellied Woodpecker	0.9	—	1.9
Downy Woodpecker	5.2	—	15.0
Great Crested Flycatcher	0.4	—	1.5
Blue Jay	17.2[5]	—	30.1
Black-capped Chickadee	25.1[6]	—	33.1
White-breasted Nuthatch	0.2	—	0.8
Red-breasted Nuthatch	3.4	—	3.8
House Wren	7.8	11.9	11.7
Gray Catbird	15.7	31.4	29.7
Brown Thrasher	20.1	19.7	22.8
American Robin	32.2	28.8	30.8
Wood Thrush	7.4	14.0	13.7
Cedar Waxwing	4.9	—	4.1
European Starling	0.9	v	v
Common Yellowthroat	1.3	4.9	3.8
Red-winged Blackbird	1.0	1.6	1.3
Northern Oriole	1.1	3.7	3.4
Common Grackle	41.0	v	v
Brown-headed Cowbird	18.4	15.7[7]	20.7[7]
Cardinal	21.0	20.3	26.3
Rose-breasted Grosbeak	6.4	12.6	15.8
Indigo Bunting	1.7	3.2	3.4
American Goldfinch	3.7	3.0	3.8
Rufous-sided Towhee	7.5	6.0[8]	4.9[8]
Field Sparrow	5.7	9.4	10.5
Song Sparrow	0.7	0.8	1.1

[1] No values are given in column 2 for nonsinging species and in columns 2 and 3 for species that were represented only by vagrants (v).
[2] Calculated for 100 acres from column 3 in Table 2
[3] Calculated from column 4 in Table 2 and adjusted for song frequency (column 5) and for undetected females.
[4] Calculated from column 6 in Table 2 and adjusted for undetected females
[5] Fledged juveniles (est. 2 per average family flock of 4) have been subtracted
[6] Fledged juveniles (est. 4 per average family flock of 6) have been substracted
[7] Observed sex ratios of cowbirds suggest an average of about two females per male. Male territories were very large and difficult to plot.
[8] Only one of the two singing males on the tract was paired

placing the symbol on the map is complementary to, rather than competitive with that needed for assigning a lateral distance value on the tally sheet.

Conversion to absolute density estimates.—The adjustment or conversion factor for a count of singing males in a song-cue transect strip is the reciprocal of the song incidence for that population and period. This holds for both high and low song frequencies, a low frequency simply indicating the need for a large adjustment. The method is thus applicable over wide ranges of singing activity.

Densities computed for a song-cue strip should be converted to standard units such as birds per 100 acres or square kilometers. Where the strip width for a species has been set as 200 feet on either side of the trail, one mile of strip will cover 48.5 acres. Conversion to birds per 100 acres in this case is accomplished by multiplying the density in the strip by 100/48.5 = 2.06.

To obtain total population density for a species, the value obtained for male density must be adjusted for the uncounted females. For monogamous singing species in the Wisconsin test area I applied the imprecise but not unreasonable assumptions that the song tallies reflected both resident and vagrant males, and that

TABLE 4

SINGING INCIDENCE OF TERRITORIAL MALES AT MADISON, WISCONSIN, DURING FIVE PERIODS BETWEEN 18 JUNE AND 17 AUGUST 1974.[1]

	18–29 June		1–7 July		14–19 July		21 July–5 August		12–17 August	
	Inc.	N	Inc.	N	Inc.	N	Inc.	N	Inc.	N
Mourning Dove	0.37	(30)	0.43	(40)	0.43	(30)	0.27	(30)	0.33	(30)
Common Flicker	0.30	(30)	0.15	(40)	0.18	(40)	+	X	+	X
House Wren	0.70	(50)	0.64	(80)	0.50	(60)	0.60	(20)	—	X
Gray Catbird	0.50	(100)	0.38	(90)	0.31	(110)	—	(90)	—	(120)
Brown Thrasher	0.18	(80)	0.20	(60)	0.03	(80)	—	(60)	—	(70)
American Robin	0.06	(80)	0.19	(90)	0.23	(90)	0.40	(10)	—	X
Wood Thrush	0.58	(80)	0.43	(60)	0.43	(80)	0.23	(60)	0.03	(30)
Common Yellowthroat	0.35	(20)	0.20	(20)	0.40	(20)	0.20	(10)	—	X
Brown-headed Cowbird	0.60	(50)	0.37	(30)	—	X	—	X	—	X
Cardinal	0.64	(80)	0.54	(80)	0.41	(80)	0.35	(60)	0.40	(50)
Rose-breasted Grosbeak	0.45	(40)	0.10	(50)	0.04	(50)	—	X	—	X
Indigo Bunting	0.65	(20)	0.35	(20)	0.30	(10)	—	X	—	X
American Goldfinch	0.10	(20)	0.15	(20)	0.35	(20)	0.13	(30)	0.10	(30)
Rufous-sided Towhee	0.80	(20)	0.65	(20)	0.80	(20)	0.70	(10)	0.50	(20)
Field Sparrow	0.70	(30)	0.50	(30)	0.37	(30)	0.55	(20)	0.35	(20)
Song Sparrow	0.80	(10)	0.70	(10)	0.20	(10)	0.10	(10)	—	X

[1] Values are the proportions of 4–6-min early morning visits to (crossings through) territories during which the resident bird sang. Numbers in parentheses give the sample size for each value (territories × visits).

the overall sex ratio in the populations was roughly equal. On this basis I simply multiplied the computed male density by two.

Procedures for nonsinging species.—A number of species in a breeding community such as the woodpeckers and jays may have nothing equivalent to the loud and frequent advertisement songs of most song birds, yet remain localized as pairs or small flocks for at least part of the breeding season. Such species can be treated as nonterritorial birds by recording all cues and assuming nearly complete cue frequency within the specific census strip of the species (the nonbreeding season procedure) or, when these birds are foraging in flocks or pairs on delimited home ranges, they can be sampled for total cue frequency in the same manner that singing species are sampled for song frequency. The frequency value can then be applied to the tally of pairs or flocks within the census strip of the species to provide a density estimate for pair or flock units. Adjustment of this estimate to total adult density for the species may then be accomplished by multiplying the number of flocks by an independently derived value of mean flock size. This procedure alleviates the practical problem of counting the individuals in each flock when encountered in the field.

FIELD PROCEDURES FOR MIXED AND TRANSITION POPULATIONS

The seasonal transition from breeding to nonbreeding condition and back is gradual in populations of any given species, and an avian community characteristically contains both breeding and nonbreeding species through much of the year. Thus a census taker will often be confronted with a mixture of species, some needing the all-cue method without frequency adjustments and others eligible for the song-cue method incorporating measurements of song frequency. The choice will generally be determined by the uniformity and frequency of cue production by the birds at the time, and the opportunities available for recognizing and keeping tabs on individual birds as required by cue-frequency measurement procedures. With field operations standardized and restricted to optimum weather conditions, reasonably high uniformity and frequency of cue production can be assumed for most species through much of the nonbreeding season and, for some, throughout the year. Opportunities for individual recognition are provided when individuals isolate themselves on distinct and exclusive territories where they can be visited and checked periodically, and this occurs for many species in the breeding season and for a few throughout the year.

As communities often contain representatives of both categories simultaneously and as a species may change from one category to the other rather rapidly, field procedures should be designed to cover the data requirements for each. This raises no serious problems, and a tally sheet can be planned that provides space for recording all the pertinent information for each procedure. Strip maps are, of course, required for song-frequency measurements and should be included with the tally sheet whenever the use of this procedure for one or more species seems indicated. The choice between simple cue attenuation (all cues) and song-frequency procedures can then be made after the fieldwork is completed with full data in hand. Where density values are obtained for a species by both methods simultaneously, a selection between the two can be made on the basis of size and clarity of the data samples supporting each and on considerations of the basic reliability of the two procedures (see Appendix).

Discussion

The transect method differs from the familiar territory mapping method (see Robbins 1970) in the nature of the density values obtained, in aspects of reliability and accuracy, and in overall efficiency. The summary and comparison of the two methods presented in Table 1 may be useful in selecting the best approach for various types of ecological and behavioral studies. Some of the major considerations are discussed in greater detail below.

Density values.—Transect censuses provide data on the number of birds of each species on a transect plot (strip) at the time the traverse is made. Repeated traverses along the same route within the span of a week or two provide replicate samples of the same population suitable for averaging and other statistical treatments. By contrast, the territory mapping method provides a composite record of the number of individuals of each species resident on the selected plot at one time or another during a breeding season. Repeated visits to the plot increase the completeness of the record but do not constitute replications and cannot be averaged. In the transect method time-bracketed series may be repeated on the same plot at spaced intervals to provide data for an overall record for the season, while in the territory mapping method, provided adequate data are collected, the record may be broken down by periods to provide information on direct species associations or on changes in community structure and distribution as the season advances.

Where the objective of a census operation is to determine mean density values over a large area or an extensive habitat type, a long rectangular strip transecting the area, as provided by the transect method, will produce a better sampling than a compact, truncated plot (of the same size). Where the objective is to measure the populations on a small island or an isolated block of distinctive habitat too small to accommodate an elongate transect strip, the mapping method is preferable.

Where a record of seasonal changes through a full year is desired the territory mapping method is inapplicable. The specific-strip transect method as described in this report may be applied, although the necessary changes of procedure between the breeding and nonbreeding seasons may give rise to errors.

Reliability and accuracy.—Territories that overlap census plot boundary lines present problems for evaluating densities by the territory mapping method. This problem assumes major proportions when species' territories are large in relation to the census plot. Unless information is obtained on the boundaries of such territories outside the plot, the fraction inside, and hence the number of birds represented, cannot be reliably evaluated. The problem of boundary line territories is bypassed in the transect strip method as the census units are simply birds present inside the strip at the moment of counting. For song frequency determinations in the breeding season the samples can be restricted to resident birds whose territories lie across or near the trail and who can thus be assumed to remain continuously within hearing range.

A second source of error in the territory mapping method is in the interpretation of clusters of observation points as territories. This becomes particularly difficult where a species is abundant and territories are contiguous. Supplementary notations of concurrent singing by neighboring territory holders and of behavioral interactions between such neighbors are very useful in locating boundary lines in these cases, but interpretations of the same set of data by several experienced observers may still differ considerably (Svensson 1974, Best 1975, Mannes and Alpers 1975). Transect counts do not require any interpretation of territory boundaries, and the samples for song-frequency measurements may be selected judiciously to avoid territories in confusing situations.

While the transect method escapes the hazards of misinterpreting boundary line overlaps and point clusters on census maps, a fair comparison of the two systems must balance threats to reliability against the threats to accuracy posed by the investigator's inability to verify the two basic assumptions of the variable-strip transect method, completeness of count close to the trail, and even distribution laterally from the trail. Theoretically the former can be covered by adjustments for cue frequency during the breeding season, but remains a serious factor of unknown and variable magnitude at other times; the latter must be controlled as far as possible by selecting census tracts with broad stretches of essentially uniform habitat structure.

Efficiency.—The relative efficiency of the two methods in terms of time and effort is difficult to judge because a single composite density value for a season cannot be equated readily with a series of time-bracketed values distributed through the same season. Using hypothetical values, however, I estimate in Table 1 that to obtain a single composite density value by the mapping method requires roughly twice as many hours as a series of three time-bracketed mean density values based on five transects each. This apparently greater efficiency of the transect method must, of course, be weighed against considerations of the nature of the values desired for any particular study.

Acknowledgments

Much of the fieldwork underlying the development of this method was done with support from grants from the National Science Foundation and The Frank M. Chapman Memorial Fund. In preparing this report I benefitted much from critical comments and suggestions by Joseph J. Hickey, Margaret B. Hickey, Olli Järvinen, and Chandler S. Robbins. This paper is publication No. 79 of the University of Wisconsin Arboretum.

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APPENDIX

As a test for the breeding season transect method described in this paper I conducted a field study combining transect and plot map methods on a tract of mixed woodland in the University of Wisconsin arboretum at Madison, Wisconsin in the summer of 1974. I ran 20 traverses along a 1.10 mile transect route through the tract between 18 June and 7 July, and added 30 traverses between 8 July and 17 August. The census data collected on the first 20 traverses are presented in Table 2, and density estimates calculated from them by the total-cue method, the adjusted song-cue method, and the plot map method are presented in Table 3.

All traverses (1 or 2 per day) were made during the first 3 h of daylight, while walking at an average speed of 0.70 to 0.80 mph along a well-marked trail that looped through the tract. All detections of movements, call notes, and songs for each species were tallied on prepared sheets in columns representing 10-foot strips to 100 feet, then a 100-foot and a 200-foot strip to 400 feet. All detections were also recorded as colored symbols on strip maps of the route to provide the basis for song-frequency measurements. A separate map was used for each five traverses for each species, and the symbols for each traverse were recorded in different colors. The song frequency for a species (column 5 in Table 2) was calculated from these maps by multiplying the number of different colored song symbols in each selected territory (territory crossings during which the bird was singing) by the number of selected territories on the map. The total number of territories (column 6 in Table 2) was my best estimate of the sum of whole and fractional territories lying within the strip.

The values derived by the adjusted song-cue and plot-map methods (columns 2 and 3 respectively in Table 3) correspond closely for most species. As the two are based on different sets of data this correspondence gives credence to the possibility that both reflect the actual density during the census period quite well. It also suggests that the length of the census period, 20 days, was not long enough to reveal any appreciable differences between the maximum density level during the period as measured by the plot-map method and the mean density level for the period as measured by the transect method. Which of the two sets of results is more accurate in terms of the objectives of its respective method rests on the error sources inherent in the two methods as considered in the discussion section of this paper.

Values obtained by the total cue transect method (not adjusted for cue frequency) presented in column 1 of Table 3 are, with two exceptions, lower than those obtained by the other methods, and in a few cases substantially lower. This, of course, is to be expected during the breeding season when resident birds are highly irregular in cue production. In some species it may be attributed in large part to the low detectability of female during the breeding season, but in at least the seven species where song detections (multiplied by 2 to cover females) were used because they gave higher values than the unadjusted values based on all cues (see footnote 3 in Table 2) it clearly involved nonsinging resident males. When adjusted for song frequency (column 5 in Table 2) these values are equated with the song-cue transect values. The total-cue and song-cue methods, of course, cover nonterritorial birds deliberately omitted in the plot-map method.

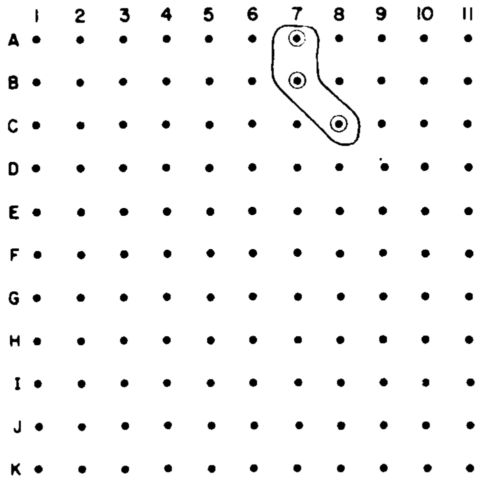
The song-frequency indices used for transect censuses in this paper (occurrence in 4–6 min periods) presumably reflect species-characteristic behavioral traits that will vary in more or less predictable patterns for each species with time of day and stage of the nesting cycle. Individual variations will inevitably occur but, roughly standardized for time of day when frequencies are not changing rapidly, mean values for the populations on a census tract may be expected to show predictable progressive changes as the breeding season advances. If this prediction can be verified with the accumulation of data, it may be possible to apply values for a specified segment of the season to song counts along a census route without recording local song frequencies for every operation.

Song frequencies for 16 species on the Madison census tract are presented in Table 4 for five periods between 18 June and 17 August of 1974. Ten traverses were run in each period to provide sample sizes of 10x the number of sample territories for each species. Incidence values (frequencies) declined for most species as the season advanced. Records for early June would doubtless reveal higher frequencies for these species. Irregular fluctuations presumably reflect the smallness of the sample sizes.

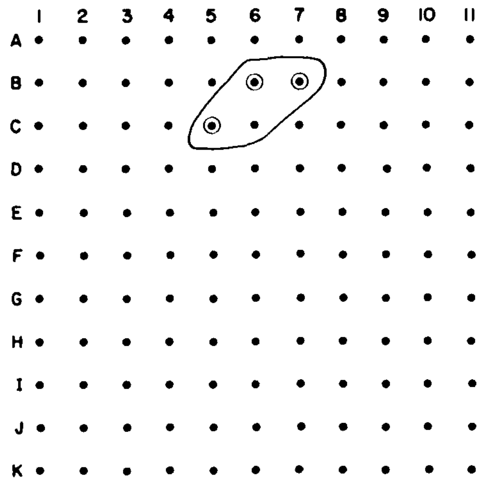
APPENDIX G:

TEST GRID AND RECAPTURE POINTS

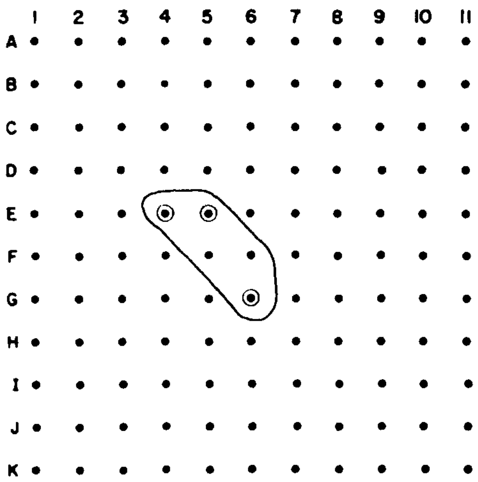
Number: 14
Species: Peromyscus leucopus



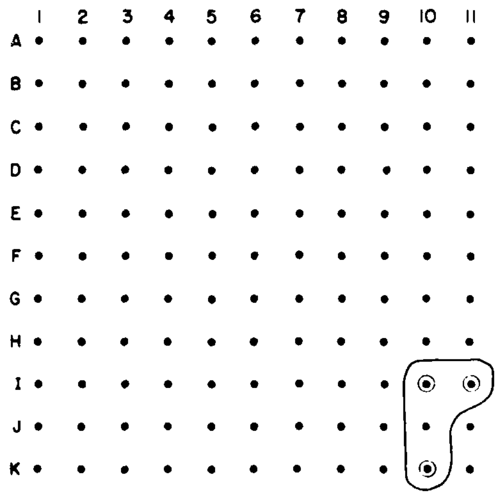
Number: 27
Species: Peromyscus leucopus



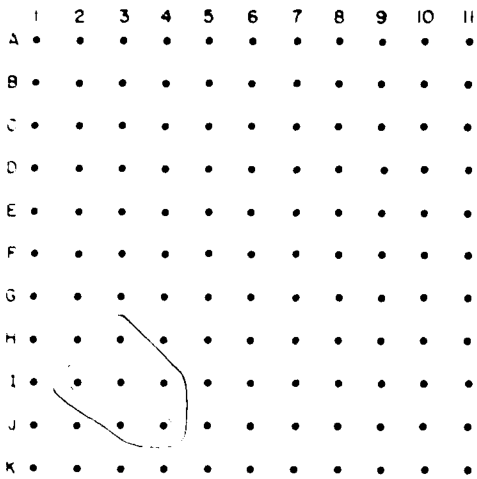
Number: 32
Species: Peromyscus leucopus



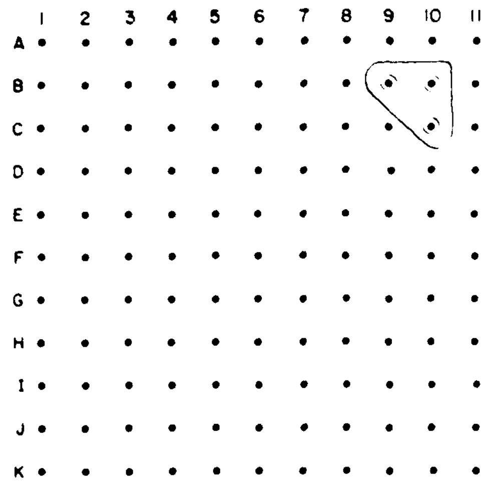
Number: 41
Species: Peromyscus leucopus



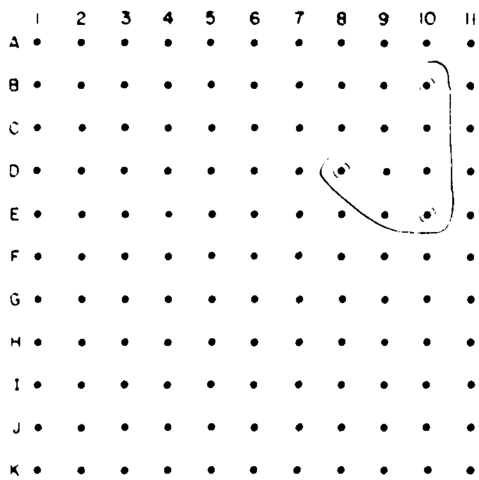
Number 56
Species *Peromyscus leucopus*



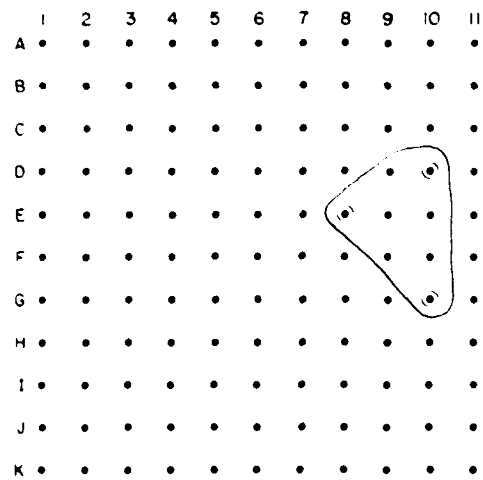
Number 73
Species *Peromyscus leucopus*



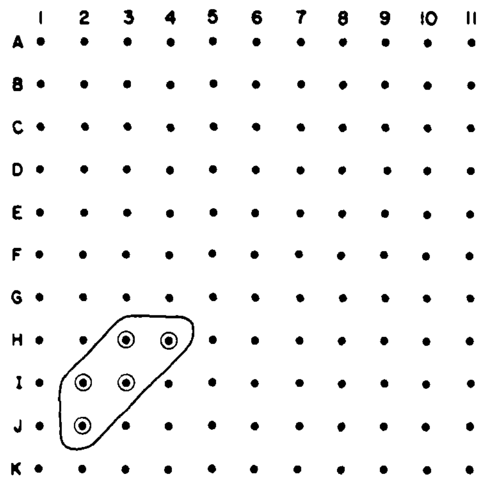
Number 77
Species *Peromyscus leucopus*



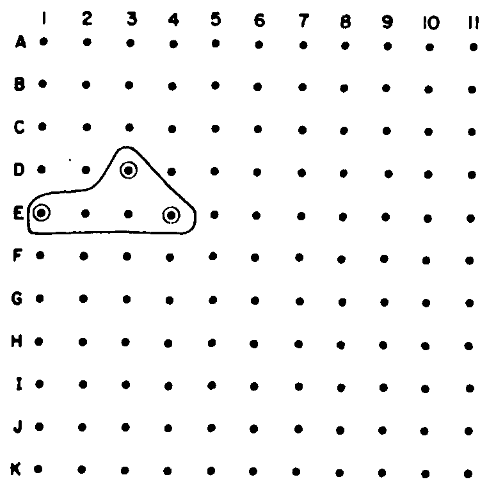
Number 81
Species *Peromyscus leucopus*



Number: 89
Species: *Peromyscus leucopus*



Number: 109
Species: *Peromyscus leucopus*



APPENDIX H:

RECORDING AND ANALYSIS OF FIELD OBSERVATIONS

The following hypothetical example shows how field observations of birds should be recorded and analyzed. The study area (a control grid) is a 16-hectare (39.5-acre) grid. For simplification, only five species are involved: the Cardinal, Blue Jay, Redwinged Blackbird, Grackle, and Carolina Wren. After drawing and copying the map of the grid, a series of symbols is devised to simplify recording of field observations:

1 = Cardinal

2 = Blue Jay

3 = Redwinged Blackbird

4 = Grackle

5 = Carolina Wren

yg = young (if "yg" is not next to the number representing the species, the bird was an adult)

♂ = male

♀ = female (if no symbol for sex is given, then the species does not show sexual dimorphism and sex cannot be determined)

N = active nest

V = vocalizing

R = roosting

F = feeding

T = territorial dispute

→ = direction of flight: beginning of arrow is the point of takeoff, the point of the arrow is the landing point, dotted line after arrow indicates bird continued flight and visual contact was lost or the bird left the grid.

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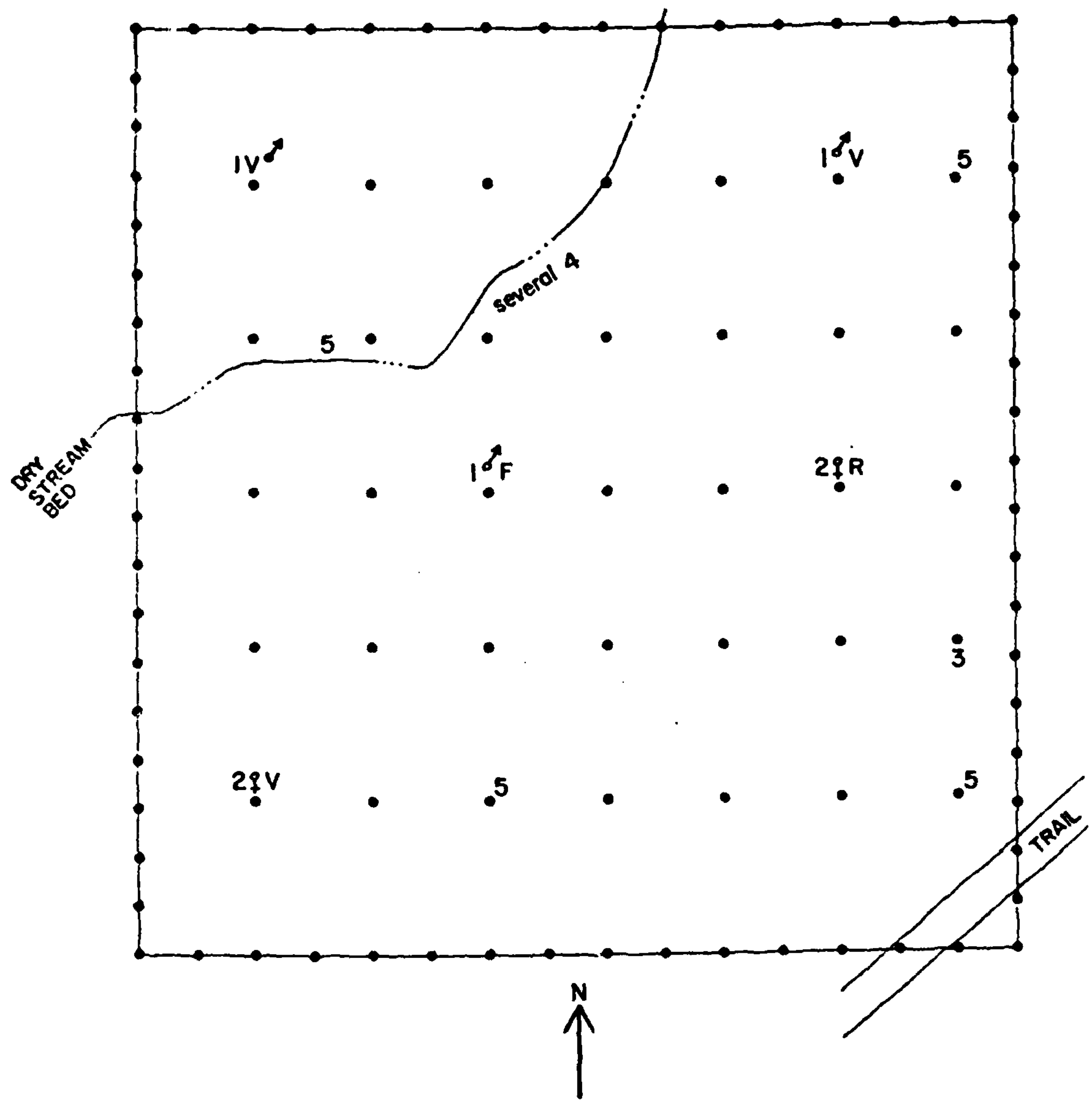
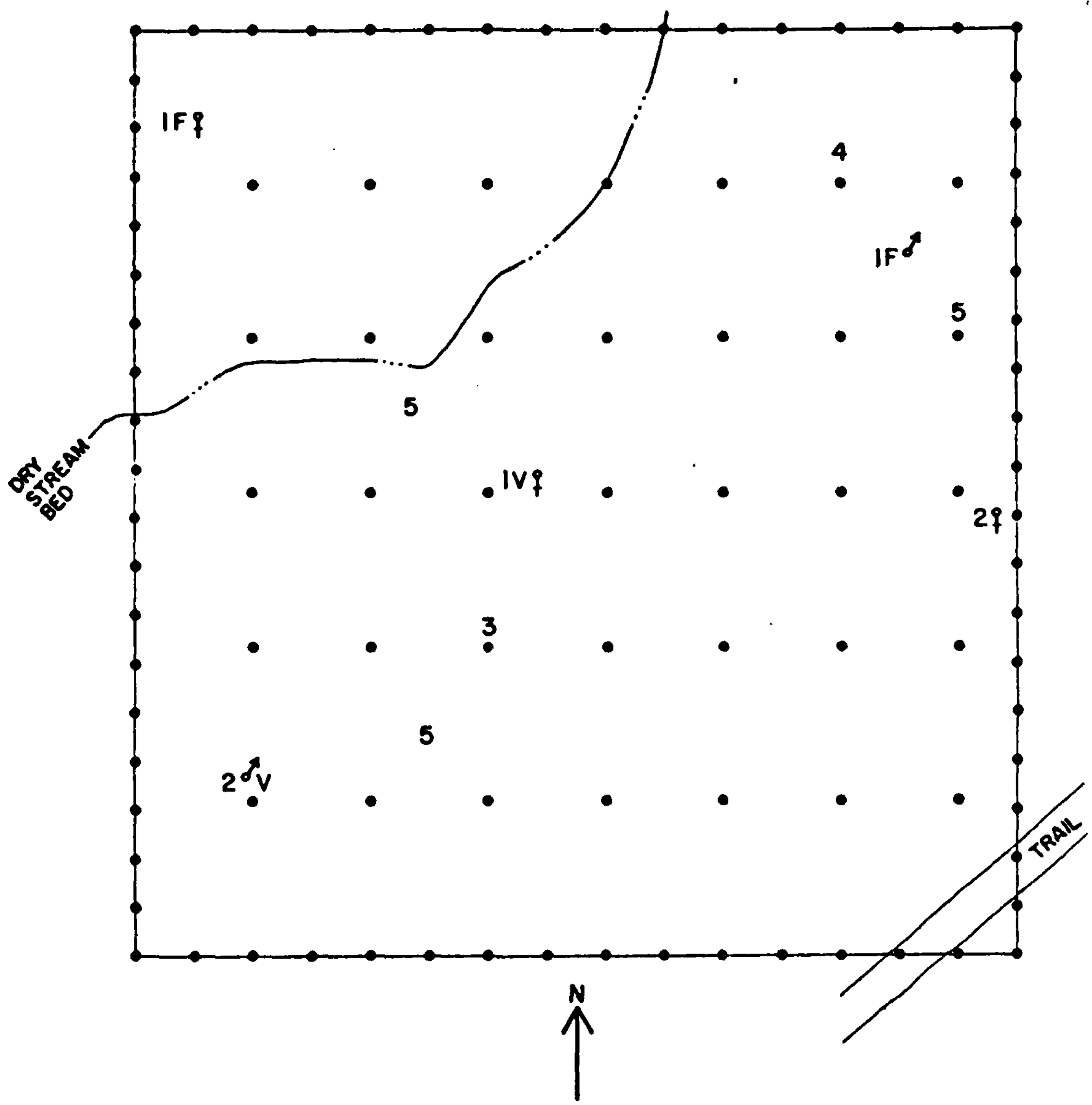
The hypothetical observations were made according to the plan previously described, and each day's "recordings" are given (see Appendix H, pp 192-206). From these data sheets a composite of the recordings for each species was made (Appendix H, pp 207-211).

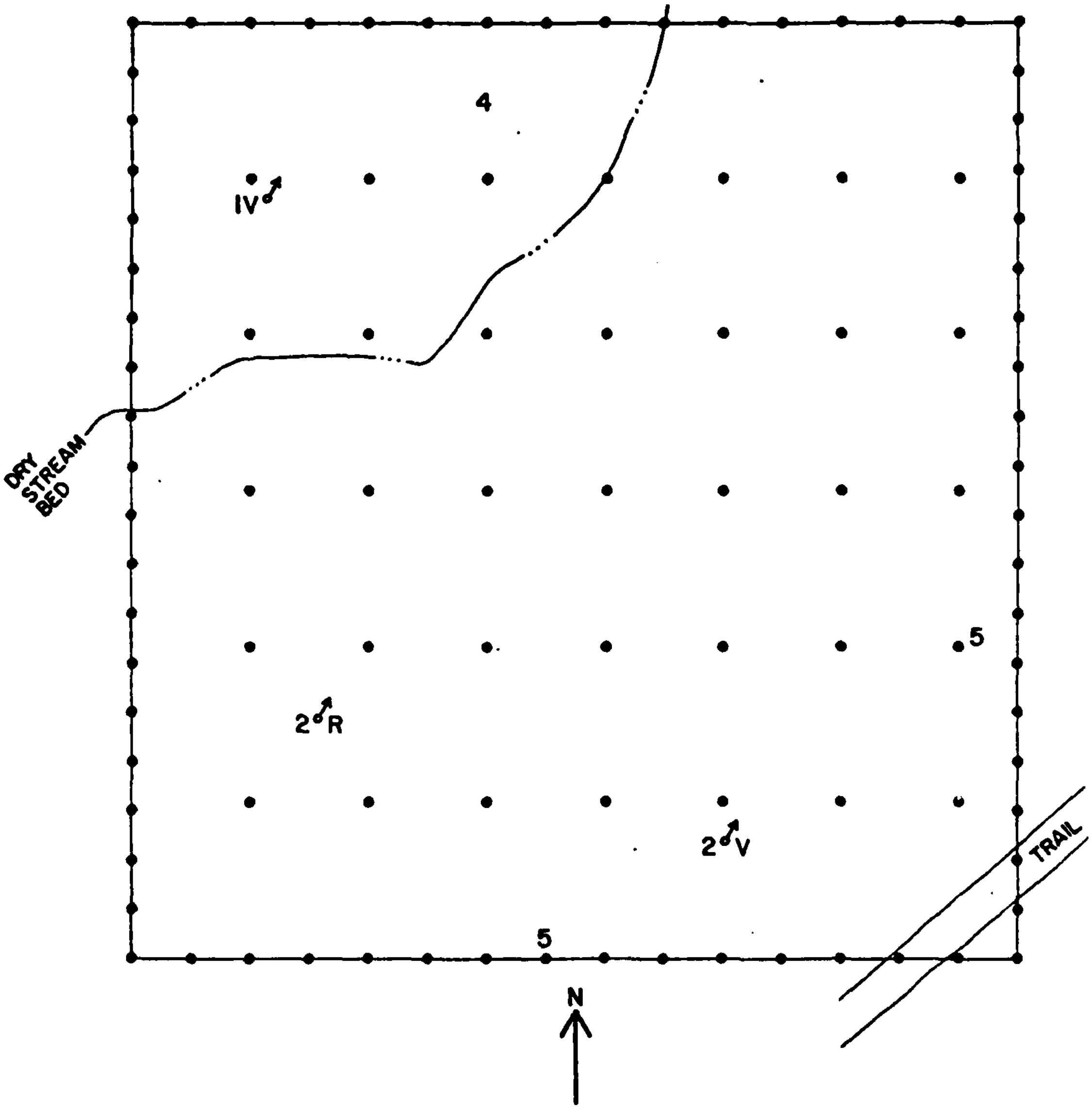
The hypothetical results indicate that there are three breeding pairs of Cardinals (six adult individuals); three breeding pairs of Blue Jays (six adult individuals), with one transient; four breeding pairs of Carolina Wren (eight adult individuals); and a number of transient Redwinged Blackbirds and Grackles.



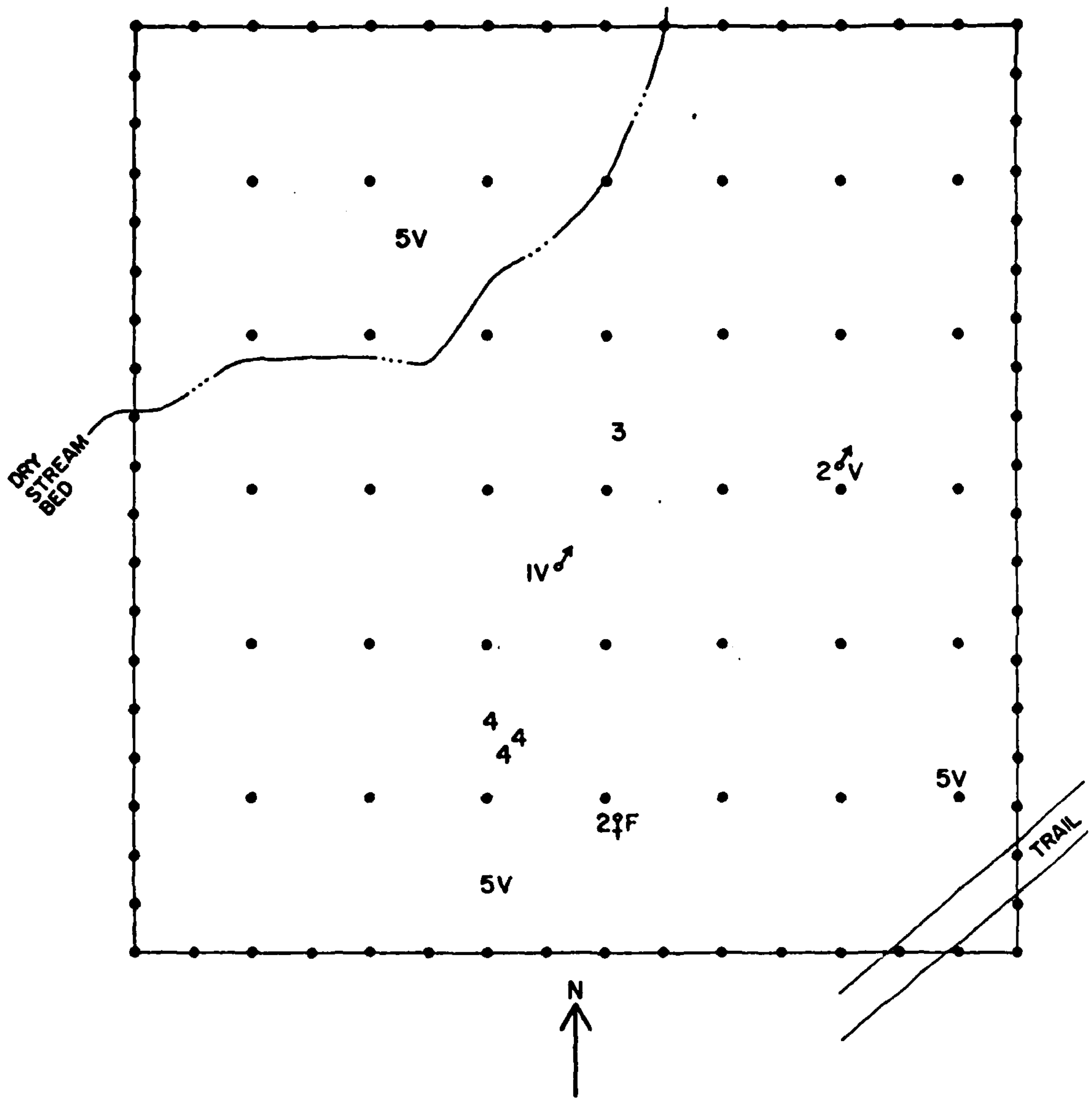
Grid: Control
Date: 17 Apr 77
Weather: Sunny, 83°F
Time: In 5:30 Out 9:30
Total Hours: 4



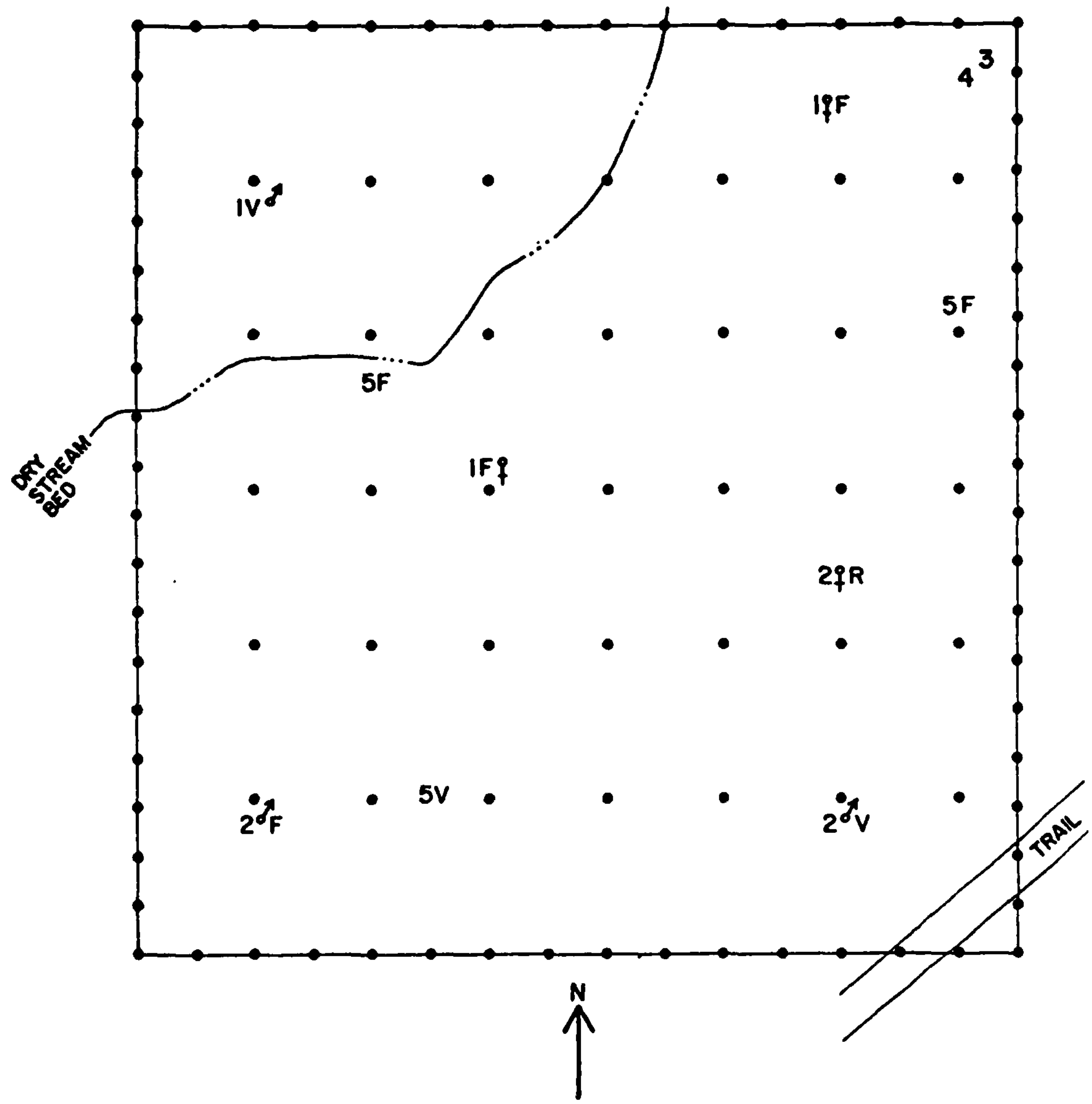
Grid: Control
Date: 18 Apr 77
Weather: Partly Cloudy, 77°F
Time: In 5:15 Out 9:15
Total Hours: 4



Grid: Control
Date: 19 Apr 77
Weather: Cloudy, 73°F
Time: In 5:45 Out 9:45
Total Hours: 4



Grid: Control
Date: 12 May 77
Weather: Sunny, 85°F
Time: In 5:30 Out 9:30
Total Hours: 4



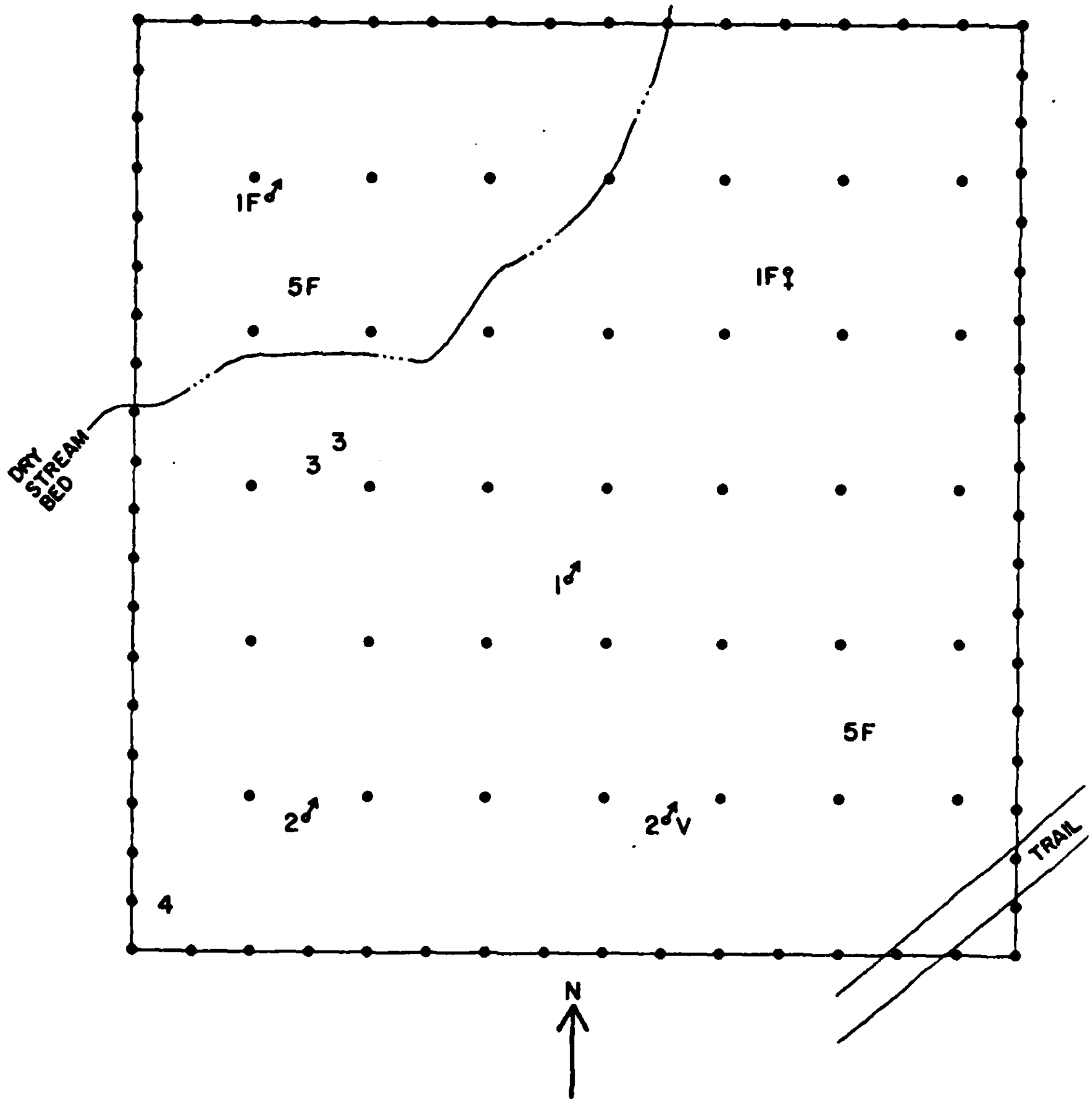
Grid: Control

Date: 13 May 77

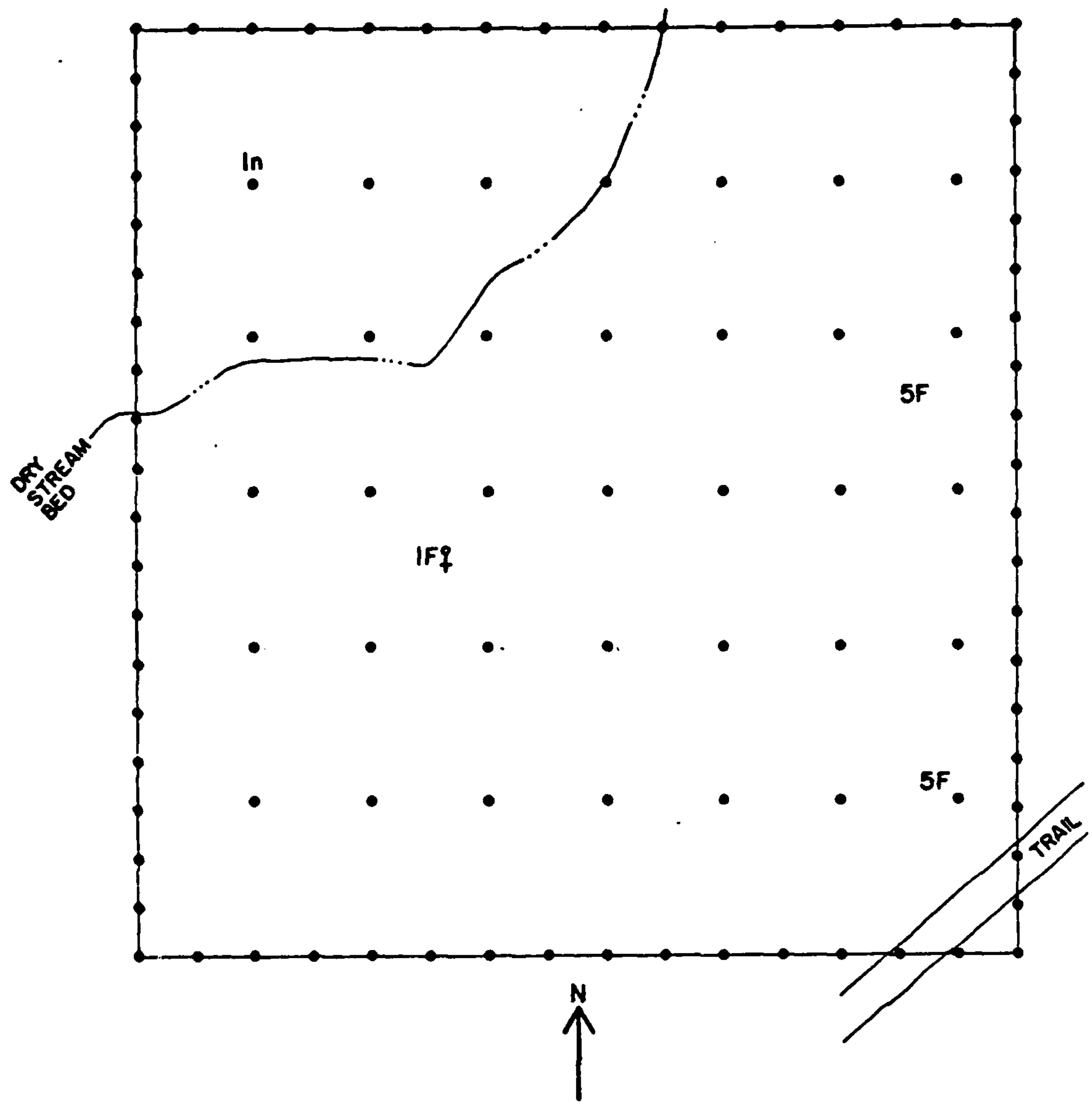
Weather: Sunny, 84°

Time: In 5:30 Out 9:30

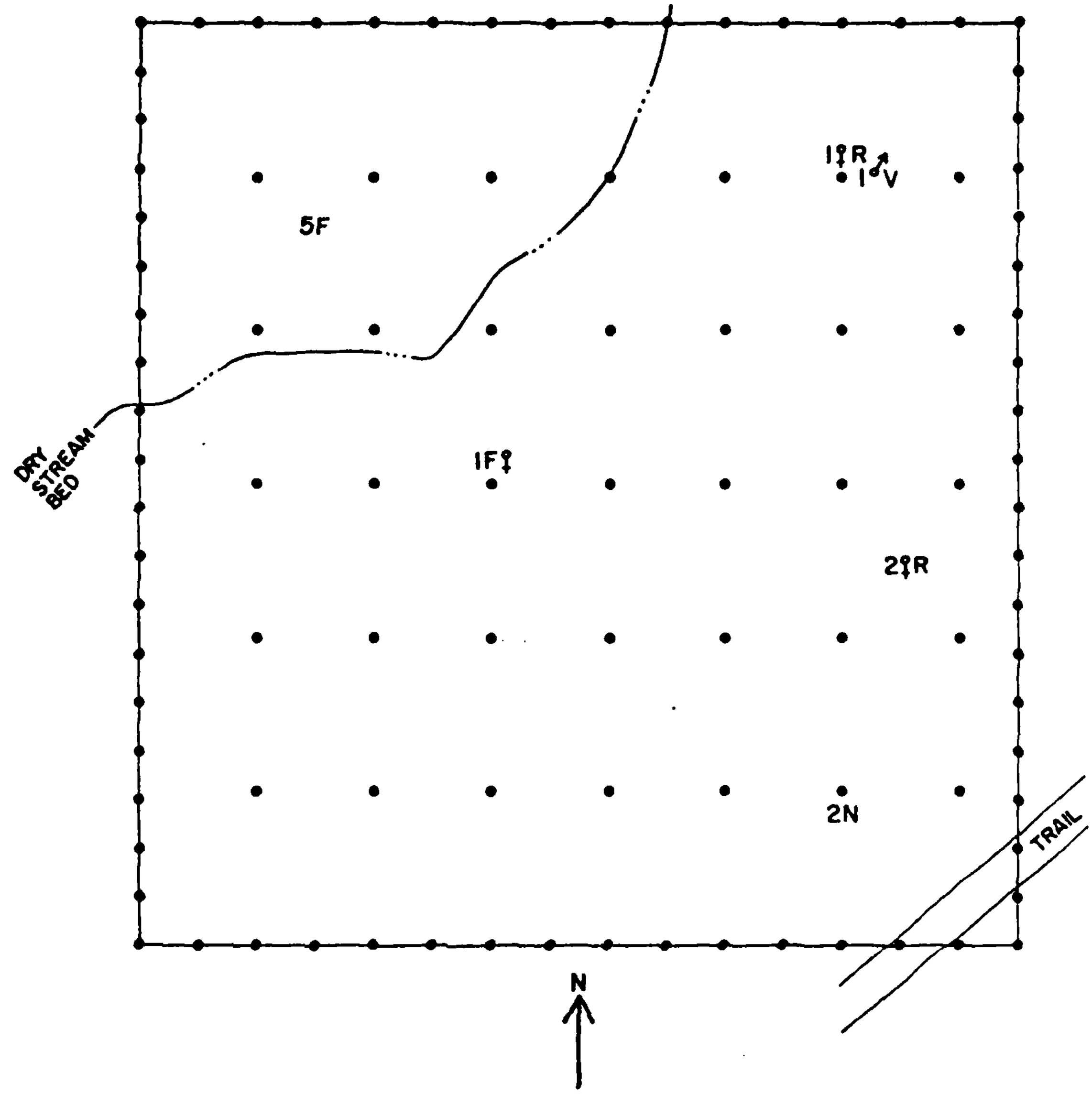
Total Hours: 4



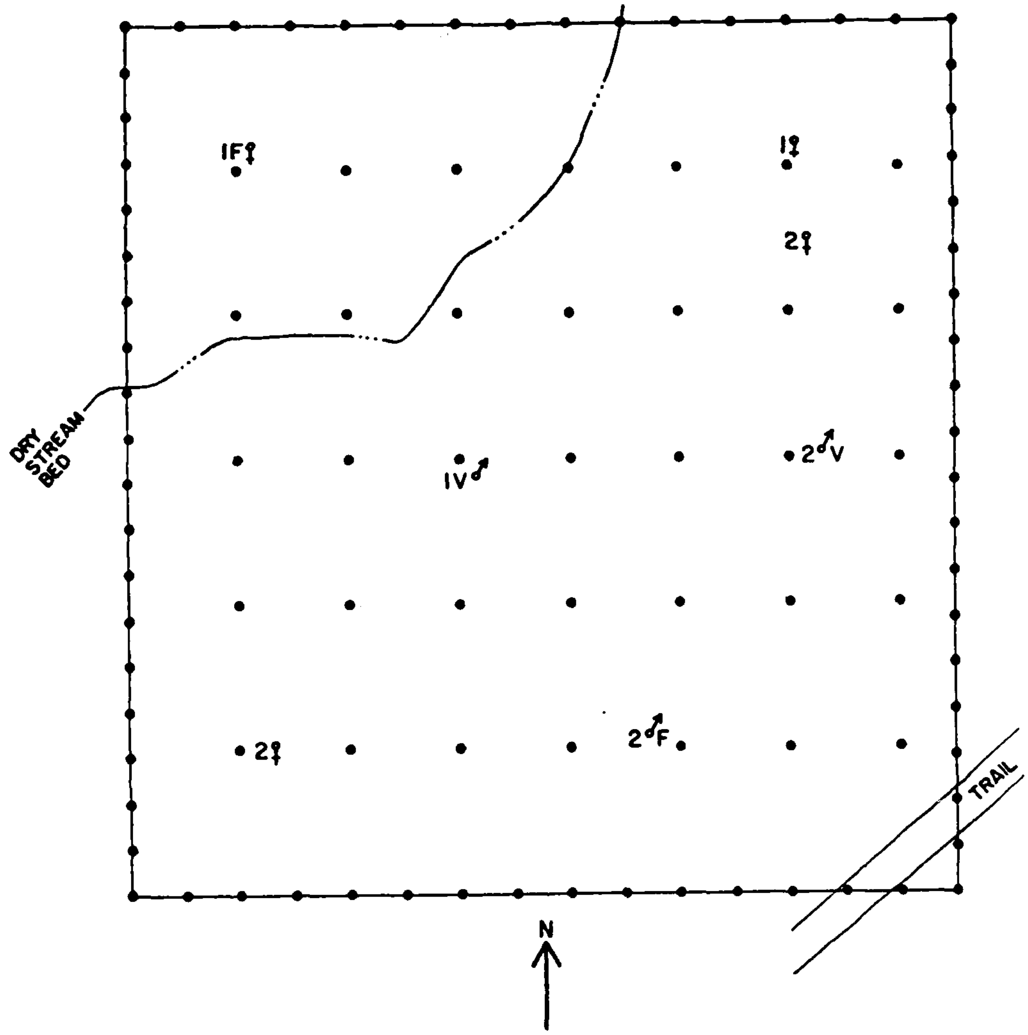
Grid: Control
Date: 14 May 77
Weather: Sunny, 86°F
Time: In 5:30 Out 9:30
Total Hours: 4



Grid: Control
Date: 5 Jun 77
Weather: Partly Cloudy, 86°F
Time: In 5:30 Out 9:30
Total Hours: 4



Grid: Control
Date: 6 Jun 77
Weather: Partly Cloudy, 86°F
Time: In 5:30 Out 9:30
Total Hours: 4



Grid: Control
Date: 7 Jun 77
Weather: Partly Cloudy, 87°F
Time: In 5:30 Out 9:30
Total Hours: 4

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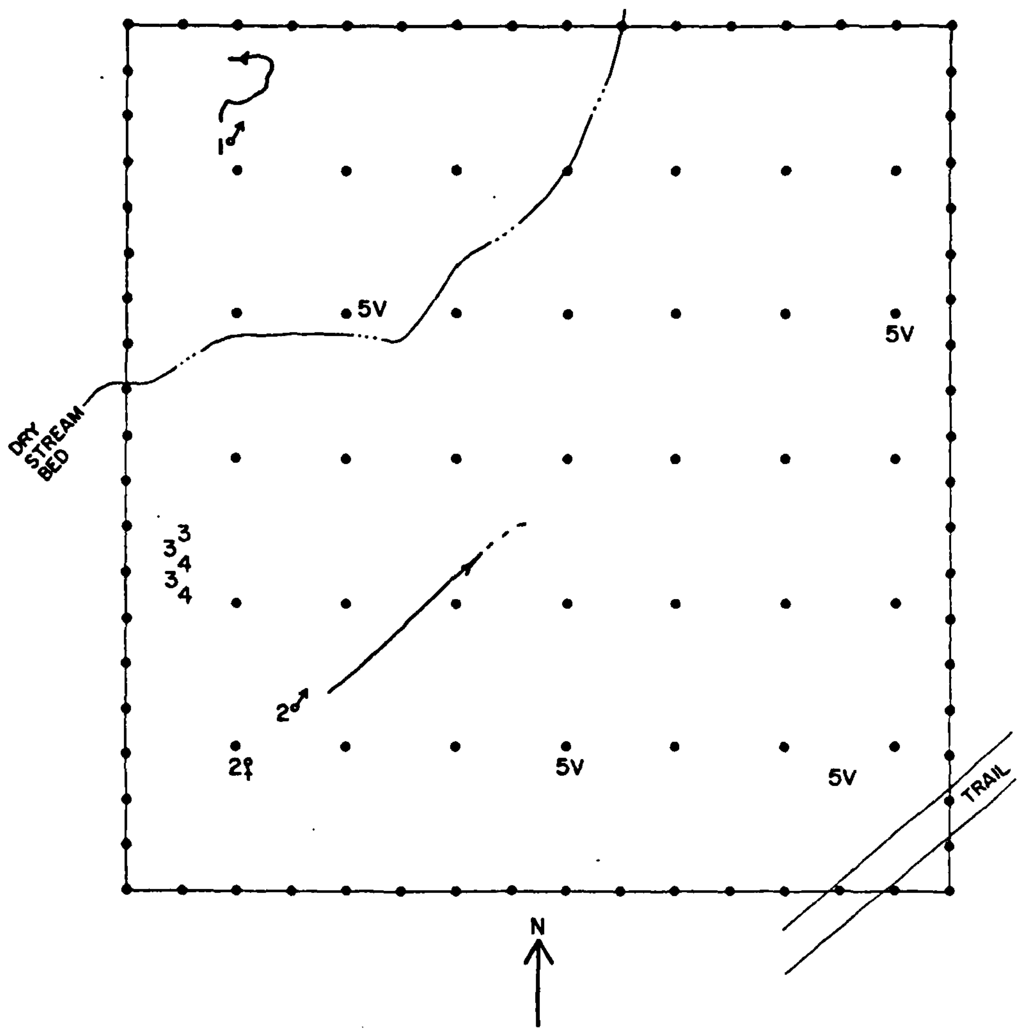

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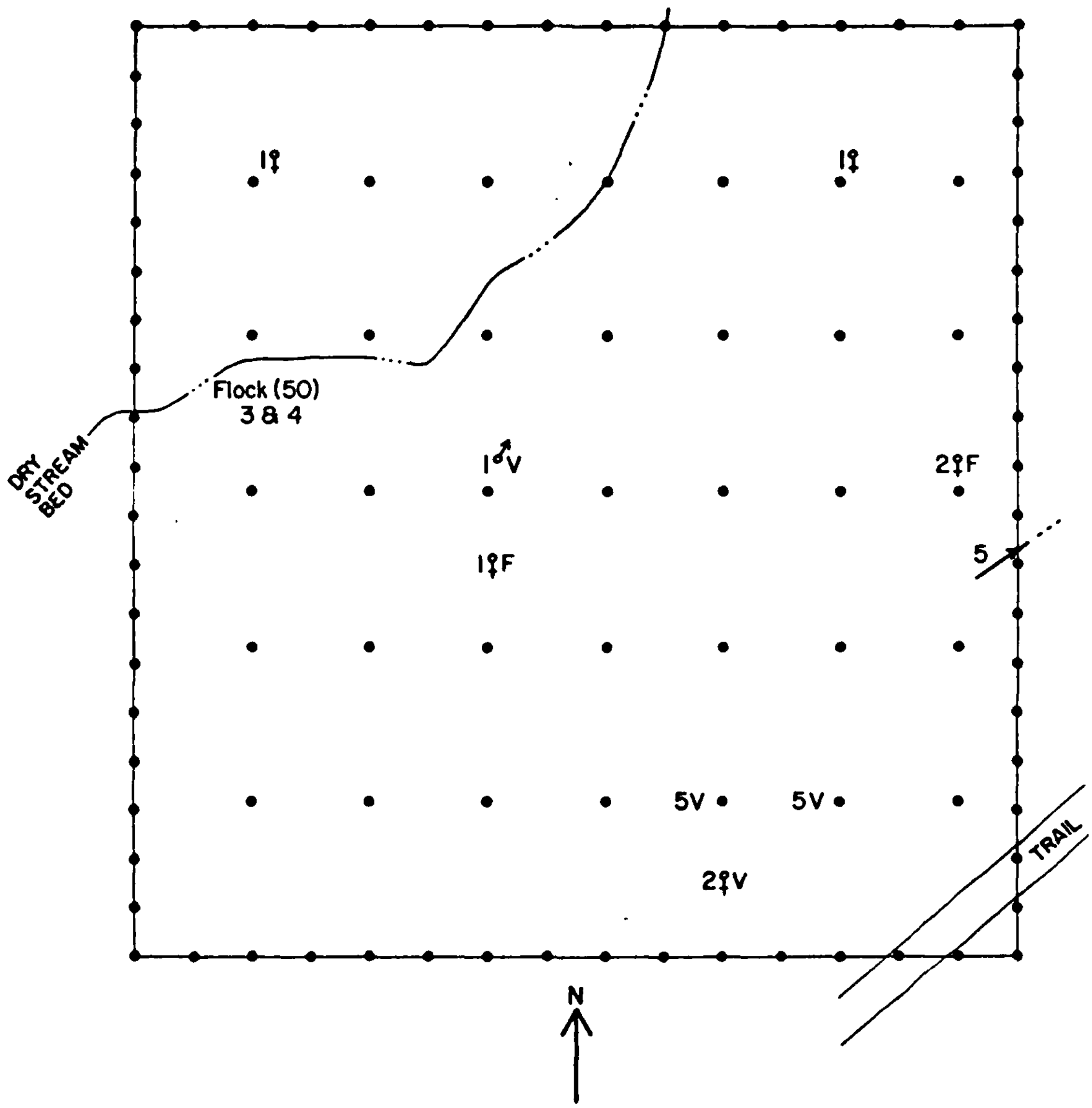
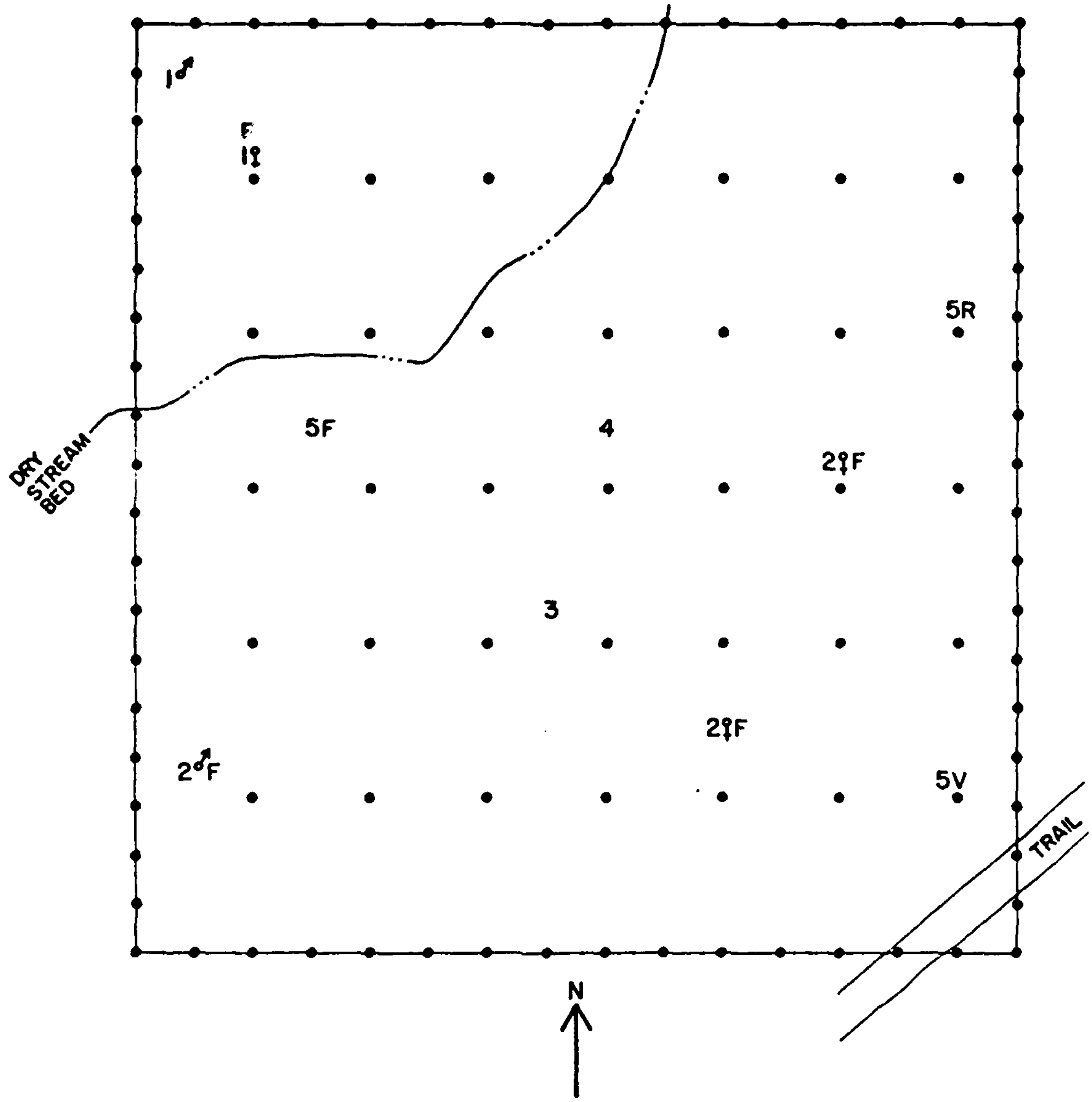
Date: 10 Jun 77
Weather: Sunny, 86° F
Time: In 5:30 Out 9:30
Total Hours: 4



Grid: Control
Date: 11 Jun 77
Weather: Sunny, 85° F
Time: In 5:30 Out 9:30
Total Hours: 4



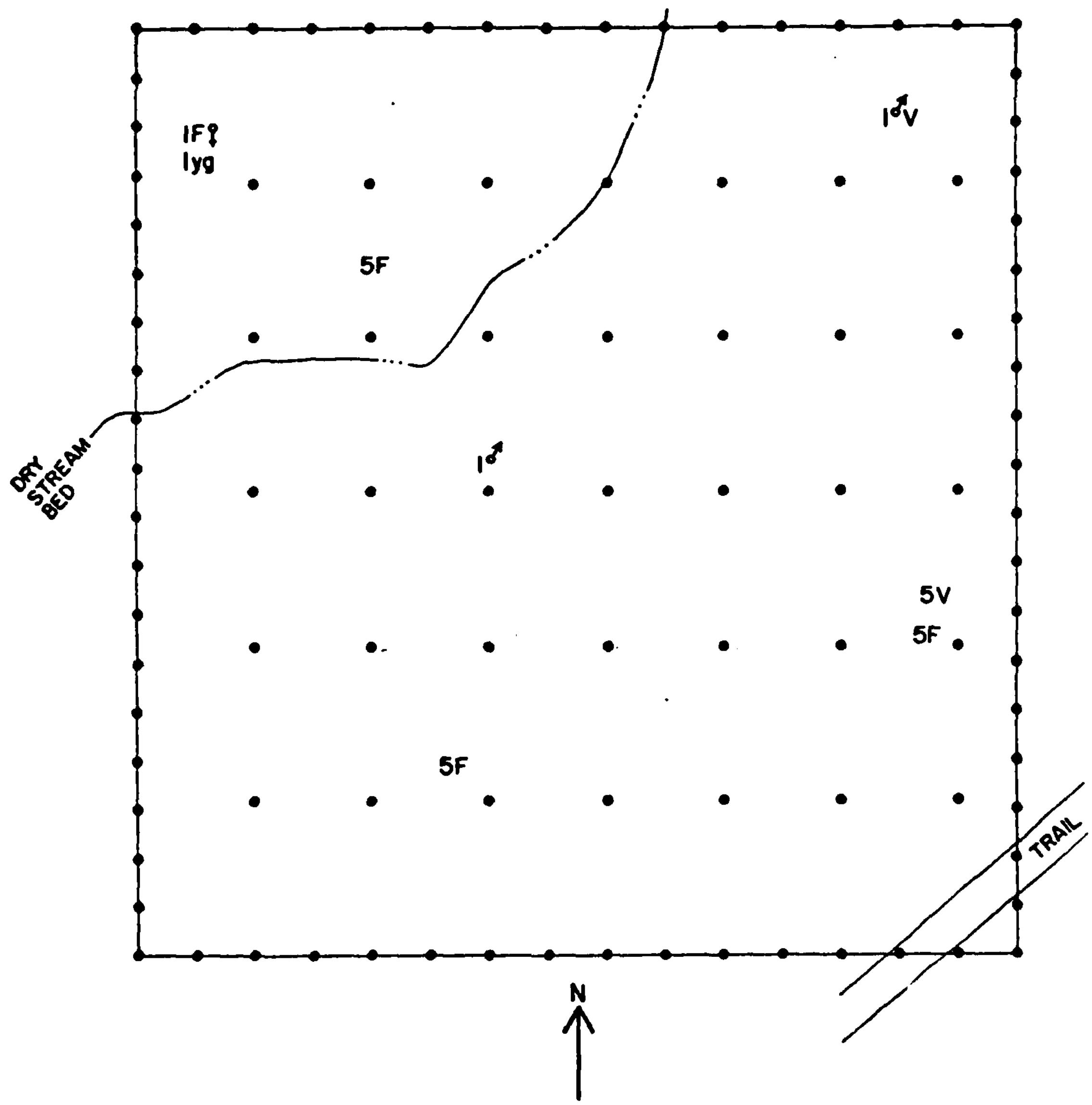
Grid: Control

Date: 12 Jun 77

Weather: Sunny, 86°F

Time: In 5:30 Out 9:30

Total Hours: 4



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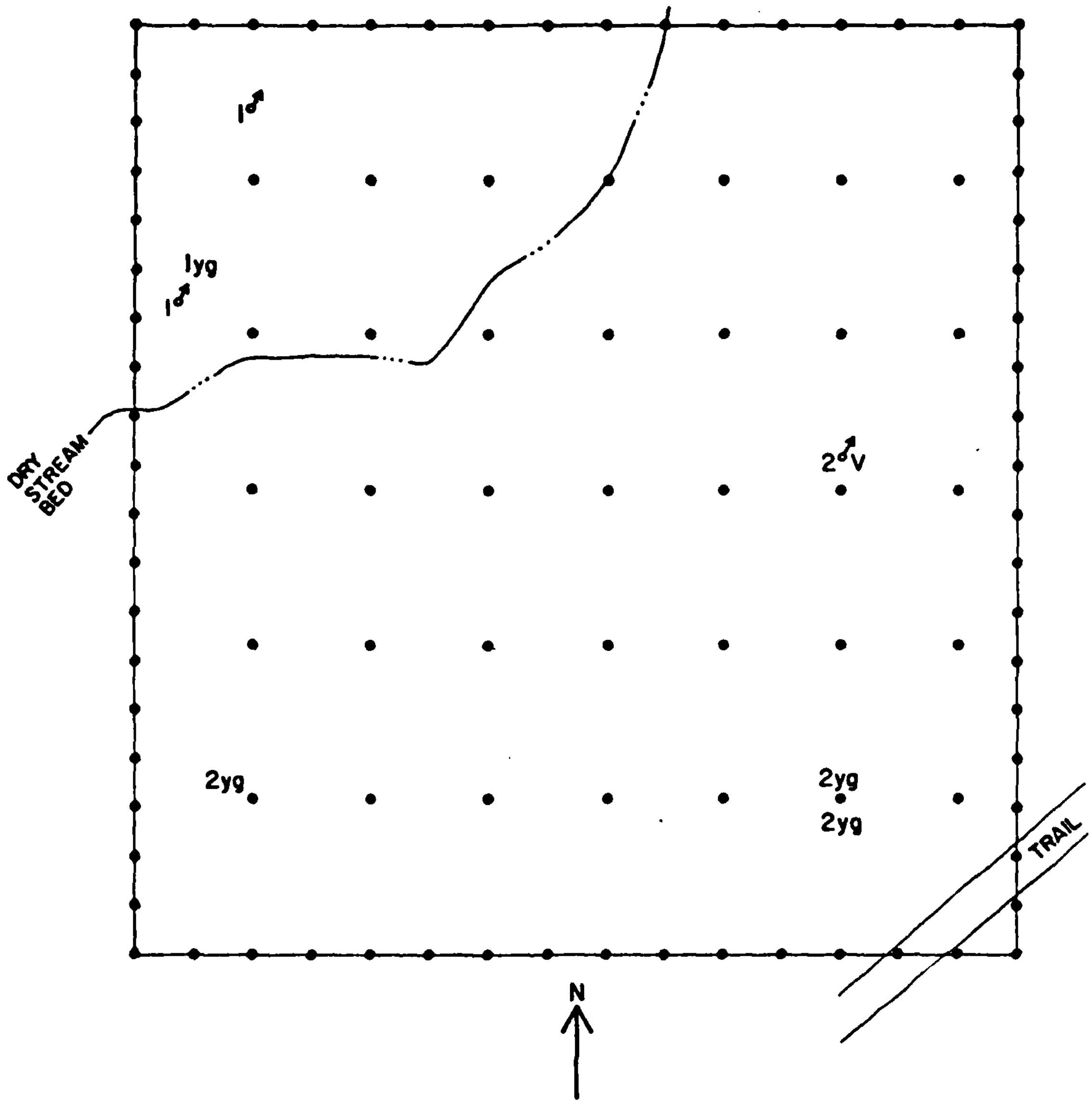
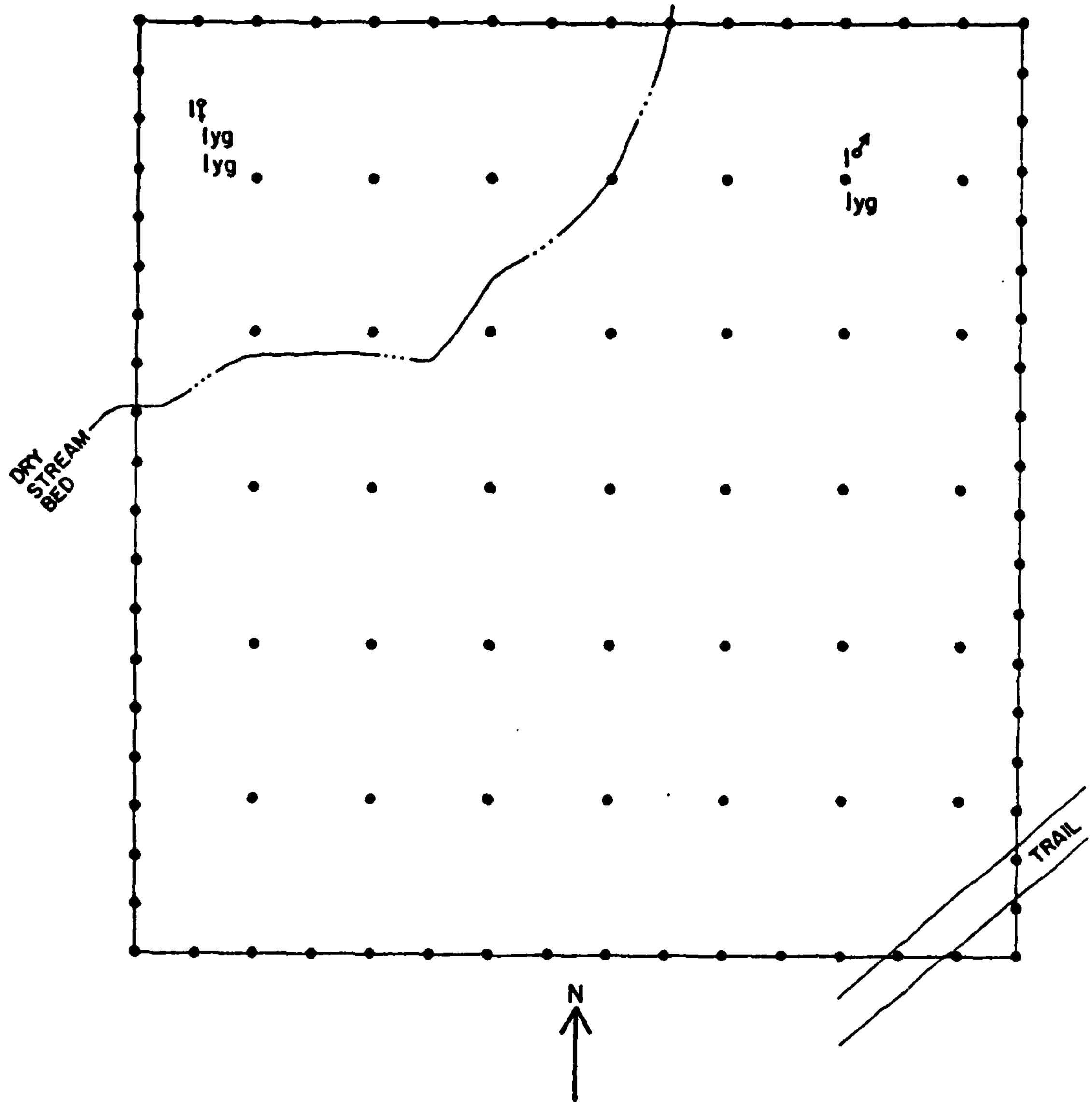
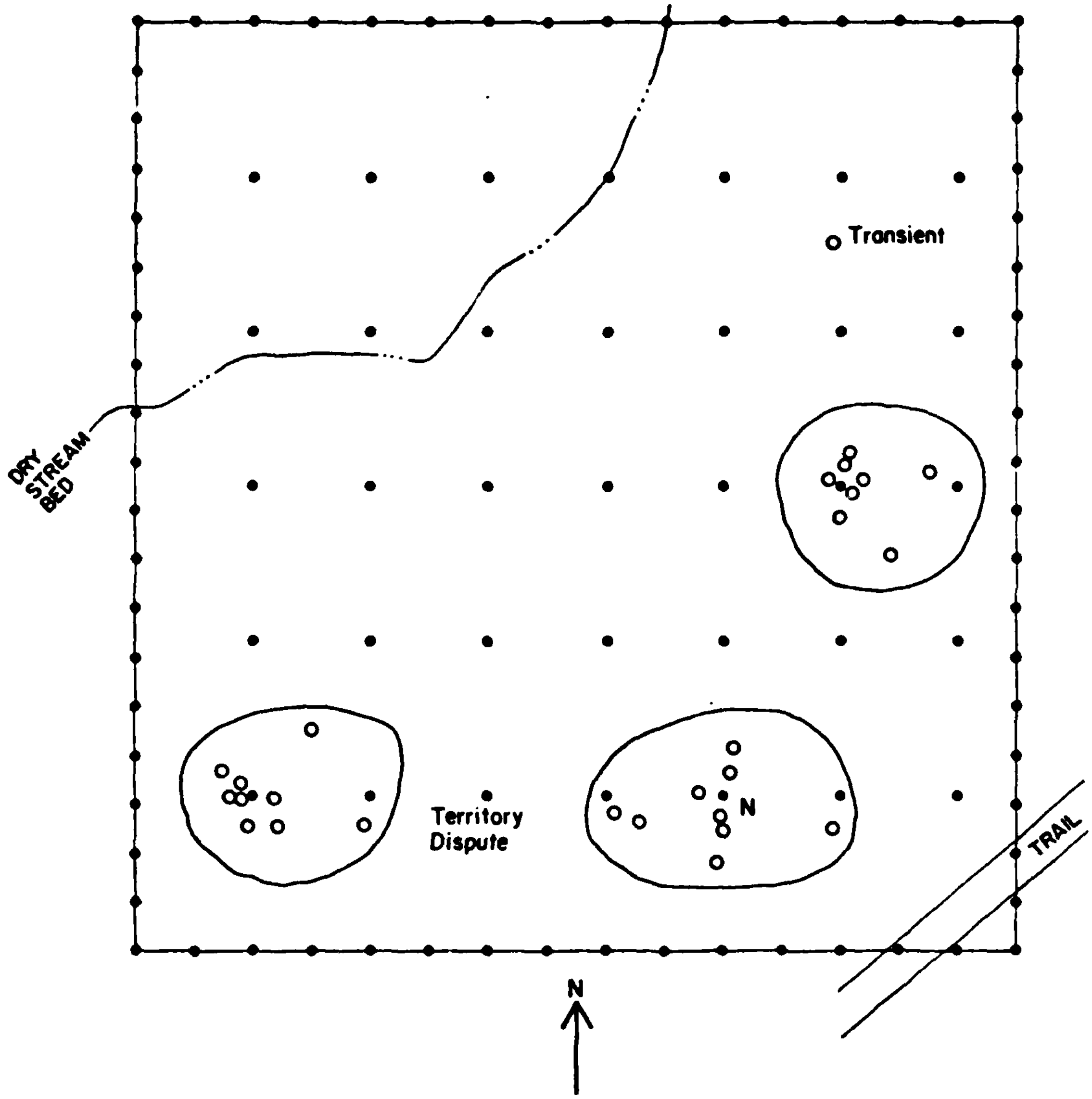
Date: 12 July 77
Weather: Sunny, 89°F
Time: In 5:30 Out 9:30
Total Hours: 4



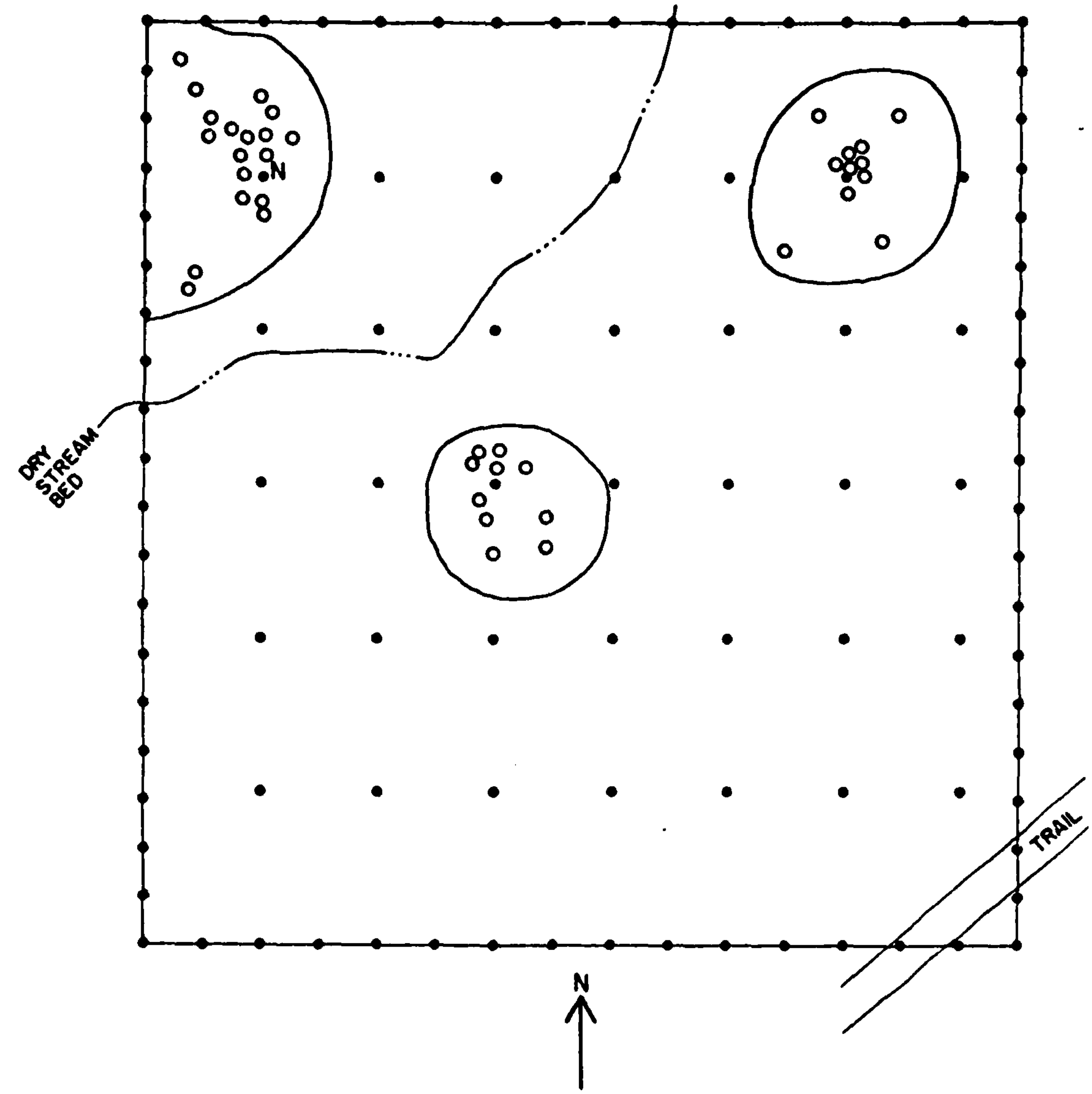
Grid: Control
Date: 13 July 77
Weather: Sunny, 91° F
Time: In 5:30 Out 9:30
Total Hours: 4



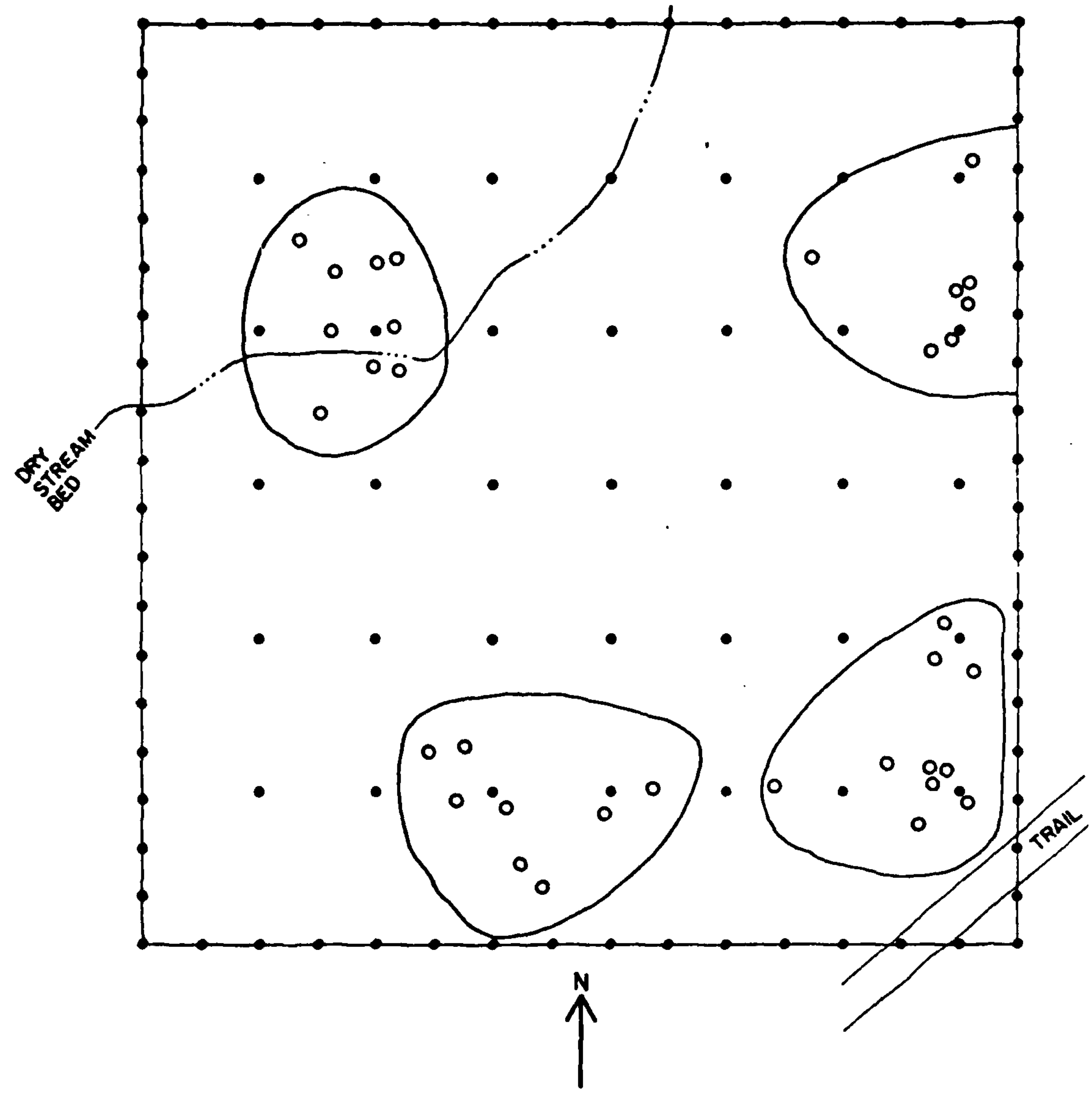
Grid: Control
Date: 14 July 77
Weather: Rain, Drizzle, 85° F
Time: In 5:30 Out 9:30
Total Hours: 4



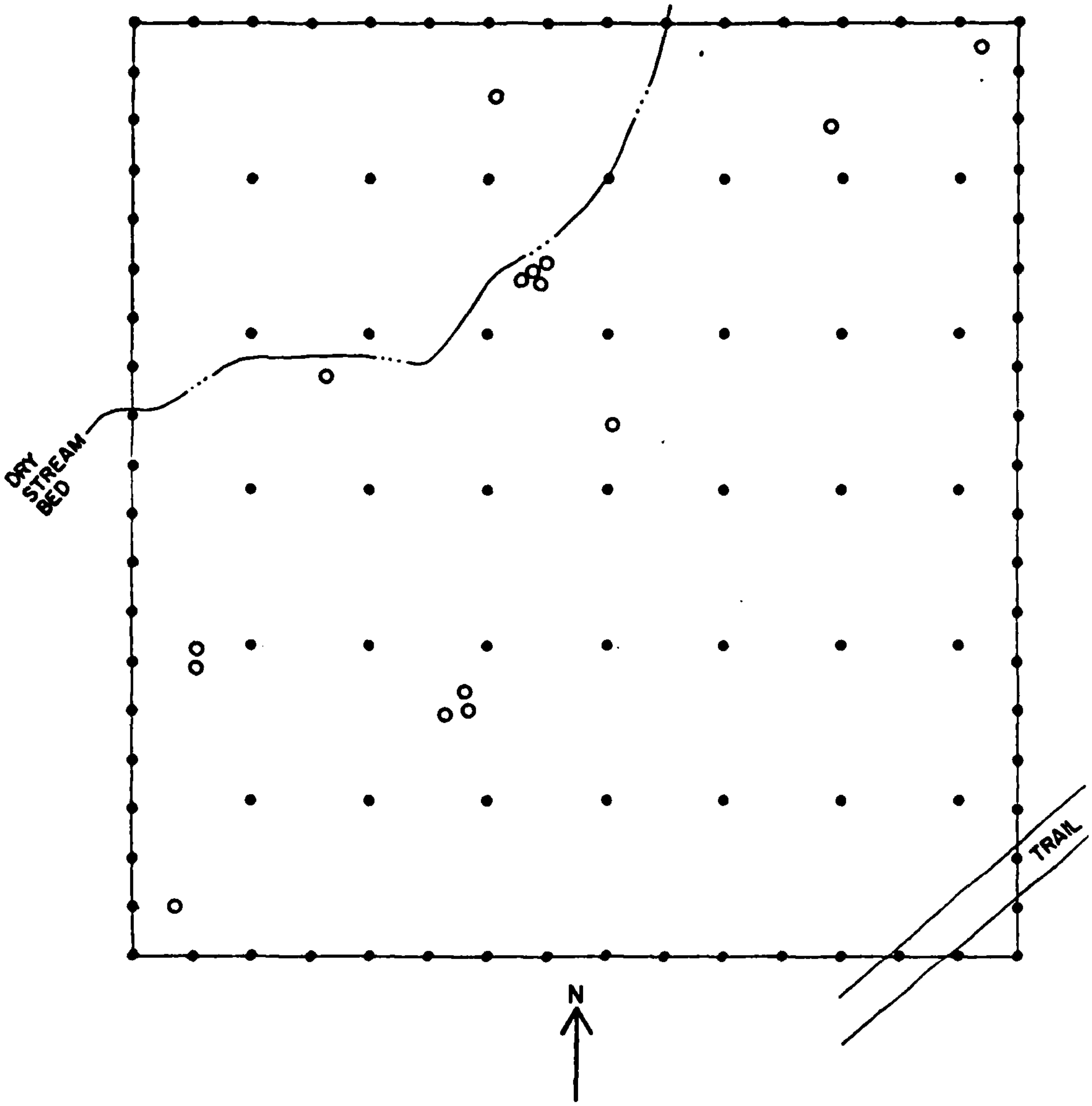
Species: Blue Jay



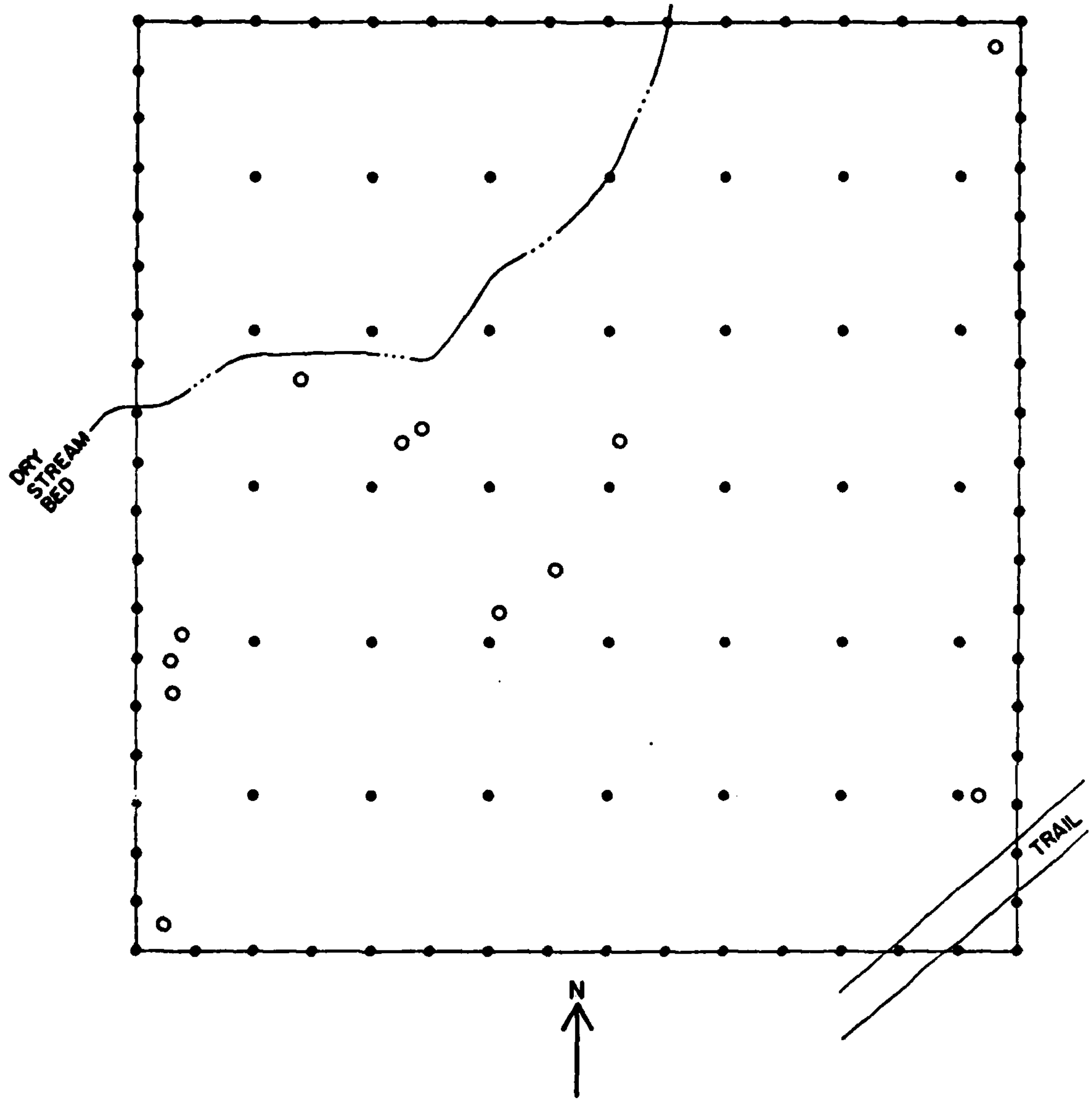
Species: Cardinal



Species: Carolina Wren



Species: Grackle



Species: Redwinged Blackbird

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Sharpe Army Depot
Seneca Army Depot
Tobyhanna Army Depot
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Fort Lewis
Fort McCoy
Fort McPherson
Fort George G. Meade
Fort Ord
Fort Polk
Fort Richardson
Fort Riley
Presidio of San Francisco
Fort Sheridan
Fort Stewart
Fort Wainwright
Vancouver Bks.

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Fort Belvoir
Fort Benning
Fort Bliss
Carlisle Barracks
Fort Chaffee
Fort Dix
Fort Eustis
Fort Gordon
Fort Hamilton
Fort Benjamin Harrison
Fort Jackson
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Fort Leavenworth
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Fort McClellan
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Guidelines for terrestrial ecosystem survey. -- Champaign, IL : Construction Engineering Research Laboratory : Springfield, VA : available from NTIS, 1980.
211 p. (Technical report ; N-89)

1. Environmental impact statements. 2. Ecological surveys. I. Title. II. Series: U.S. Army Construction Engineering Research Laboratory. Technical report ; N-89.

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