United States
Department of
Agriculture

Forest Service

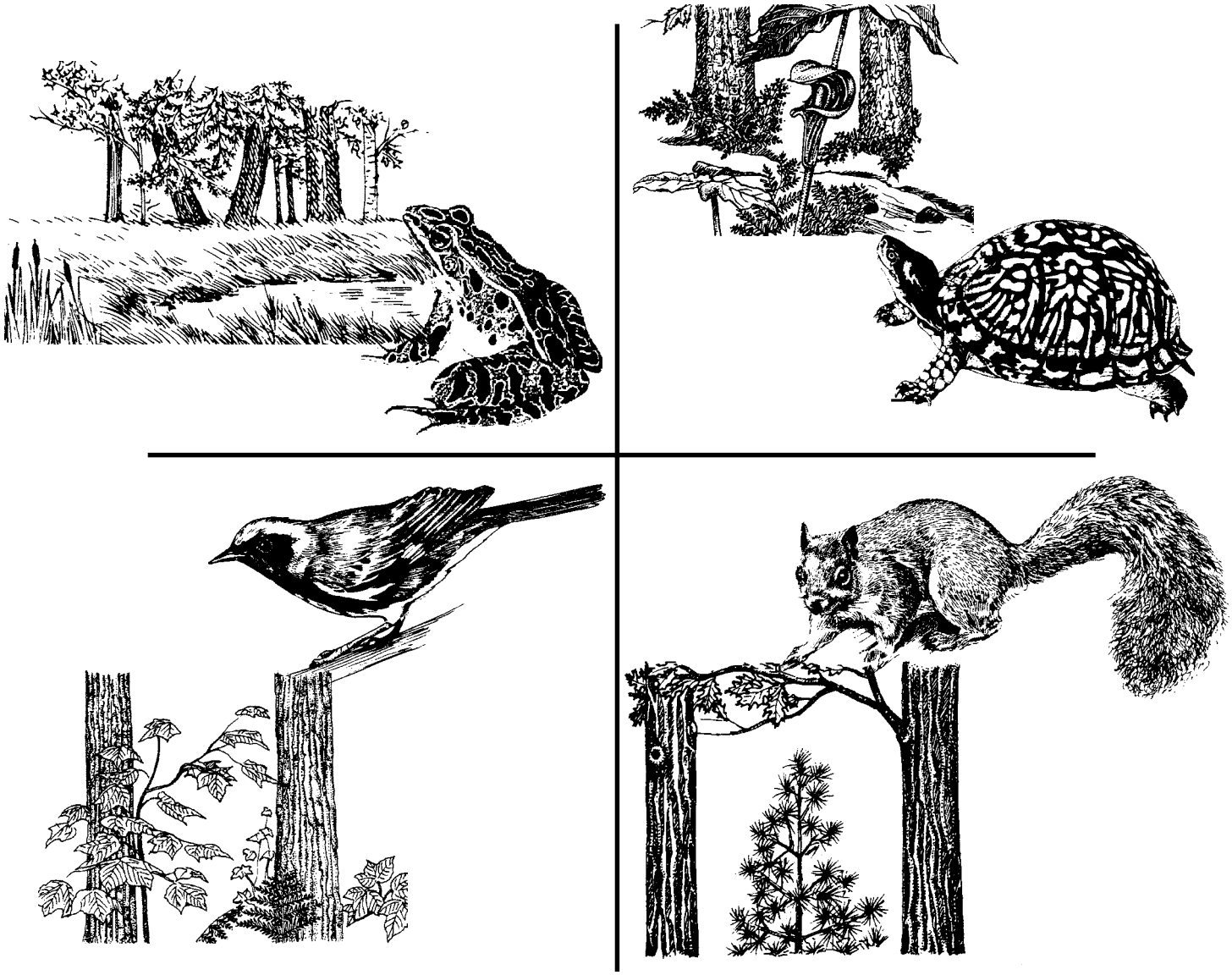
**Northeastern
Research Station**

General Technical
Report NE-283

New England Wildlife:

A Model for Ecosystem Management—ECOSEARCH (Version 1)

Henry L. Short
Jay B. Hestbeck
Richard M. DeGraaf



This General Technical Report was produced on a CD-ROM. No hard copy is available.
The software it describes is not included on the CD, but is available at:
www.mbr-pwrc.usgs.gov/software.html

Abstract

This volume describes how ECOSEARCH species-habitat models are developed using information about the natural history of species, habitat descriptions, and specific descriptors for soils, topography, water regimes, and vertical habitat structure. Also, examples are provided that demonstrate the impacts of: 1) converting a wooded swamp into a recreational lake with adjoining golf course and housing lots in western Massachusetts; 2) converting a mature forest to earlier successional stages for woodcock management on a National Wildlife Refuge; and 3) varying logging practices on a national forest. ECOSEARCH was developed as a first step to a testable, scientific basis for ecosystem management. ECOSEARCH uses a FORTRAN program to predict occurrence for >300 species of New England wildlife using natural history models and information contained in geographic-information matrices. ECOSEARCH is based on the assumptions that many wildlife species are associated with certain habitat attributes that can be estimated from vegetative structure, water regimes, soil types, and topographic conditions. The challenge of predicting species occurrences is to discover the constraints that structure particular ecosystems. The more rigid the constraint, the more reliable the prediction. Data from local landscapes are organized as raster data with 50-m pixels. At present, the vegetative-structure matrix is provided by interpreting a systematic grid of points from aerial photographs. Topography, soil types, and wetlands are provided from a variety of existing sources. The assignment of each pixel as habitat for a given species was determined by first estimating the suitability of the pixel as breeding and feeding habitat using a hypothesized species-habitat model and GIS data from a circular neighborhood, centered on the pixel, and then determining the appropriateness of the geometry between breeding and feeding habitats. Habitat assessments can be made by predicting species occurrences for existing landscapes. Impact assessments can be made by predicting species occurrences for simulated landscapes that reflect proposed development, timber harvest, or wetland modifications.

Manuscript received for publication 1 May 1997.

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

The computer program described in this publication is made available with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone as other than a Government-produced computer program.

Published by:

USDA FOREST SERVICE
11 CAMPUS BLVD SUITE 200
NEWTOWN SQUARE PA 19073-3294

December 2001

For additional copies:

USDA Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640
Fax: (740)368-0152

Visit our homepage at: **http://www.fs.fed.us/ne**

The Authors

HENRY L. SHORT, retired, was the senior scientist for the Northeast Region of the U.S. Fish and Wildlife Service, Hadley, Massachusetts. He has conducted research on deer and species-habitat relationships.

JAY B. HESTBECK was the leader of the Massachusetts Cooperative Fish and Wildlife Research Unit, University of Massachusetts, Amherst, and is now the chief of research for Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland. His background includes work in systems science, statistics, small mammal populations, migratory birds, and species-habitat models.

RICHARD M. DEGRAAF is chief research wildlife biologist and leader of the wildlife habitat research unit, Northeastern Research Station, Amherst, Massachusetts. He has conducted research on breeding bird assemblages in major forest cover types in New England and on habitat associations in the White Mountains for the last 20 years.

Acknowledgments

The development and writing of this publication was a true team effort. Consequently, order of authorship becomes problematic. To give credit where due, we describe the sections for which the coauthors had lead responsibility. Hank Short developed the idea that species occurred in distinctive layers. Hank chose the study sites and applications for South Amherst, MA and Moosehorn National Wildlife Refuge. Hank wrote most of the text and developed the habitat metrics for the Geographic Information Systems data. Jay Hestbeck developed the ideas associated with predicting species occurrence using a sample of point-intercept data, wrote the FORTRAN code for the ECOSEARCH program, supervised the GIS work, and conducted all model predictions and analyses. Dick DeGraaf developed the species-habitat models, the species range maps, selected the White Mountain National Forest study site and applications, and oversaw the publication process.

Several persons contributed significantly to this publication. David B. Foulis interpreted aerial photographs of the western Massachusetts study area to provide a new National Wetland Inventory (NWI) map and a point intercept appraisal of the area. John Eaton digitized those data. Janice Stone interpreted aerial photographs of the Moosehorn National Wildlife Refuge (MNWR) and the Kilkenny Wildlife Management Area (KWMA) to produce NWI maps of those areas. Tamia C. Rudnicky interpreted aerial photographs of the MNWR and KWMA to provide a point intercept appraisal of those areas and digitized the NWI and point intercept data. Greg Sepik assisted in the development of the woodcock model and provided data about woodcock, other vertebrates, and habitat information for the MNWR. Scott Jackson and Pete Westover provided judgments about the vertebrates present on the Massachusetts study area. Stephen Fay and Mariko Yamasaki provided information about Ecological Land Types and the vertebrates of the KWMA, respectively. David W. Goodwin, Tamia C. Rudnicky, and R. P. Schauffler managed the data through the grid programs within ARC/INFO. Kimber Sprankle produced figures used in Chapters 3-5. Range maps were produced by Linda Cahillane. Jim Hines developed the WINDOWS user-interface for ECOSEARCH. Mary A. Sheremeta and Kortidious Moreland typed the manuscript.

Contents

Chapter 1. Introduction 1
Background 1
Data Needed 1
ECOSEARCH Output 2
ECOSEARCH Examples 2

Chapter 2. Development of species-habitat models 3
Habitat codes 3

Chapter 3. Determination of biological values and assessment of impacts from land-use change 19
Study area and habitat evaluation 19
Species possibly breeding in the study area 31
Performing a biological impact assessment 39

Chapter 4. Developing a management plan 58
Habitat requirements of woodcock on the MNWR 58
Prediction of woodcock habitat on the MNWR 58

Chapter 5. Assessing management options 83
Habitat conditions for the different management options 83
Management option A 87
Management option B 87
Management option C 87
Management option D 87
Management option E 87
Impact of management options A-E on wildlife habitat 87
Future directions 88

Appendix A. Range maps for the non-fish, inland, vertebrate wildlife species of New England A-1

Appendix B. Coded wildlife models for the non-fish, inland, vertebrate wildlife species of New England B-1

Appendix C. Species-habitat groups for the non-fish, inland, vertebrate wildlife species of New England C-1

Appendix D. Run instructions for ECOSEARCH D-1

Chapter 1. Introduction

Background

Private and public forest-land owners manage ecosystems daily; yet, a scientific basis for ecosystem management does not exist (Christensen et al. 1996). ECOSEARCH was developed as a first step of a testable, scientific basis for ecosystem management. ECOSEARCH is a computer program that contains predictive pixel-based, habitat-selection models for 331 non-marine, non-fish vertebrate wildlife speceis based on natural history models for New England vertebrates (DeGraaf and Rudis 1986) and geographic data for vegetative structure, wetlands, soils, and topography. We chose these variables because we believe that more reliable species predictions can be made from models that slice along the physical and biological constraints that species use to partition their environments (Allen and Hoekstra 1992). The more rigid the constraints, the more reliable the prediction. Thus, the challenge of predicting species occurrences is to discover and estimate the constraints that structure particular environments. ECOSEARCH can be used to evaluate wildlife habitat, to assess proposed impacts, and to predict outcomes for alternate management scenarios.

Historically, wildlife managers in New England predicted species occurrences from data collected and analyzed by foresters for forest management. Forests were managed according to a composition objective: planned distributions of stands with particular forest cover types and size classes. These data could be readily mapped from forest inventories. Relationships between wildlife species and stand cover types and size classes were developed from field surveys and exhaustive literature reviews — DeGraaf and Rudis (1986) for New England, Verner and Boss (1980) for California, and Thomas (1979) and Brown (1985) for the Pacific Northwest. Predicted species occurrences were then based on mapped data and the developed wildlife-habitat associations.

Although cover types can be identified and delineated and size classes can be defined from forest records, vegetative structure is not addressed. Most studies of habitat selection, especially among birds, have used vegetative structure to describe habitats. The notion that birds select breeding habitats in response to structural aspects of the vegetation was first proposed by Lack (1933). Vegetative structure is the most important factor affecting habitat selection by temperate forest birds (Hilden 1965, Willson 1974), and the diversity of breeding forest birds is a function of both habitat patchiness or horizontal diversity (Roth 1976) and stand structure or vertical diversity (MacArthur and MacArthur 1961, Helle 1985). Breeding forest birds perceive structural habitat features or patterns (Lack 1971, Cody 1985) such that the set of resources partitioned along forest structure gradients is likely unique to each bird species (Cody 1974, 1975, Mengel 1964). Vegetative structure constrains forest birds, so vegetative structure should provide a more powerful basis for predicting bird species occurrences than cover type or size class (DeGraaf et al. 1998).

Birds (Rabenold 1978, Geibert 1979), mammals (Maser et al. 1981), and herptiles (Heatwole 1982) have been associated with vertical vegetative structure. Vertical vegetative structure is composed of a mix of habitat layers from the canopy to the terrestrial surface or water surface to bottom of water column. Measures of foliage volume within various habitat layers have been used as predictors of species richness (MacArthur et al. 1962, Short 1992) and species habitat (DeGraaf et al. 1998). Wildlife species that use the same habitat layers for feeding and breeding are members of the same species-habitat group (Short 1983). Species-habitat groups are listed for New England terrestrial vertebrates in Appendix C. Species within a species-habitat group will be similarly impacted if changes occur to required habitat layers. Both local knowledge and caution must be used when considering these species-habitat groups; some species may not occur in the study area and/or factors other than those used to develop these groups may be involved. One approach to multiple-use management would be to determine the optimal mix of habitat layers that achieve desired goals (Short 1985). The habitat evaluation and assessment information listed in chapters 3 to 5 is organized by species-habitat groups.

Topography, soils, and water regimes also constrain species. Elevational gradients in precipitation and temperature commonly occur and affect growing seasons and vegetation communities. Soil particle size and drainage class may affect vegetative structure and composition and directly impact fossorial species. Wetlands, commonly called marshes, sloughs, and swamps, include a variety of wet habitats where water saturation or periodic flooding during the growing season determines the nature of soil development and the biotic community (NWI 1990). Deep-water habitats are areas where surface water is permanent and often deep, making water the principal medium in which organisms live (NWI 1990).

Data Needed

Three data sets are necessary to run ECOSEARCH. First, a list of candidate species that may occur in the area is needed. Approximate distribution for inland terrestrial wildlife species derived from DeGraaf and Rudis (1986) is provided in Appendix A. Second, candidate landscapes must contain data on vegetative structure, water regimes, soil types, and topographic conditions. Landscape data are stored outside ECOSEARCH and are loaded during the initialization phase.

Information from local landscapes is organized as raster data with 50-m pixels (0.25 ha) for vegetative structure, water regime, soils, and topography. Information on vegetative structure is provided as a matrix of point-intercepts at the cell center. Points can be classified into one of 173 categories. Our broadest classifications include combinations of upland, fresh or brackish water wetlands, tree canopy, midstory, understory, subsurface, deciduous, coniferous, natural surface, and man-made. Vegetative structure is estimated for

a species-specific neighborhood as a frequency of point-intercepts, or intercept-pairs, within a circular neighborhood. For example, a high frequency of coniferous overstory point-intercepts suggests a mature conifer forest. A high frequency of deciduous overstory and herbaceous surface point-intercepts suggest two separate areas. A high frequency of deciduous overstory - herbaceous surface, intercept-pairs suggests edge habitats. At present, the vegetative-structure matrix of point-intercept data is provided by interpreting a systematic grid of points from aerial photographs.

Topographic position, soil type, and water regime are defined for each cell based on information from a variety of sources. Topographic position is classified into valley floor, >100 m above valley floor, krummholz, or alpine. Topographic data are frequently obtained from published U.S. Geological Survey (USGS) maps or can be obtained from CD-ROM containing USGS Digital Elevation Model (USGS 1990). Our broadest soil categories are excessively drained, well drained, poorly drained, very poorly drained, exposed subsoil or rock. Soils data are frequently obtained from published U.S. Soil Conservation Service maps, but again may be obtained from field measurements. Water regimes are classified as temporarily flooded, saturated, seasonally flooded, seasonally flooded/well drained, seasonally flooded/saturated, semipermanently flooded, intermittently exposed, permanently flooded, subtidal, tidal/irregularly exposed, tidal/regularly flooded, and tidal/irregularly flooded. Water regime data are available from National Wetlands Inventory (NWI) maps or can be classified directly from aerial photographs used to provide the vegetative structure data.

Third, species-habitat models are required for all candidate species. Species-habitat models for 331 New England wildlife species are in the ECOSEARCH program (Appendix B). Habitat requirements of individual species were based on apparent dependencies on particular vegetative structure, water regime, soil condition, and topography.

ECOSEARCH Output

The model first predicts breeding and feeding habitats for a species, then determines whether an adequate geometry exists between the breeding and feeding habitats. Useable-resource categories were defined separately for breeding and feeding habitat submodels for each species based on the natural-history models described in DeGraaf and Rudis (1986). Useable resources were defined for the one landscape-variable that was assumed to most strongly constrain the species submodel (for example, water regime was the most constraining variable for amphibian breeding submodels). Constraining variables could be soil types, water regimes, topographic classes, or vegetative structure and composition classes including vegetative-edge classes. Excluded habitat types were defined for certain water regimes that precluded the existence of certain species in the pixel. A full description of variables used in the species-habitat models is presented in Chapter 2.

ECOSEARCH uses a FORTRAN program to search geographic-information matrices matching observed landscape conditions to hypothesized species-habitat models. A map of occurrences for a given species is constructed by evaluating the suitability of each pixel within the local landscape. A pixel is classified as either breeding or feeding habitat based on the physical attributes of the landscape within a circular neighborhood. If the proportion of useable habitat in the neighboring pixels is above a habitat- and species-specific critical value (P^*), the pixel is defined to be either breeding or feeding habitat. The pixel is classified as species habitat if an appropriate geometry exists among breeding and feeding habitats.

ECOSEARCH provides predicted occurrence maps for selected species or for species richness by adding individual maps for several species. ECOSEARCH is based on the assumptions that many wildlife species are associated with certain habitat attributes and that these attributes can be estimated from vegetative structure, water regimes, soil types, and typographic conditions. Habitat assessments can be made by predicting species occurrences for existing landscapes. Impact assessments can be made by predicting species occurrences for landscapes that have been altered to reflect proposed developments from forest succession or harvest to engineered wetland modifications.

ECOSEARCH Examples

Chapter 3 illustrates the use of ECOSEARCH to evaluate the predicted impacts that would occur to the wildlife community of a wooded swamp in western Massachusetts if the swamp is developed into a recreational lake with adjoining golf course and building lots. Management plans can be developed for selected wildlife species by predicting species occurrences for landscapes that optimize manipulations to achieve desired goals. In Chapter 4 we develop a management plan for woodcock on a portion of the Moosehorn National Wildlife Refuge in Maine and predict outcomes to the wildlife community if the management plan is implemented. In Chapter 5 we predict the impact on the wildlife community under several management scenarios that vary logging practices for a unit of the White Mountain National Forest in New Hampshire.

Instructions for running ECOSEARCH are included in Appendix D.

Chapter 2. Development of Species-Habitat Models

This chapter describes how ECOSEARCH species-habitat models (Appendix B) are developed using information about the natural history of the species, habitat descriptions, and specific descriptors for soils, topography, water regimes, and vertical habitat structure. Eleven habitat descriptors included in species-habitat models are identified by Roman numerals in Table 2-1, and form the box headings in Appendix B where habitat codes are provided for each of the 331 non-fish wildlife species of New England. A portion of a page from Appendix B is presented in Figure 2-1 to facilitate the explanation of species-habitat models. The array of habitat codes for a species across all applicable columns in Appendix B comprises a species-habitat model used in ECOSEARCH.

The remaining text in this chapter lists the habitat codes for the main descriptors used in the species-habitat models.

Habitat Codes

I. Status of the species in New England. Describes types of residency and is identified on the range maps in Appendix A, and by the following codes in column I in Appendix B:

A. The species is considered a permanent resident of New England. The breeding and wintering ranges of the species within New England may or may not coincide.
B. The species migrates to and breeds in New England. Most neotropical migratory birds are listed as “B”. Those, however, that migrate within New England and have overwintering populations in southern New England are listed as “A”.
C. The species occasionally or frequently migrates to and overwinters in New England.
D. Other.

Table 2-1.—Main descriptors used in the development of species-habitat models identified by Roman numerals and explained.

I.	**Status of the species in New England.** Describes types of residency in New England.
II.	**(Model type) and [habitat bounds].** **(Model type).** Indicates whether the species uses one or multiple habitat types and shows the most important descriptor of each habitat type. **[habitat bounds].** Identifies a characteristic of a landscape cell that causes that cell to be non-habitat for the species.
III.	**Habitat block description and size (ha).** **Habitat block description.** Identifies specific habitat components important to the species. **size (ha).** Identifies the minimum area required for a landscape parcel to be considered habitat for a species.
IV.	**a. Reproduction layers.** Layers of habitat where reproduction occurs. **b. Foraging layers.** Layers of habitat where feeding occurs. **c. Other layers.** Layers of habitat required for other activities, for example, hibernation.
V.	**a. No. of neighborhood cells.** The number of nearby cells evaluated to predict the utility of an individual cell as habitat for the species. **b. Cells with essential variable(s) as proportion of neighborhood.** Provides a way to quantify the frequency with which a variable needs to occur within a landscape neighborhood by indicating the proportion of landscape cells that must provide specific variables.
VI.	**Topography.** Describes broad topographic zones that likely influence the distribution of the species**.**
VII.	**Soil types.** Describes particular soil characteristics that likely influence the distribution of the species.
VIII.	**Water regimes.** Describes the duration and timing of surface water innundation that likely influence the distribution of the species.
IX.	**Vertical structure-cell.** Describes particular vertical habitat features that likely influence the distribution of the species.
X.	**Relation of habitat blocks (x) to (y).** Describes how the species uses areas within multiple habitat types.
XI.	**Data quality.** Describes the level of confidence in an individual species-habitat model.

Habitat

Species	I. Status of species in New England	II. (model type) and [habitat bounds]	III. Habitat block (x) description & size (ha)	IVa. Reproduction layers	IVb. Foraging layers	IVc. Other layers	Va. Block (x) - no. of neighborhood cells
Spotted salamander (*Ambystoma maculatum*) --------- Breeds in shallow woodland ponds or in marshy pools with semi-permanent water, and otherwise inhabits deciduous or mixed woods especially on rocky hillsides.	A	(2.a:e) [L-P]	D 1-2 D 20 (0.4)	e f g	E F G	NA	9

Box Heading

Habitat Codes

I. A Indicates that the species is a permanent resident in NE. (See explanation for column I).

II. (2.a:e) Indicates that the species uses two different habitats, the first of which is best described in terms of water regimes, and the second of which is best depicted by vertical habitat descriptors.(See explanation for column II).

[L-P] Indicates that cells with water regimes having salinities µ 0.05 ppt are "out of bounds" or are non-habitat for the species.

III. D 1-2, D 20 Indicates that the first habitat type can be described as forested or woodland swamps and bogs, shrub swamps or bogs, and temporary pools.

(0.4) Indicates that a necessary block of suitable wetland habitat is estimated to be about 0.4ha in area. (See explanation for column III).

IVa. e,f,g Indicates that an important reproductive function (egg hatch and larval development) occurs in the water surface layer, the water column and at the bottom of the water column of suitable wetlands. (See explanation for column IV).

IVb. E,F,G Indicates that the life stage of the species occupying habitat block (x) forages in the water surface layer, the water column and at the bottom of the water

IVc. NA Indicates that no other habitat layers are utilized by the species when occupying habitat block (x).

Va. 9 This number indicates that 9, 50m x 50m, "neighborhood" cells are evaluated in the Ecosearch assessment to provide a statistical probability to the prediction of an individual cell as habitat. (See explanation for column V).

Figure 2-1.—A portion of a page from Appendix B indicating the format used to code species-habitat information for ECOSEARCH. The columns represent descriptors identified in Table 2-1 and rows contain the appropriate coded values for individual wildlife species.

II. Model type and habitat bounds. Model type indicates single or multiple habitat blocks, relationships between multiple habitat blocks, and the most important variable within a habitat block. The information is conveyed by a series of numbers and letters in parentheses, for example, (1.a), (2.a:e), (1.c,e).

The number in parentheses indicates whether the species uses a single habitat block or multiple habitat blocks, and some relationships between multiple habitat blocks. The codes are:

1. The species occurs in habitat block (**x**) and requires a specified area of that habitat block. Block (**x**) can be a water body, a single recognizable landscape type, or an area with a variety of landscape types (if the species is ubiquitous and makes no apparent selection for individual landscape types).

2. The species occurs at the interface of, or within, two distinguishable and contiguous habitat blocks, (**x**) and (**y**). Both (**x**) and (**y**) are identified and the necessary areas of both (**x**) and (**y**) habitats are estimated.

3. The species uses two distinguishable habitat blocks, (**x**) and (**y**), that are not necessarily contiguous. Both (**x**) and (**y**) are identified and the necessary areas of both (**x**) and (**y**) habitats are estimated.

4. The species is an aerial feeder that uses point source habitat features for reproductive or resting activities. The point source habitat features can be anthropogenic structures (purple martin houses, chimneys, silos, barns, etc.) or rare physical features (caves, clay banks, etc.). Habitat block (**x**) describes the point source habitat variable, and habitat block (**y**) is implied to be an air column above and surrounding the point source habitat feature. The (**y**) habitat is a specified radius (termed **Cz,** see explanation for column X) around **(x),** and landscape features under the air column are specified in general terms, in the belief that feeding activities may be more prevalent over particular habitat features such as certain wetland types or forest edges. For example, habitat (**y**) could be the air column within 500-m of a cave mouth, and habitat descriptors for **(y)** could indicate that the bat forages over areas covered by semi-permanent and permanent waters and forest, agricultural lands, or old field clearings.

The letters in parentheses in column II indicate the most important variable within a habitat block and are:

a. **Water regime** (duration and timing of surface water inundation). Many species depend significantly on the presence of general wetland conditions. For example, successful amphibian reproduction may occur in a wide variety of wetland types if water inundation is sufficiently long for egg hatching and larval development. The potential presence of some species within a study area can be predicted on the basis of the presence and distribution of wetland types as determined from recent assessments similar to those by National Wetland Inventory (NWI) within that study area. The indication that water regime is an important variable in describing potential habitat for a species is conveyed by an “a” in column II, and the identification of the particular water regimes potentially important to the species is made in columns VIII of Appendix B.

b. **Water “structure”** (location of seeps, springs, rapids, etc.). A few species require the presence of a specific type of wetland like a seep, a spring, a rapidly flowing stream, or a tamarack bog. The potential presence of these species, within a study area, can sometimes be predicted if the specific wetland type (for example, upper perennial stream) has been identified on recent NWI - like assessments of the study area or from the point intercept assessment of the study area. The useful prediction of the presence of adequate habitat for some of these species (if a habitat component as specific as a spring or seep is significant habitat) may require a search scale beyond that usually represented in ECOSEARCH. For these species a “b” is listed in column II, and the specific habitat requirement, when discernible, is listed as a structural variable in columns IX of Appendix B.

c. **Soil conditions.** Information on the location of specific soil conditions as determined from Natural Resources Conservation Service surveys or other similar field assessments helps predict the presence of adequate habitat for several species. Some species have restricted ranges because of soil conditions. For example, the eastern spadefoot toad requires sandy or loose soils, woodchucks do not burrow in saturated soils, and timber rattlesnakes inhabit hibernacula on rocky hillsides. The importance of soil conditions as a significant variable in predicting habitat suitability is indicated by “c” in column II, and specific soil descriptors are listed in columns VII in Appendix B.

d. **Topography.** A few species seem characteristically restricted to environmental conditions associated with specific topographic zones. For example, the blackpoll warbler inhabits stunted spruce and fir in the krumholz. Species whose distribution seems restricted because of topography are identified by modifier “d” in column II, and by a limited number of descriptors in columns VI of Appendix B. Topography is determined from U.S. Geological Survey charts or field assessments.

e. **Vertical habitat structures and their products.** The habitat of many species is associated with the vertical structure, whether that habitat occurs within the canopy of deciduous upland hardwoods or within the leaf litter underneath the canopy of deciduous upland hardwoods. A species that depends on vertical habitat structure is identified by “e” in column II, and by listing specific habitat descriptors in columns IX of Appendix B. Vertical habitat structure on a study area is determined from a point intercept appraisal.

f. **Air envelope over identified habitat types.** The significant use of an aerial feeding strategy is indicated by modifier "f" in column II. These species rest or reproduce in habitats often described on the basis of soil conditions or vertical habitat features and forage in the aerial column above and at some distance from their resting and/or reproductive habitats.

If a species uses a single habitat type then the habitat model may be listed as (1.a), for example, which indicates that the required habitat is the distribution of wetlands exhibiting particular water regimes. The apparent requirement for two habitat variables is indicated by a comma (,). For example, the designation (1.c,e) indicates a single habitat block, and that soils are a critical determinant of the distribution of the species, and that certain vertical habitat descriptors, within the area with the important soil conditions, are also important.

If a species uses multiple habitat types, then the variables describing the first habitat type are separated by a colon (:) from the variables describing the second habitat type. For example, (2.a:e) indicates that a species uses two contiguous habitat types, and that wetlands with specific water regimes determine the distribution of the first habitat type and that areas with particular vertical habitat structures determine the distribution of the second habitat type. The distribution of the species is that area where the two habitat types are contiguous, after certain dimension considerations (described for column X later in this chapter) are fulfilled.

The model types for five species are explained below to help interpret the information conveyed in column II in Appendix B.

1. Mudpuppy

II. (1.a). The possible distribution of the mudpuppy, which breeds and feeds in permanent water within a restricted area of New England, is estimated from the distribution of appropriate wetlands with permanent water.

2. Eastern spadefoot

II. (1.c,e). The eastern spadefoot toad breeds in rainwater pools in sparsely wooded habitats with sandy or loose soils. Estimates of suitable habitat for the eastern spadefoot toad are based on the distribution of excessively drained and somewhat excessively drained soils or of well-drained and moderately well-drained soils, each occurring within sparsely wooded habitats.

3. Green heron

II. (3.a:e). The green heron feeds in aquatic habitats that are described on the basis of water regimes. This heron also utilizes nest sites within moderate-sized blocks of woody shrubs and trees within close proximity, but not necessarily contiguous to the foraging habitats.

4. Woodcock

II. (3.c,e:e). The nest sites and diurnal habitats of woodcock occur on deep, finely grained, well-drained to very poorly drained soils that support a high earthworm biomass and that are covered by early successional woodlands and second-growth hardwood stands. Nocturnal habitats include nearby, but not necessarily contiguous clearcuts, pastures, and abandoned agricultural fields.

5. Bank swallow

II. (4.c:f,a,e). The bank swallow nests in clay banks and is an aerial feeder over open lands and wetlands that occur at a defined radius around those clay banks.

Eighteen different species-habitat model types, listed in Appendix B, are used to estimate the suitability of habitat for the New England wildlife species included in this volume. The different combinations of variables emphasize the complexities in modeling species-habitat relationships to predict biodiversity in landscapes, to develop habitat management plans for individual species and landscapes, and to estimate how presumed changes to habitat may potentially impact the distribution of species.

Habitat bound codes in column II identify certain characteristics within cells that make those cells non-habitat for the individual species. This information is represented by a series of letters in brackets that refer to the water regimes identified in the description for column VIII described later in this chapter.

Habitat bounding excludes cells with characteristics that are non-habitat for a species. This convention bounds the portion of the study area that will be evaluated by ECOSEARCH to predict habitat for a species. Thus, cells with a permanently flooded water regime can be excluded from habitat predictions developed for a terrestrial species.

III. Habitat block description and size. Columns III in Appendix B list two types of information. The first, identified by a letter and a number (for example, A 6), describes specific habitat attributes important to the species. For example, A 6, as interpreted from Table 2-2, suggests that important habitat for the species is the forest floor litter underneath a coniferous tree canopy, or the understory layer underneath a coniferous tree canopy. Additional columns in Appendix B may describe the size of the forest tract, the types of trees, and the degree of canopy closure believed necessary to provide the required forest litter condition.

Wetland descriptors listed in section D of Table 2-2 are more detailed than the upland descriptors because we have incorporated digitized map data from the National Wetlands Inventory (NWI) into our database.

Habitat block size in column III is an estimate of the area of a habitat block that needs to be present for the landscape to be considered habitat for the species. Habitat block size is

Table 2-2.—Specific habitat components listed in columns III in Appendix B.

A. Upland tree crowns or overstory
- A1 = crown of deciduous trees
- A2 = bole of deciduous trees
- A3 = forest floor litter from the deciduous tree overstory, or understory cover beneath the tree overstory
- A4 = crown of coniferous trees
- A5 = bole of coniferous trees
- A6 = forest floor litter from the coniferous tree overstory, or understory cover beneath the tree overstory
- A7 = crown of mixed forest types
- A8 = bole of mixed forest types
- A9 = forest floor litter from the mixed forest overstory, or understory cover beneath the tree overstory
- A10 = buildings or other man-made objects in the zone corresponding to the overstory layer

B. Upland shrub crowns or midstory
- B1 = crown of deciduous shrubs or deciduous midstory vegetation
- B2 = bole of deciduous shrubs or boles within the midstory layer
- B3 = woodland floor litter from deciduous midstory vegetation or understory cover beneath the midstory
- B4 = crown of coniferous shrubs or coniferous midstory vegetation
- B5 = bole of coniferous shrubs or boles within the midstory layer
- B6 = woodland floor litter from coniferous midstory vegetation or understory cover beneath the midstory
- B7 = crown of mixed shrubland types or mixed midstory vegetation
- B8 = bole of mixed shrubland types or boles within the midstory layer
- B9 = woodland floor litter from mixed midstory vegetation or understory cover beneath the midstory
- B10 = buildings or other man-made objects in the zone corresponding to the midstory layer

C. Upland understory (in the absence of overstory and midstory layers)
- C1 = bare surface
- C2 = rock covered surface
- C3 = short woody vegetation
- C4 = old field herbaceous vegetation
- C5 = mowed field
- C6 = pasture
- C7 = agricultural crops
- C8 = hayfield
- C9 = man-made object in the zone corresponding to the understory layer

D.Wetlands (habitat attributes whose locations can be estimated from NWI maps or recent aerial photographs interpreted using NWI procedures)

(NWI Codes within parentheses)
- D1 = forested or woodland swamp or bog (PFO)
- D2 = shrub swamp or bog (PSS)
- D3 = emergent marsh, fen or wet meadow (PEM)
- D4 = pond (PUB)
- D5 = pond shoreline (PUS)
- D6 = pond with floating or submerged aquatic vegetation (duck weeds, pond lilies) (PAB)
- D7 = freshwater tidal river (R1UB)
- D8 = slow-moving river with floodplain (R2UB)
- D9 = river with aquatic vegetation (pickerelweed) (R2AB)
- D10 = bank or shoreline of fast-flowing river (R3US)
- D11 = intermittent stream channel (R4SB)
- D12 = salt or brackish tidal marsh (E2EM)
- D13 = estuarine shrub swamp (E2SS)
- D14 = estuarine flats, beach, or sand bars (E2US)

(Continued)

Table 2-2.—Specific habitat components listed in columns III in Appendix B. - Continued

D15 = open water estuary (E1UB)
D16 = deepwater zone of lake (L1UB)
D17 = lake shore or shallow water zone of lake (L2US)
D18 = aquatic vegetation in lake (L2AB)
D19 = shallow water zone of lake (L2UB)
D20 = temporary pools (water regimes A, C and D in column VIII of Table A)
D21 = riverine shoreline
D22 = lake shoreline
D23 = fast-moving river (R3UB)
D24 = seeps and springs

E. Wetland tree crowns or overstory
E1 = crown of deciduous trees
E2 = bole of deciduous trees
E3 = forest floor litter from the deciduous tree overstory, or understory cover beneath the tree overstory
E4 = crown of coniferous trees
E5 = bole of coniferous trees
E6 = forest floor litter from the coniferous tree overstory, or understory cover beneath the tree overstory
E7 = crown of mixed forest types
E8 = bole of mixed forest types
E9 = forest floor litter from the mixed forest overstory, or understory cover beneath the tree overstory
E10 = buildings or other man-made objects in the zone corresponding to the overstory layer

F. Wetland shrub crowns or midstory
F1 = crown of deciduous shrubs or deciduous midstory vegetation
F2 = bole of deciduous shrubs or boles within the midstory layer
F3 = woodland floor litter from the deciduous midstory, or understory cover beneath the midstory
F4 = crown of coniferous shrubs or coniferous midstory vegetation
F5 = bole of coniferous shrubs or boles within the midstory layer
F6 = woodland floor litter from the coniferous midstory, or understory cover beneath the midstory
F7 = crown of mixed shrubland types or the mixed midstory
F8 = bole of mixed shrubland types or boles within the midstory layer
F9 = woodland floor litter from the mixed midstory, or understory cover beneath the midstory
F10 = buildings or other man-made objects in the zone corresponding to the midstory layer

G. Wetland understory (in the absence of overstory and midstory layers)
G1 = emergent wetland, non-persistent herbaceous
G2 = emergent wetland, persistent herbaceous
G3 = emergent wetland, persistent woody: broad-leaved deciduous
G4 = emergent wetland, persistent woody: needle-leaved evergreen
G5 = emergent wetland, persistent woody: needle-leaved deciduous
G6 = emergent wetland, persistent woody: broad-leaved evergreen

H. Subsurface
H1 = caves or rock crevices
H2 = mine shafts
H3 = burrows

I. Air

Habitat Layer where reproduction occurs	Habitat Layer where foraging occurs: air (A)	wetland overstory (B)	wetland midstory (C)	wetland understory (D)	water surface (E)	water column (F)	bottom of water column (G)	upland overstory (H)	upland midstory (I)	upland understory (J)	subsurface (K)
wetland overstory (b)											
wetland midstory (c)											
wetland understory (d)											
water surface (e)											
water column (f)											
bottom of water column (g)											
upland overstory (h)											
upland midstory (i)											
upland understory (j)											
subsurface (k)											
breeds elsewhere (l)											

Figure 2-2.—Species-habitat matrix for forming wildlife groups that have similar habitat-structure dependencies.

represented by a number in parentheses, for example, (3.0) indicates a minimum required block size of 3.0 ha. Habitat block size is often difficult to estimate because the information base is frequently inadequate.

IV. Reproduction foraging and other layers. The 'niche space' of a species in ECOSEARCH is the vertical position within a habitat where breeding and feeding occur. Species are located within vertical habitat layers, and species-habitat groups are formed for species that use similar vertical structure of habitats and are similarly impacted by changes to that habitat structure.

Habitat layers provide volumes of space that may contain particular habitat features important to individual wildlife species. Vertical habitat layers extend along a gradient from mesic to xeric. Rarely flooded or upland habitats provide upland overstory, midstory, understory, and subsurface habitat layers, and permanently flooded habitats provide water surface, water column, and bottom of water column habitat layers. Temporarily flooded, seasonally flooded, or semi-permanently flooded habitats provide wetland overstory, midstory, and understory habitat layers.

The vertical habitat layers are ordered into a matrix in Figure 2-2. Habitat layers where reproduction occurs are listed along the y-axis, and habitat layers where foraging occurs listed along the x-axis.

A habitat layer is present if a recognizable structure occurs at a prescribed distance above or below the land-air or water-air interface. The overstory layer includes structures within a volume of space at or greater than 6 m above the upland or wetland surface. Structures within this layer include the tree bole, the canopy and supporting limbs of trees, other vegetation and other structural inclusions that are anthropogenic in origin (portions of houses, barns, other buildings, bridges, transmission towers and poles, etc.) that also occur at and above 6 m from the surface. Structures that occur within the overstory layer are coded "B" in aquatic-wetland habitats and "H" in upland habitats.

The midstory layer includes structures within a volume of space greater than 1 m, but less than 6 m, above the upland (I) or aquatic-wetland surfaces (C).

The understory layer includes structures within a volume of space that extends from 10 cm below the surface up to 1 m above the upland and non-flooded wetland surfaces, and from the surface water-air interface to 1 m above the surface water-air interface in flooded wetland habitats. Structures within the upland understory (J) and wetland understory (D) layers include the uppermost soil horizons (if applicable), leaf and woody litter, herbaceous vegetation, woody vegetation, and a wide variety of anthropogenic structures. Beaver lodges and muskrat houses occur within the wetland understory layer. Stems, leaves, and woody tissues emerging from the water surface and extending to 1 m above that surface are also components of the wetland understory layer.

The water surface layer (E) extends from the surface water-air interface to 25 cm below that interface. Structures within this layer can be floating vegetation, portions of rooted herbaceous or woody vegetation and various anthropogenic structures. Very shallow surface water, which may be classified as temporarily flooded habitats or seasonally flooded habitats, may only have a water surface layer. When surface water in these wetlands disappears, the resulting surface may be considered a wetland understory layer.

Other wetland and deepwater habitats, classified in the NWI vocabulary as semipermanently flooded, intermittently exposed, or permanently flooded are considered to provide a water surface layer, a water column layer (F), and a bottom of the water column layer (G). The water column extends from the water surface to the bottom of the water column. This layer contains stems of rooted herbaceaous and woody vegetation, vegetation that floats below the surface, and a variety of anthropogenic structures. The bottom of the water column layer may have a rocky bottom consisting of bedrock and rubble or an unconsolidated bottom of cobble-gravel, sand, mud, or organic matter. Aquatic vegetation is rooted in this layer.

1 - salamander
2 - barn swallow
3 - bog turtle
4 - porcupine
5 - scarlet tanager

Habitat Layer where foraging occurs

Habitat Layer where reproduction occurs	air (A)	wetland overstory (B)	wetland midstory (C)	wetland understory (D)	water surface (E)	water column (F)	bottom of water column (G)	upland overstory (H)	upland midstory (I)	upland understory (J)	subsurface (K)
wetland overstory (b)	2	5	5					5	5		
wetland midstory (c)	2	5	5					5	5		
wetland understory (d)				3	3	3	3				
water surface (e)				1	1	1	1			1	
water column (f)				1	1	1	1			1	
bottom of water column (g)				1	1	1	1			1	
upland overstory (h)	2	5	5					5	5		
upland midstory (i)	2	5	5					5	5		
upland understory (j)		4	4	4				4	4	4	
subsurface (k)		4	4	4				4	4	4	
breeds elsewhere (l)											

Figure 2-3.—An example of how five species partition the physical structure of habitats. Species are placed in matrix cells on the basis of their use of habitat layers for reproductive and foraging activities. A species - habitat group consists of all species that share the same matrix cells.

The subsurface layer (K) extends beneath 10 cm of the upland surface-air interface. This layer has soil characteristics described later in this chapter in the discussion of column VII.

The air envelope (A) occurs above the highest recognizable structural layer in a habitat.

Habitat layers where reproduction occurs are listed in columns IVa, and habitat layers where foraging occurs are listed in columns IVb in Appendix B. Other habitat layers (columns IVc in Appendix B) are volumes of space required by the species for activities other than reproduction or foraging, for example, hibernation. A "not applicable" (NA) listing in columns IV in Appendix B indicates that the species does not use identifiable habitat layers for reproduction, foraging, or other activities while in New England. For example, a species that migrates to New England to overwinter would have NA in column IVa (reproduction layers) of Appendix B.

Species-habitat groups are formed after individual species have been positioned in the species-habitat matrix as shown in Figure 2-3. The species-habitat groups for the New England wildlife species are listed in Appendix C. Both local knowledge and caution must be used when considering these species-habitat groups; some species may not occur in the study area and/or factors other than those used to develop these groups may be involved.

Species-habitat groups provide a way to organize data and to demonstrate the relative usefulness of habitats, and the impacts from habitat changes, on different segments of the wildlife community. The assessments in Chapters 3 to 5 are summarized on the basis of species-habitat groups.

V. Number of neighborhood cells and cells with essential variables as a proportion of the neighborhood in the habitat block. A 50- x 50-m cell (0.25 ha) is the basic unit of area in ECOSEARCH. Although the ECOSEARCH analysis predicts the suitability of an individual cell as habitat for the species, a "neighborhood" of cells around that individual cell is evaluated to provide a proportion of cells that are habitat.

Table 2-3 lists the number of 0.25-ha cells required to provide habitat blocks of given sizes and the radius of the neighborhood circle necessary to provide a requisite number of neighborhood cells. The cell being evaluated is considered the center of a circle with the radius consisting of x +0.5 cell widths (where x is measured in cell widths). All cells with their center within this area are included in the neighborhood. For a 2-ha block size, the radius of the neighborhood circle is thus 1.5 cell widths, and the area of the neighborhood circle includes all cells with centers within 1.5 cell widths of the cell being evaluated. Nine cells are included in the neighborhood to assess the potential utility of a 2.25-ha block as habitat for a species requiring the 2 ha habitat block. Likewise, for a 5.0-ha block size, the radius of the neighborhood circle is 2.5 cell widths, and the area of the neighborhood circle includes all cells with centers within 2.5 cell widths of the cell being evaluated. Twenty-one cells are included in the neighborhood to assess the potential utility of

Table 2-3.—The radius of the neighborhood circle (expressed in terms of numbers of 50-m-wide cells), and the number of 0.25-ha cells needed to provide a sampling neighborhood for habitat blocks of different areas.

Habitat block size (ha)	Radius of the neighborhood circle	No. of cells in the neighborhood circle
2.25	1	9
5.25	2	21
9.25	3	37
17.25	4	69
24.25	5	97
34.25	6	137
44.25	7	177
56.25	8	225
73.25	9	293
87.25	10	349
105.25	11	421
122.25	12	489
144.25	13	577
166.25	14	665
187.25	15	749
215.25	16	861
243.25	17	973
271.25	18	1,085
300.25	19	1,201
328.25	20	1,313
364.25	21	1,457
399.25	22	1,597
435.25	23	1,741
471.25	24	1,885
513.25	25	2,053
554.25	26	2,217
594.25	27	2,377
640.25	28	2,561
683.25	29	2,733
733.25	30	2,933
781.25	31	3,125
828.25	32	3,313
880.25	33	3,521
936.25	34	3,745
992.25	35	3,969
1049.25	36	4,197
1105.25	37	4,421
1167.25	38	4,669
1226.25	39	4,905
1292.25	40	5,169
1354.25	41	5,417
1420.25	42	5,681
1489.25	43	5,957
1555.25	44	6,221
1627.25	45	6,509
1696.25	46	6,785
1772.25	47	7,089
1848.25	48	7,393
1926.25	49	7,705
2005.25	50	8,021

a 5.25-ha block as habitat for a species requiring the 5-ha habitat block. The number of cells represented in the neighborhood is determined by the presumed requisite block size and is that number listed in columns labeled Va in Appendix B. The computer search is based on the radius of the neighborhood circle.

Columns Vb in Appendix B list the proportion of cells in the neighborhood that need to provide the critical variables for the evaluation cell to be considered habitat for the species. The proportion is a robust descriptor of habitat conditions. For example, a species-habitat model with a small proportion (P value) of 0.3 with structural habitat variables denoting old fields, pastures, meadows, etc., might predict habitat for the species in forest openings or small pastures; whereas the same species-habitat model with a large P value of 0.7 may only recognize large openings or large meadows as habitat. A species-habitat model with a small P value of 0.3 with structural habitat variables denoting a forest cover type would allow a neighborhood with relatively few trees to be described as habitat; whereas, the same species-habitat model with a large P value of 0.7 might require areas with a nearly closed forest canopy to be recognized as habitat. Edge habitats are described in the species-habitat models as contiguous cells with intercept pairs describing different structures, for example, overstory : understory borders. A species-habitat model with a small P value of 0.3 with structural habitat variables denoting an edge condition would recognize borders between different habitat structural types as habitat; whereas, the same species-habitat model with a large P value of 0.7 would describe, for example, a savannah condition representing a grassland with scattered trees, or a very open forest condition, as habitat.

A species that uses two habitat blocks may have one area and one neighborhood cell proportion requirement for habitat block (x) and a different area and neighborhood cell proportion requirement for habitat block (y). Both block requirements will need to be satisfied for a landscape area to be considered habitat for the species.

VI. Topography. The topographic zones occupied by the species differentiate or limit some habitats for some species. Topographic extremes, reflecting the altitudinal gradient within New England, affect climatic events such as total precipitation, quantity of snowfall, length of the frostfree growing season, the subsequent composition and structure of the vegetation and wildlife communities, and the applicability of various forest management practices. Species-habitat models with a (d) in column II in Appendix B indicate a species that is apparently limited to broad topographic zones, and these associations are coded in columns VI in Appendix B as:

A. Valley floor implies lowlands ranging from coastal wetlands to river valleys, and stream valleys in the hill country.

B. Midslope (>100 m above valley floor) implies upland habitats, but not the severe climatic zones of the higher mountains.

C. Krummholz is the transition zone from subalpine forest to alpine tundra characterized by dwarfed, deformed, and wind-sheared trees.

D. Alpine has elevated slopes above timber line characterized by low, shrubby, slow-growing woody plants and a ground cover of boreal lichens, sedges, and grasses.

E. Combinations of A-D

VII. Soil types. Soil conditions are included in the species models because they can determine the structure of vegetation communities, the nature of food chains, and where burrowing animals occur. Species-habitat models with a (c) in column II in Appendix B indicate a species whose apparent distribution may be associated with particular soil characteristics, and these associations are coded in columns VII in Appendix B. Soil descriptors consider particle size, drainage class, depth to the water table, depth to bedrock, and the type of plant community that is expected to occur on the area. These data are sufficient to help predict places where a woodchuck would likely place its burrows, or where earthworms would likely be found by vermivorous probers. The soils data summarized in Appendix B is based on criteria contained in standardized and published soil surveys. The soil codes and their definitions, as abstracted from Swenson (1989, page 99) are:

A. Excessively drained and somewhat excessively drained. Water is removed from the soil rapidly or very rapidly so these soils tend to be droughty. The soils are coarse textured, rocky, sandy or shallow, and some are steep. These soils are usually poorly suited to the growth of cultivated crops, and usually are poor for the growth of grains, grasses, wild herbaceous plants, hardwood trees, coniferous plants and wetland plants, and are poor as shallow water areas, and fair to poor as openland wildlife habitat, woodland wildlife habitat, and very poor for wetland wildlife habitat. A woodchuck could burrow in these soils if the depth to bedrock was sufficient, but the soils are usually too droughty to be good earthworm habitat.

Excessively drained and somewhat excessively drained soils are subdivided into A1 and A2 to make textural distinctions that may be useful in some species-habitat models. The A1 and A2 designations are listed in columns VII in Appendix B.

A1. Soils that are generally deep and classified as fine sandy loams, gravelly loams, and sandy plains, in level or gently sloping landscapes, and soils that are shallow and classified as fine sandy loams and sandy loams that occur on moderately steep to steep slopes. Also includes beaches composed of poorly sorted sands, gravels, gravelly sands, cobble and cobbly sands.

A2. Soils that are shallow or deep and classified as very stony or extremely stony or very rocky silt loams or very rocky sandy loams. Also includes soils that have some exposed bedrock, or that are shallow overlays of

fractured bedrock, or that appear as beaches with a mix of stones and boulders. These soils can occur on level to steep slopes and frequently have 20 percent or more of their volume composed of cobble or larger sized rocks.

B. Well drained and moderately well drained. Water is removed from the soil, not rapidly, but readily or somewhat slowly during some periods. Soil water is available to plants throughout most of the growing season but wetness does not inhibit root growth for significant periods during most growing seasons, or the soils are wet for only a short time during the growing season but that time is sufficient for most mesophytic crops. These soils are usually well suited to the growth of cultivated crops, and usually are fair to good for the growth of grains, grasses, wild herbaceous plants, hardwood trees, and coniferous plants. The soils are poor for the growth of wetland plants and for the production of shallow water areas, poor to good as openland wildlife habitat, fair to good as woodland wildlife habitat, and very poor as wetland wildlife habitat. These soils may provide good habitats for both woodchucks and earthworms. Temporarily flooded water regimes may occur on well-drained and moderately well-drained soils.

Well-drained and moderately well-drained soils are subdivided into B1 and B2 to help distinguish textural conditions. The B1 and B2 designations are listed in columns VII in Appendix B.

B1. Soils that are generally deep or very deep, gently sloping or nearly level and classified as silt loam, fine sandy loam, and loamy fine sand. These soils are often considered Class I soils indicating slight limitations that restrict their use, or Class II soils with moderate limitations that reduce the choice of plants or that require moderate conservation practices, but also sometimes as Class III soils with severe limitations that reduce the choice of plants or that require special conservation practices.

B2. Soils that are shallow to deep and occur on ridges, sides and gentle to steep slopes of hills and classified as stony fine sandy loam, very stony fine sandy loam, rocky fine sandy loam, and rock outcrop – well-drained soil complexes. These soils are often considered Class VI soils with severe limitations that make them unsuitable for cultivation, and Class VII soils with very severe limitations that make them unsuitable for cultivation. These soils frequently have 20 percent or more of their volume composed of cobble or larger sized rocks.

C. Poorly drained and somewhat poorly drained. Water is removed slowly so the soil is wet for significant periods during the growing season, or the soil is saturated periodically or remains wet for long periods during the growing season, or free water is commonly at or near the surface sufficiently long during the growing season so that most mesophytic crops cannot be grown. These soils are fair to very poor for the growth of grains, grasses, wild herbaceous plants, hardwood trees, coniferous plants, and as openland and woodland wildlife habitats. The soils are good for the production of wetland plants that are annual and perennial wild herbaceous plants that grow on moist or wet sites. The soils are considered to have fair to very poor potential as shallow water areas (marshes, swamps, and ponds) and as wetland wildlife habitat (open, marshy, or swampy shallow water areas). These soils are considered non-habitats for the fossorial woodchuck but provide habitat for earthworms. Seasonally flooded and saturated water regimes may occur on poorly drained and somewhat poorly drained soils.

Poorly drained and somewhat poorly drained soils are subdivided into C1 and C2 to make textural distinctions that may be useful in some species-habitat models. The C1 and C2 designations are listed in columns VII in Appendix B.

C1. Soils that are frequently classified as deep and poorly drained with sandy loams, fine sandy loams, or silty loams, and that are formed on marine, lacustrine, or alluvial deposits on level to gentle slopes.

C2. Soils classified as very stony silt loam, extremely stony silt loam, stony fine sandy loam, very stony loam that frequently occur on glacial outwashes on level to gently sloping terrains. These soils frequently have 20 percent or more of their volume composed of cobble or larger sized rocks.

D. Very poorly drained. Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season so most mesophytic crops cannot be grown. These soils are fair to very poor for the growth of grains, grasses, wild herbaceous plants, hardwood trees, coniferous plants, and as openland and woodland wildlife habitats, but are good for the production of wetland plants, shallow water areas, and as wetland habitats. These soils, which include fresh water marshes, are considered non-habitat for the woodchuck but may provide habitat for earthworms. Semipermanently flooded and seasonally flooded/saturated water regimes may occur on very poorly drained soils.

Very poorly drained soils are subdivided into D1 and D2 to make textural distinctions that may be useful in some species-habitat models. The D1 and D2 designations are listed in columns VII in Appendix B.

D1. Soils that are frequently classified as fine sandy loam, loamy fine sand, silt loam, silt clay, and that are deep, occur on floodplains, and may be derived from organic materials, organic materials mixed with mineral soils, or from lacustrine and/or marine sediments.

D2. Soils classified as D1 that are also considered to be extremely stony. These soils frequently have 20 percent or more of their volume composed of cobble or larger sized rocks.

E. Gravel pits, quarries, rock outcrops, anthropogenic surfaces, and areas with very shallow soils and very limited vegetation. Cut areas expose subsoil and sometimes bedrock. Rock outcrops often occur on steep slopes. These areas have very limited or no potential as wildlife habitat, and represent non-habitat for both the woodchuck and the earthworm.

F. Covered by permanent water. Intermittently exposed and permanently flooded water regimes occur on soils covered by permanent water.

G. Soils are not an important variable for the particular wildlife species.

VIII. Water regimes. Water regimes describe the duration and timing of surface water inundation. They are included in the species-habitat models because: (1) many wildlife species have wetland dependencies; (2) some wetland designations limit the distribution of some fossorial species and limit favorable habitats for other species; (3) the locations of permanent water may describe the potential distribution of fish and piscivorous species, and areas that may be of limited value to some species and life stages (for example, amphibian eggs and larvae preyed upon by fish); and (4) flooding regimes affect the structure of wetland vegetation communities and may provide specific habitats for individual wildlife species. Water regimes may also cause a cell to be inappropriate habitat for a species. Water regimes are an essential variable in those species-habitat models with (a) in model type in column II in Appendix B. Water "structure" is a specific water regime descriptor indicated for those species-habitat models with (b) in model type in column II in Appendix B. Water "structure" refers to a specific wetland feature and is described later in this section.

We have used NWI databases in the development of wetland Geographic Information System layers and the U.S. Fish and Wildlife Service's official wetland classification system (Cowardin et al. 1979) when describing water regimes and wetland habitat dependencies. The benefit of using NWI maps in ECOSEARCH is that a massive, significant, high-resolution data base already has been developed for the total land area in New England, and a small proportion of these New England NWI maps have been digitized and are available for ECOSEARCH assessments.

The water regime codes, for the most part, are those used by the NWI so that estimated requirements of species can be associated with an important descriptive attribute identified on NWI maps. Water regime codes for columns VIII and within brackets in column II in Appendix B are:

Nontidal Water Regimes (used for Riverine, Lacustrine and Palustrine Systems):

A. Temporarily flooded habitats. The habitat floods most years for less than 2 weeks during the growing season, but the habitat is usually dry by mid-growing season. Plants that grow in both uplands and wetlands are characteristic of this regime.

B. Saturated. The substrate is saturated for most of the growing season (commonly year round) but rarely floods, so surface water is seldom present.

C. Seasonally flooded habitats. The habitat floods for 2 weeks or more during the growing season, but usually is dry by the end of the growing season, in most years.

D. Seasonally flooded/well drained.

E. Seasonally flooded/Saturated. The habitat floods most years for 2 weeks or more during the growing season and remains saturated near the surface for most of the growing season.

F. Semipermanently flooded. The habitat remains flooded throughout the growing season in most years.

G. Intermittently exposed. The habitat is nearly permanently flooded and is exposed only during drought conditions.

H. Permanently flooded. The habitat remains flooded throughout the year in all years and vegetation is composed of obligate hydrophytes, for example, cattails (*Typha latifolia*).

Tidal water regimes (used for Marine and Estuarine systems where salinities >0.5 ppt).

L. Subtidal. The habitat is permanently flooded by tides throughout the year.

M. Irregularly exposed. The habitat is flooded most times except during extreme low tides.

N. Regularly flooded. The habitat is flooded and exposed by tides at least once daily. This is sometimes considered to be "low marsh" and the dominant vegetation may be smooth cordgrass (*Spartina alterniflora*).

P. Irregularly flooded. The habitat is flooded by tides less often than once a day. This is sometimes considered to be "high marsh" and may feature species varying from salt grass to needlerushes.

Water Structure.

S. Water "structure". Species-habitat model types identified with a (b) in column II in Appendix B indicate that specific wetland features such as seeps, springs, rapidly flowing streams, etc. are believed to be essential habitat variables for the species. These variables are sometimes specifically notated on NWI maps and sometimes included in data bases digitized from those maps. Such small-scale features, however, are sometimes missed in the development of ECOSEARCH data bases so that species that are mapped on the basis of this dependency may sometimes be misrepresented in ECOSEARCH assessments. The importance of a

water structure variable is indicated by an S in columns VIII and this notation is often accompanied by a structure entry in columns IX in Appendix B.

Other.

Z. Not applicable. The species, or the species life stage being modeled, is not dependent on the presence of a particular surface water inundation pattern or a specific water "structure" (columns VIII), or the water regime described for a cell does not preclude the use of that cell as habitat for the species (column II [Z]).

IX. Vertical habitat descriptors. The listing of critical or essential variables in column II in Appendix B indicates that vertical structure is an important habitat variable for many wildlife species. The vertical structure of habitat represents physical surface features, vegetative structure, and anthropogenic structures on landscapes. This GIS data layer is obtained from the interpretation of point intercept data developed from an analysis of medium- to large-scale aerial photographs or some similar representation of a study area.

Physical structure on a defined landscape can be depicted by overlaying a clear Mylar grid of points on quality, high-resolution aerial photographs. The habitat is classified according to the structural attribute that is encountered by the photo interpreter at each point. Samples of these point intercept values are used to estimate vertical habitat structure, ecotones, corridors, and other landscape patterns.

The codes to express the structural features that are identified in the point intercept assessments of habitats are listed in Table 2-4. These codes, when built into the species-habitat models, are listed in columns IX in Appendix B. An NA in columns IX in Appendix B indicates that vertical habitat structure is apparently not a critical variable within that habitat block for a particular species-habitat model.

We have incorporated map data from NWI into our codes of vertical structure. An NWI map provides a taxonomic listing of wetlands on an area. The taxonomy is described in Smith (1991). The pertinent NWI taxa include:

System (Riverine, lacustrine, palustrine, etc.)
Subsystem (Tidal, intermittent, littoral, etc.)
Class (Forested wetland, etc.)
Subclass (Broadleaf deciduous, etc.)
Water regime (nontidal seasonally flooded, etc.)
Special modifier (beaver modified, etc.)

The point intercept data in column IX in Appendix B incorporate Class (wetland tree canopy = NWI Forested wetland) and Subclass (broad-leaved deciduous = NWI broadleaf deciduous) attributes of the NWI because they represent physical structures identified in point intercept assessments. The point intercept assessment also identifies rivers, lakes, and other water bodies (the System designation) when a point intercepts open water. Water regime is a modifier listed in columns VIII in Appendix B. Additional wetland attributes are listed in columns III in Appendix B.

Frequently, inferences are made about the possible presence of rather specific habitat criteria based on the appearance of features represented on aerial photographs. For example, sub-canopy conditions may be inferred from our experiences about the habitat structure that occurs under overstories of different closures. Some interrelationships between components of vertical structure are listed below.

A minimal overstory canopy closure occurs when 30 percent or less of the intercept points in a neighborhood encounter a tree overstory. This condition can be found in abandoned fields, old pastures, sedge meadows, savannas, open bogs, stands defined as commercially nonstocked, recently clearcut stands and some shelterwood or seed tree cuts (DeGraaf et al. 1992). Sufficient solar insolation occurs in these habitats so that a substantial understory cover occurs under these overstory conditions.

A partial overstory canopy occurs when 30 to 70 percent of the intercept points in a neighborhood encounter a tree overstory. The more open conditions occur in clearcuts, open shelterwoods, sugarbush stands, and low-density pine stands. The more closed conditions occur in intermediate thinnings and closed shelterwoods. Partial overstory conditions are often temporary as the tendency is to develop a closed canopy. A developing shrub and midstory vegetation layer is characteristic of this cover condition (DeGraaf et al. 1992), especially in areas with the lesser canopy closure.

A closed overstory canopy occurs when 70 percent or more of the intercept points in a neighborhood encounter a tree overstory. These conditions can occur when there is uneven-age management of northern hardwoods, and in even-age management systems where stocking levels are maintained to produce maximum form, quality, and growth. There is a minimal development of midstory and understory layers under these overstory cover conditions (DeGraaf et al. 1992).

It is additionally assumed that trees with large rounded crowns are likely to be more mature and to have larger boles and to potentially provide more cavities for wildlife species. It is inferred that high exposed perches will be present where large trees occur in a non-forest setting, and that low perches will occur where midstory trees and shrubs occur in a non-forest setting. The presence of dead and down material and forest litter is assumed to be a normal component of forest floors. It is also assumed that habitats suitable for fossorial species can be determined from the GIS layer describing soil conditions.

Some of the descriptors listed in Appendix B will likely be too detailed when medium scale (1:40,000) aerial photographs are interpreted, but are achievable when large scale (1:5,000) aerial photographs, or analogous representations such as aerial videography, are interpreted. The point intercept data used to interpret the vertical dimension of cells incorporate as much detail as possible in order to enhance the assessment effort.

Table 2-4.—Vertical habitat descriptors used to characterize wildlife habitats.

UPLANDS: WELL-DRAINED HABITATS

UPLAND TREE CANOPY (> 6 m)

1. Broad-leaved deciduous
- a. round crown (sawtimber)
- b. conical crown (poletimber)

2. Needle-leaved evergreen
- a. round crown (sawtimber)
- b. conical crown (poletimber)

3. Needle-leaved deciduous
- a. round crown (sawtimber)
- b. conical crown (poletimber)

4. Broad-leaved evergreen
- a. round crown (sawtimber)
- b. conical crown (poletimber)

5. Live broken top trees

6. Dead trees
- a. snags

7. Man-made structure
- a. houses, in-use
- b. derelict buildings and debris
- c. power poles and lines
- d. barns and out-buildings
- e. commercial buildings
- f. other

UPLAND SHRUB OR MIDSTORY CANOPY (> 1 m, < 6 m)

11. Broad-leaved deciduous
- a. hardwood regeneration (natural)
- b. hardwood regeneration (managed)
- c. orchard
- d. other

12. Needle-leaved evergreen
- a. softwood regeneration (natural)
- b. softwood regeneration (managed)
- c. orchard — Christmas tree plantation
- d. other

13. Needle-leaved deciduous

14. Broad-leaved evergreen

15. Krummholz

16. Dead shrubs

17. Man-made structure
- a. houses, in-use
- b. derelict buildings and debris
- c. power poles and lines
- d. barns and out-buildings
- e. commercial buildings
- f. other

UPLAND UNDERSTORY (from 10 cm below the surface-air interface up to 1 m)

21. Barren surface
- a. sand
- b. cobble, gravel
- c. other

22. Rock covered surface
- a. ledge and/or cliff
- b. rubble
- c. bedrock
- d. other

23. Stable bank (unconsolidated)

24. Short woody vegetation
- a. early woodland succession (natural)
- b. early woodland succession (managed)
- c. alpine
- d. ornamental plantings

25. Herbaceous cover
- a. old field (often can be viewed as a very early forest successional stage)
- b. mowed field (vegetation is mechanically controlled — includes golf courses, yards, hayfields)
- c. pasture (vegetation is controlled by domestic animals)

26. Agricultural cropland
- a. rowcrops
- b. other (alfalfa)

27. Man-made structures
- a. roads and parking lots
- b. derelict structures and debris
- c. other
- d. woody debris

UPLAND SUBSURFACE (From 10 cm below the surface-air interface down)

31. Cave mouths or openings

32. Man-made structures (tunnels)

33. Other

WETLAND OR DEEPWATER HABITATS

WETLAND TREE CANOPY (> 6 m) (NWI = Forested (FO) wetland class; fresh water and brackish water conditions)

41. Broad-leaved deciduous (NWI =broad-leaved deciduous subclass (PFO1))
- a. round crown (sawtimber)
- b. conical crown (poletimber)

42. Needle-leaved evergreen (NWI = PFO4)
- a. round crown (sawtimber)
- b. conical crown (poletimber)

43. Needle-leaved deciduous (NWI = PFO2)
- a. round crown (sawtimber)
- b. conical crown (poletimber)

44. Broad-leaved evergreen (NWI = PFO3)
- a. round crown (sawtimber)
- b. conical crown (poletimber)

45. Live broken top trees

46. Dead trees (NWI = PFO5)
- a. snags

47. Man-made structure
- a. structures like bridges
- b. derelict structures and debris
- c. power poles and lines
- d. other

(Continued)

Table 2-4.—Vertical habitat descriptors used to characterize wildlife habitats. - Continued.

WETLAND SHRUB OR MIDSTORY CANOPY (> 1 m, < 6 m) (NWI=scrub/shrub (SS) wetland class; fresh water and brackish water conditions)

51. Broad-leaved deciduous (NWI =broadleaved deciduous subclass (PSS1))
- a. hardwood regeneration (natural)
- b. hardwood regeneration (managed)
- c. orchard
- d. other

52. Needle-leaved evergreen (NWI = PSS4)
- a. softwood regeneration (natural)
- b. softwood regeneration (managed)
- c. orchard — Christmas tree plantation
- d. other

53. Needle-leaved deciduous (NWI = PSS2)
54. Broad-leaved evergreen (NWI = PSS3)
55. Emergent wetland (phragmites, tall cattails, etc. (NWI = PEM1)
56. Dead shrubs (NWI = PSS5)
57. Man-made structure
- a. structures like bridges
- b. derelict structures and debris
- c. power poles and lines
- d. other

FRESH WATER WETLAND UNDERSTORY (from the wetland surface-air interface up to 1 m above the surface).

61. Barren surface: (includes river banks, lakeshores, pond banks, other)
- a. mud (NWI = PUS3; RUS3; L2US3)
- b. sand (NWI = PUS2; RUS2; L2US2)
- c. cobble, gravel (NWI = PUS1; RUS1; L2US1)
- d. rubble (NWI = PRB2; RRS2; L2RS2)
- e. bedrock (NWI = PRB1; RRS1; L2RS1)
- f. other

62. Short woody vegetation
- a. broad-leaved deciduous (NWI = PSS1)
- b. needle-leaved evergreen (NWI = PSS4)
- c. needle-leaved deciduous (NWI = PSS2)
- d. broad-leaved evergreen (NWI = PSS3)

63. Moss/lichen understory (NWI = PML)
64. Emergent wetland — wet meadows
65. Emergent wetland — persistent herbaceous (species such as bulrushes, cattails, saw grass, sedges, purple loosestrife, dock.) (NWI = PEM1)
66. Agricultural lands
67. Man-made structures
68. Debris
69. Other

BRACKISH WETLAND UNDERSTORY (from the brackish wetland surface-air interface up to 1 m above the surface).

71. Barren surface: (includes estuarine flats, beaches, or sand bars, rocky shores, unconsolidated shores)
- a. mud (NWI = E2US3)
- b. sand (NWI = E2US2)
- c. cobble, gravel (NWI = E2US1)
- d. rubble (NWI = E2RS2)
- e. bedrock (NWI = E2RS1)
- f. reef (NWI = E2RF)
- g. other

72. Short woody vegetation
- a. broad-leaved deciduous (NWI = E2SS1)
- b. needle-leaved evergreen (NWI = E2SS4)
- c. needle-leaved deciduous (NWI = E2SS2)
- d. broad-leaved evergreen (NWI = E2SS3)

73. Emergent wetland- non-persistent herbaceous (NWI = E2EM2)
74. Emergent wetland- persistent herbaceous (NWI = E2EM1)
75. Agricultural lands
76. Man-made structures
77. Debris
78. Other

FRESH WATER SURFACE (from the water surface-air interface to 25 cm below that interface)

81. Permanently flooded river (riverine system of NWI)
- a. tidal river (NWI = R1UB)
- b. slow moving river (NWI = R2UB)
- c. fast flowing river or stream (NWI = R3UB)
- d. rooted vascular aquatic vegetation bed in river (NWI = R1EM2; R1AB3; R2EM2; R2AB3)
- e. other aquatic vegetation bed in river

82. Permanently flooded lake (lacustrine system of NWI)
- a. shallow water zone (NWI = L2UB)
- b. deep water zone (NWI = L1UB)
- c. rooted vascular aquatic vegetation bed in lake (NWI = L2EM, L2AB)
- d. other aquatic vegetation bed in lake

83. Permanently flooded pond, freshwater swamps, marshes and bogs (Palustrine system of NWI)
- a. herbaceous vegetation emerging through water
- b. woody shrubs or midstory vegetation emerging through water
- c. trees and overstory vegetation emerging through water

84. Non-permanently flooded river channel (NWI = R1US; R2US, R3US)
85. Non-permanently flooded lakebed (NWI = L2US)
86. Non-permanently flooded pond (vernal or seasonal ponds) (NWI = PUS)
87. Other

BRACKISH WATER SURFACE (from the brackish water surface-air interface to 25 cm below that interface)

91. Rooted vascular aquatic beds in estuary (NWI = E2AB)
92. Other aquatic beds in estuary
93. Open water estuary (NWI = E1UB)
94. Other

X. Relationship of habitat block x to habitat block y. Many species use two distinct habitat types for different life functions. For example, some amphibians use various wetlands as breeding habitat, but otherwise occupy non-aquatic habitats; certain reptiles use specific upland areas as nest sites but otherwise occupy aquatic habitats; some birds nest in tree canopies away from their wetland feeding habitats; and many bats are cave dwellers and aerial feeders away from the cave.

ECOSEARCH recognizes that the distribution of some species depends on the presence of two habitat blocks (**x** and **y**) within a landscape, and further recognizes three different **x, y** associations. The three associations are listed as A, B or C in column X in Appendix B.

A. Habitat block **x** is contiguous with, or adjacent to, habitat block **y**. Give the maximum number of 50- x 50-m cells that individuals of the species can presumably traverse in both **x** and **y** habitats, away from the **x**:**y** interface and still have **x** and **y** function as useful habitats to the species. Frequently, an "edge" species has similar and small **Ax** and **Ay v**alues and frequently, a "corridor" species has dissimilar **Ax** and **Ay** values.

Axmax = (Ax =)
Aymax = (Ay =)

B. Local habitat blocks are not necessarily contiguous such that a continuous corridor must exist between feeding and breeding habitats. Give the maximum number of 50-m cells that can separate **x** and **y** habitats and still allow the **x** and **y** habitat blocks to be considered useful habitat for the species. Corridors can be either **x** or **y** habitats and the maximum distance that can be traveled can be different (denoted **Bx** and **By**). Corridors consist of a continuous string of 4 cell (1 ha) areas that connect the **x** and **y** habitats.

Bxmax = (Bx =)
Bymax = (By =)

C. Local habitat blocks are not necessarily contiguous, and a continuous corridor is not needed. It is assumed that most of these species fly from habitat **x** to **y** such that the habitat between habitats, **z**, is not important. An example of such a species would be a heron whose rookery was some unspecified distance, **Cz**, from its wetland feeding area. Habitat **x** could also represent a point, such as purple martin houses, chimneys, silos, barns, caves, clay banks, where reproduction, resting, etc., occurs and **y** represents a volume of foraging space with a radius **Cz** (measured in number of 50-m cells) extending from **x**. ECOSEARCH will predict distribution patterns for these aerial feeders if the "**x** habitat" is found, often without describing surface conditions under the air column.

Czmax = (Cz =)

XI. Data quality. The information summarized in Appendix B was developed from published literature and the field experiences of professional wildlife biologists. Habitat requirements of some species are well known, though knowledge of the habitat requirements of other species may be quite fragmentary. Some specific types of habitat descriptors, seem particularly poorly known. For example, habitat block sizes required to make a land unit useful to individual wildlife species. The data quality descriptor is the level of confidence we have in the information included in the species-habitat models described in Appendix B. We have a low level of confidence in several of the species-habitat models, and believe those species represent worthy candidates for the next generation of field biology studies. Data quality codes are:

H. High level of confidence.
M. Moderate level of confidence.
L. Low level of confidence.

Chapter 3. Determination of Biological Values and Assessment of Impacts from Land-use Change

ECOSEARCH can estimate and identify the areas within a landscape that represent adequate habitat for a particular wildlife species or for the total non-fish vertebrate wildlife community potentially occurring on the study area. If habitat areas are predicted before and after a land-use change, then any change in predicted areas of habitat can provide an estimate of the impact caused by that habitat change. This chapter describes the application of ECOSEARCH in evaluating the utility of a wooded swamp as wildlife habitat and measuring the impact on the wildlife community that would be caused by developing that swamp into a recreational lake with an adjoining golf course.

Study Area and Habitat Evaluation

This example of an ECOSEARCH habitat evaluation and impact assessment was developed for a 36-km^2 area within Hampshire County, Massachusetts, and is within the towns of Amherst, Belchertown, Granby, and Pelham. The central feature of this landscape area is Lawrence Swamp. Portions of the Holyoke Range, the Pelham Hills, and the agricultural lands around South Amherst are also prominent and provide ecological diversity. The study area encompasses two U.S. Geological Survey topographic quadrangles: Belchertown and Mount Holyoke.

Four data layers — topography, soil characteristics, water regime, and vertical structure — were developed to describe the study area and were digitized to provide the habitat data base.

Topographic gradients for the study area were traced from the existing U.S. Geological Survey maps for the study area, and were digitized as a first data layer. These topographic gradients subdivided the study area at midslope elevations.

Soil characteristics of the study area were derived from Swenson (1981, 1989). The descriptive detail in these maps was reduced to the seven broad categories described in Chapter 2. The reconfigured soils maps were digitized as a distinct data layer and are represented in Figure 3-1.

Data on wetland and deepwater habitats for the study area were developed from the photointerpretation of 1:40,000 color infrared aerial photographs acquired from the National Aerial Photography Program (NAPP). Photointerpretation was conducted using standard NWI techniques (NWI 1990). Wetland delineations produced on a clear Mylar overlay were converted to digital form using equipment compatible with the NWI operational version of the Wetland Analytical Mapping System software (NWI 1992). The digital data were later formatted in a cellular form using GRID programs in ARC/INFO (ESRI 1992). A representation of the wetlands is presented in Figure 3-2.

Vertical habitat structure was determined using point intercept data. The point intercept appraisal was accomplished by overlaying a transparency with intercept points positioned and marked on a 120-row by 120-column sampling grid on the aerial photograph. The intercept points were set to represent 50-m intervals on the ground. The sampling grid was imprinted on a 36 in^2 clear Mylar overlay, which was pin registered to the aerial photographs allowing a repeatable subsampling to occur. Each of the 14,400 intercept points was classified according to the structural classification system listed in Table 2-4. The classified point data were recorded in tabular form and later transformed into the GRID programs of ARC/INFO (ESRI 1992) with 50- x 50-m cells.

Quality control of the point intercept data was achieved by checking row counts and randomly resampling selected rows. Less than 25 hours were required to classify the 14,400 intercept points because the average time to classify an individual point required only 3 to 4 seconds. Certain potential sources of error were recognized in the point intercept data: the relatively large intercept point occasionally intercepted two cover types; points that fell on shadowed areas were sometimes difficult to interpret; points identified as a tree crown within a wooded landscape could have occasionally fallen between tree crowns; palustrine aquatic bed wetlands could have been underrepresented because photography was taken before leaf out occurred, and the palustrine unconsolidated bottom and deepwater habitat data, into which the aquatic bed points were clumped, could be overrepresented in the data. Difficulties also were encountered in distinguishing pastures from tilled row crops in early growth stages. A small number of intercept points also fell on cover types that are not recognized as wildlife habitat and that are not represented in any of the species-habitat models developed for this study. Systematic sampling could also provide a biased estimate of certain cover types under certain circumstances. For example, if a row or column of the sampling points fell along a road, that road signature could be overrepresented in the point samples. Likewise, if the intercept samples ran parallel to the road, the road signature could be underrepresented in the point samples. A representation of the vertical structure of the habitat is presented in Figure 3-3.

The vertical structure can be segmented to indicate the distribution of overstory, midstory, and understory layers of habitat (Figures 3-4 to 3-11).

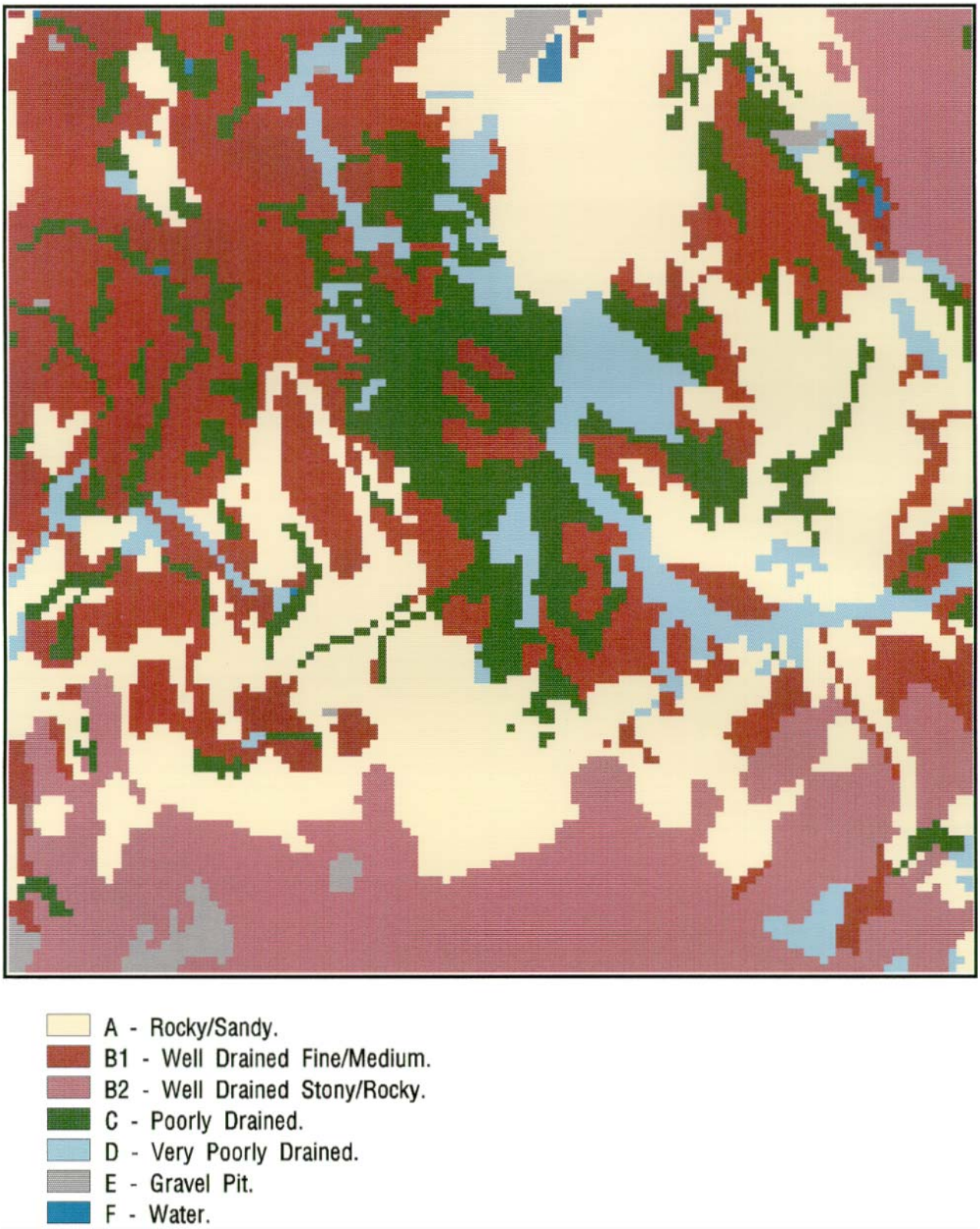


Figure 3.1.—Soil characteristics within the Massachusetts study area. See “Chapter 2. VII. Soil types” for further explanation of key.

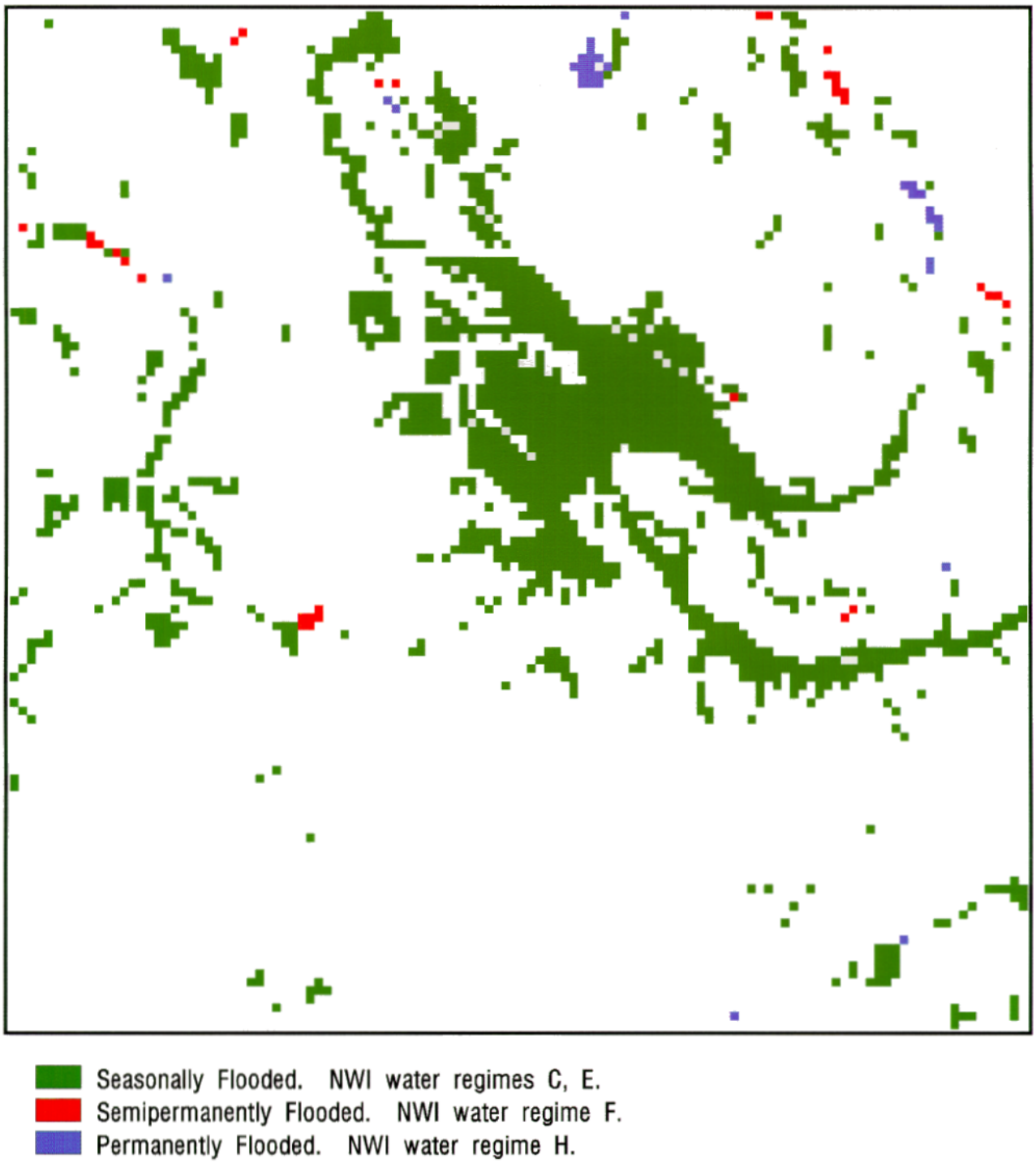
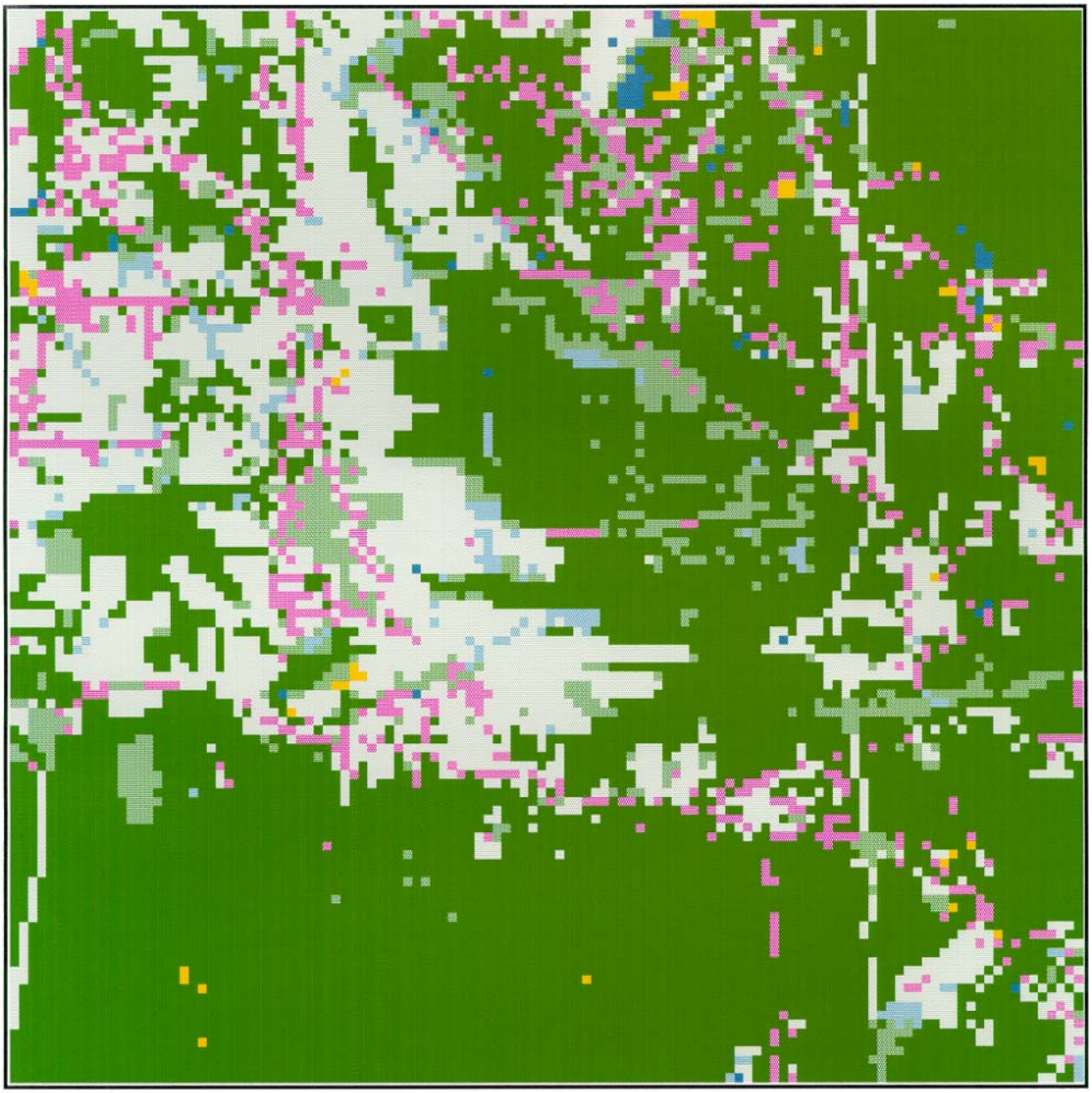


Figure 3.2.—Water regimes within the Massachusetts study area before the proposed habitat change. See “Chapter 2. VIII. Water regimes” for further explanation of key.



Tree Canopy. Intercept points 1-4, 41-44.
Shrub Midstory. Intercept points 11-14, 51-54.
Upland Understory. Intercept points 24-26.
Wetland Understory. Intercept points 62, 64-65.
Human Structures. Intercept points 7, 17, 27, 47, 57, 67.
Water. Intercept points 81-83.
Barren or Rock Covered Surface. Intercept points 21-23.

Figure 3.3.—A representation of the vertical structure of vegetation within the Massachusetts study area. Details of habitat structure are shown in Figures 3-4 to 3-11. See “Table 2.4, Chapter 2,” for further explanation of key.

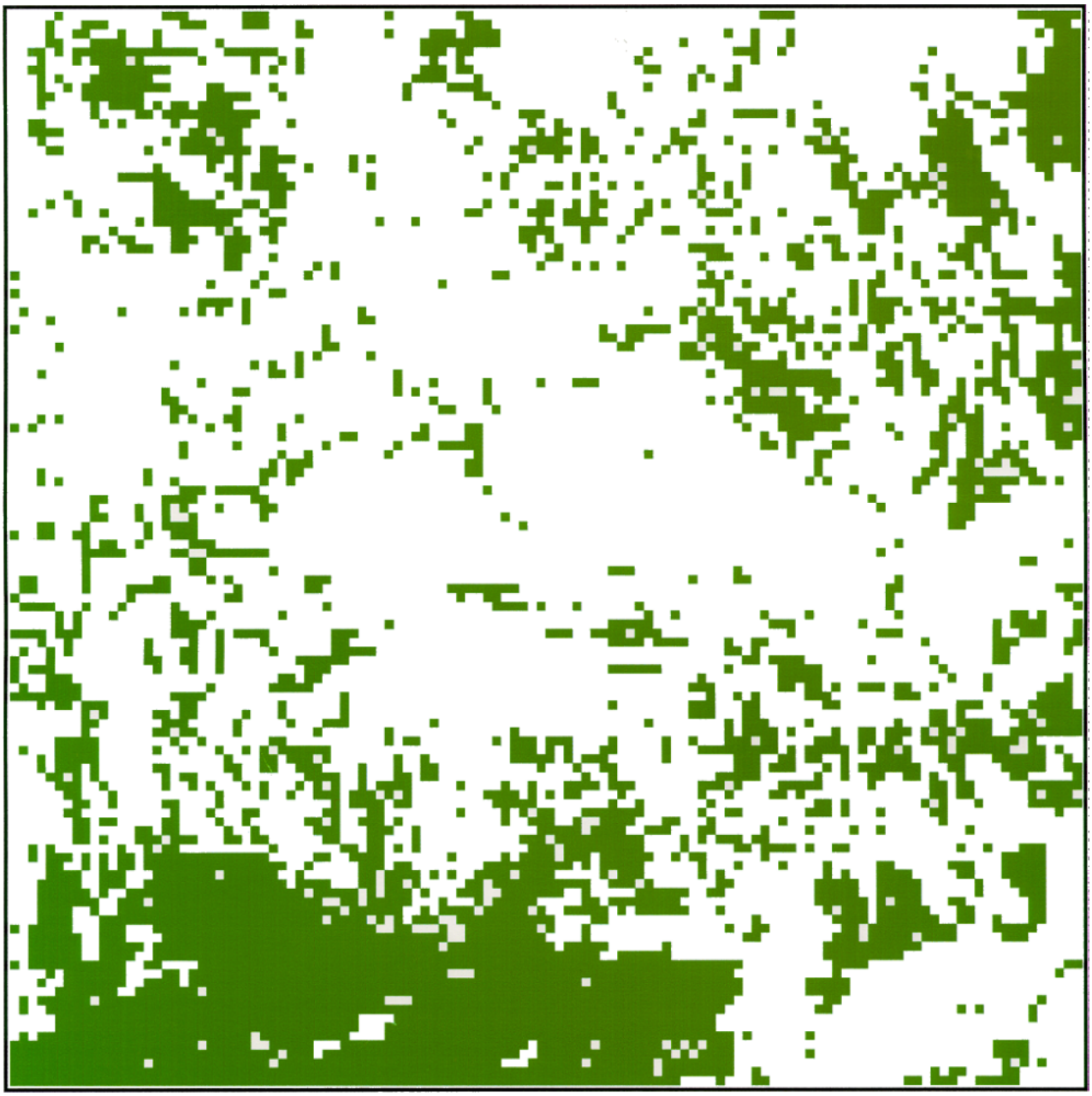


Figure 3.4.—The distribution of broad-leaf deciduous upland trees on the study area indicates where cells provide upland overstory, midstory, and understory layers of habitat.

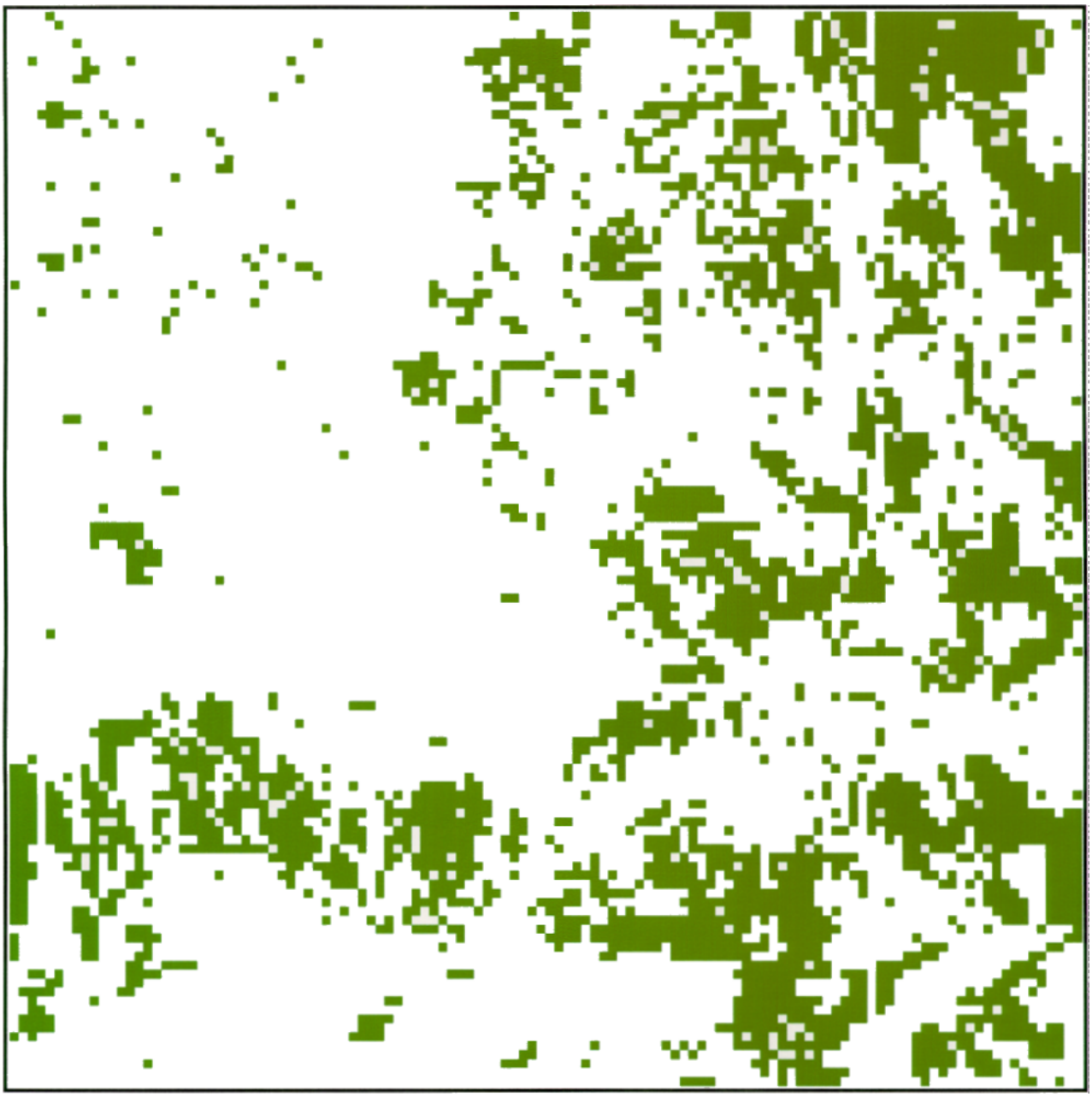


Figure 3.5.—The distribution of needle-leaf evergreen upland trees on the study area indicates the presence of cells that provide upland overstory, midstory, and understory layers of habitat.

Figure 3.6.—The distribution of broad-leaf deciduous upland shrubs indicates the presence of cells that provide upland midstory and understory layers of habitat.

Figure 3.7.—The distribution of upland herbaceous vegetation indicates the distribution of cells that provide an upland understory layer of habitat.

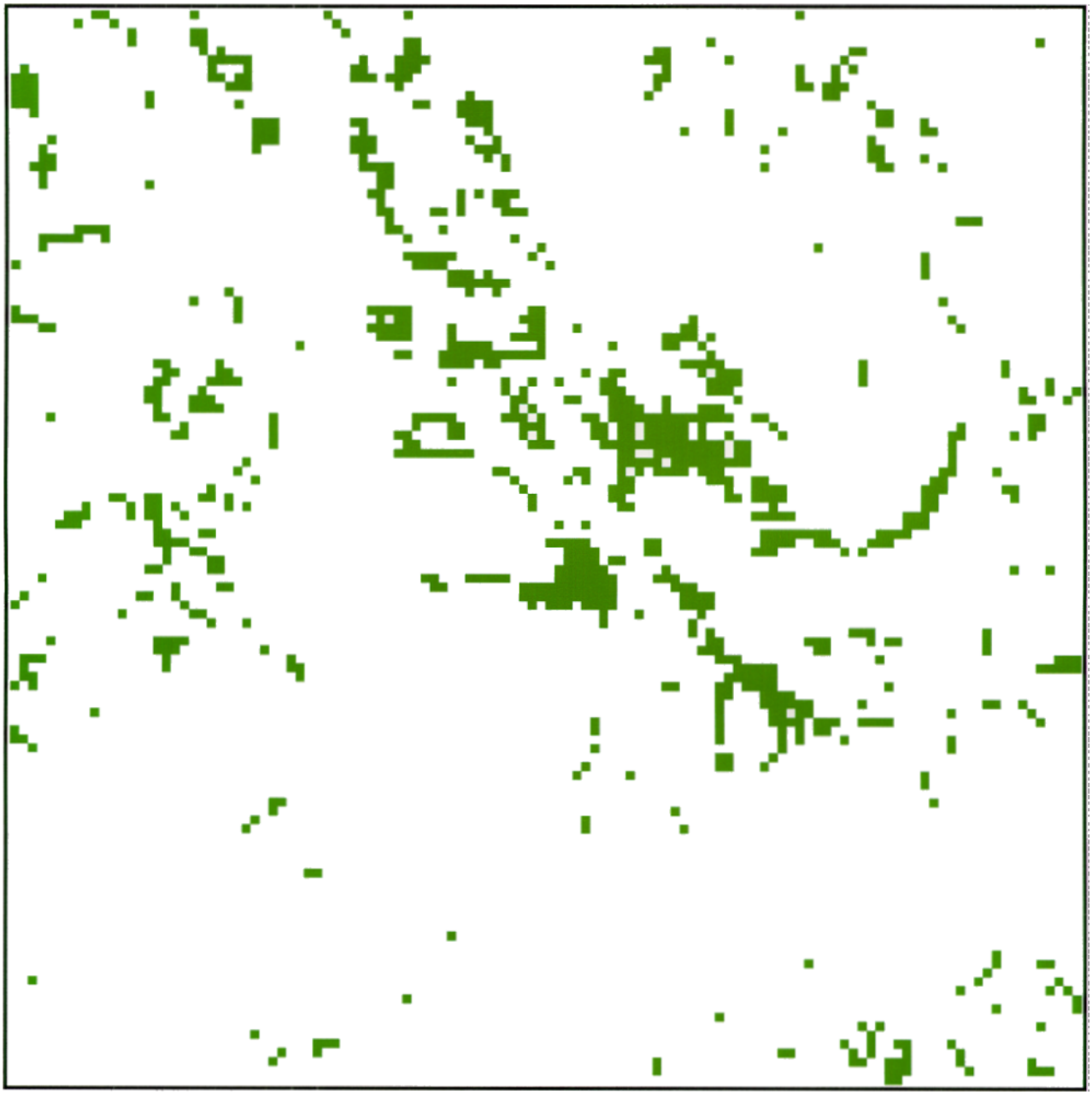


Figure 3-8.—The distribution of broad-leaf deciduous wetland trees indicates the distribution of some cells that provide wetland overstory, midstory, and understory layers of habitat.

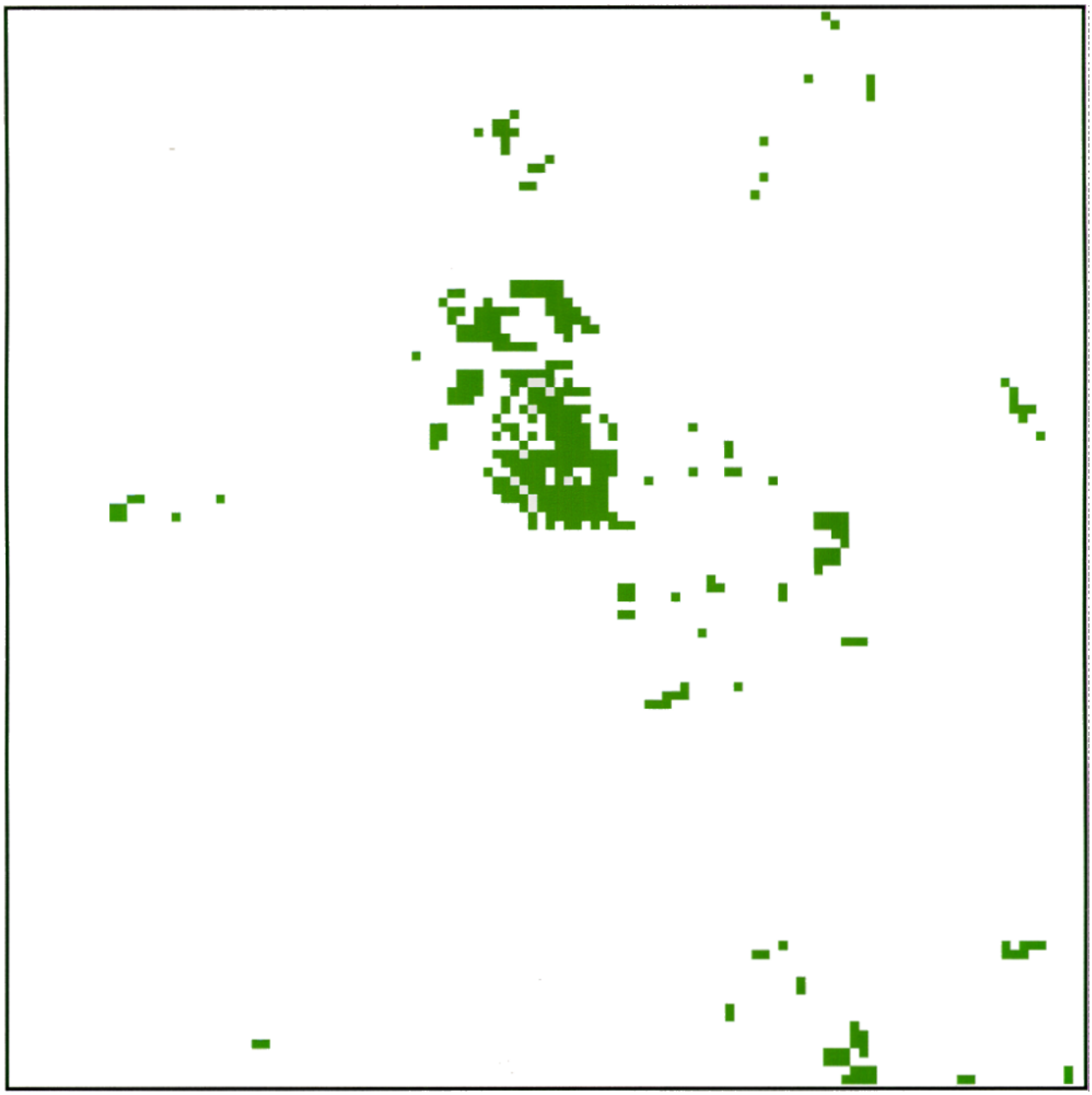


Figure 3-9.—The distribution of needle-leaf evergreen wetland trees indicates the distribution of additional cells that provide wetland overstory, midstory, and understory layers of habitat.

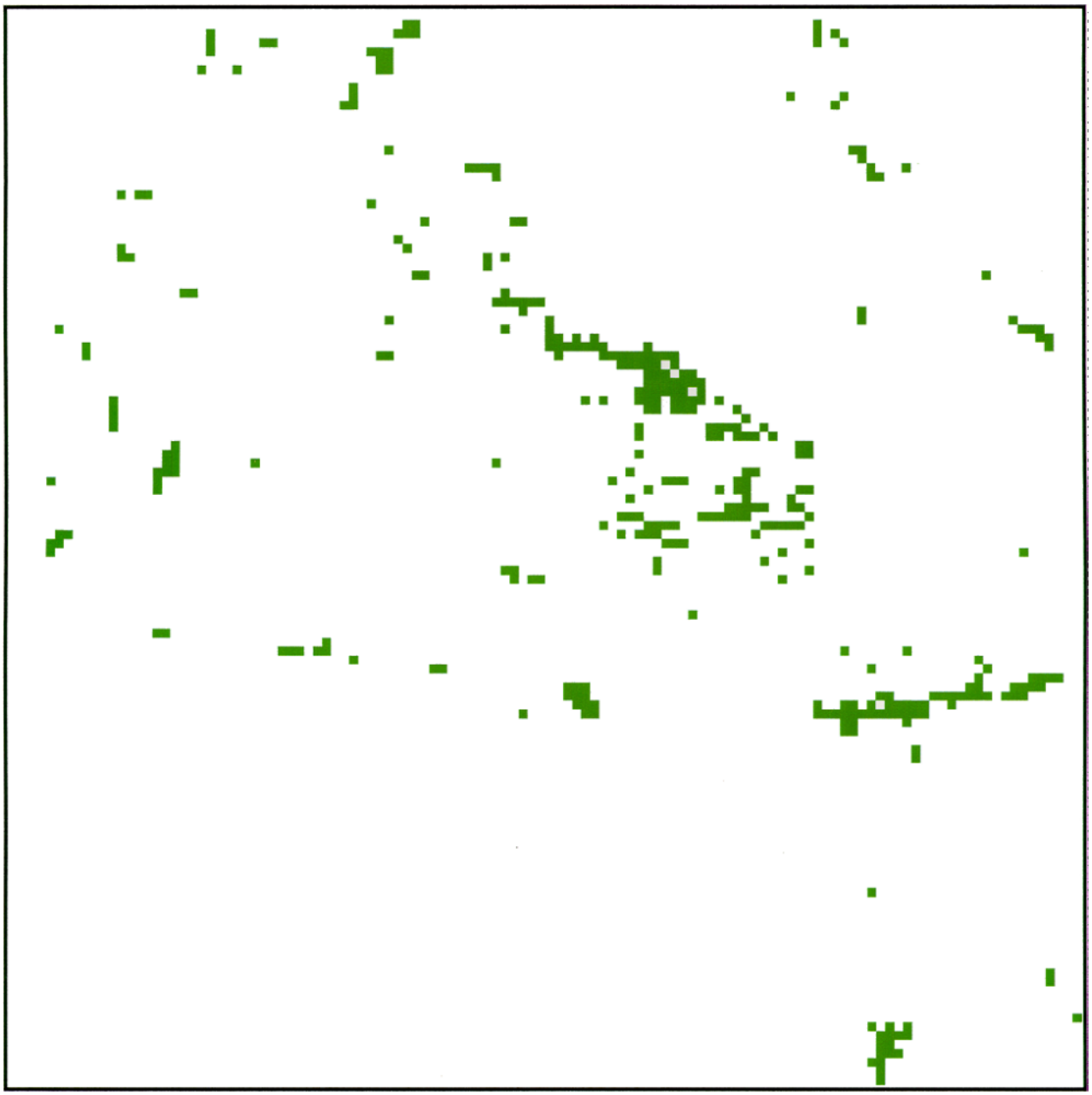


Figure 3-10.—The distribution of broad-leaf deciduous weland shrubs indicates the distribution of cells that provide wetland midstory, and understory layers of habitat.

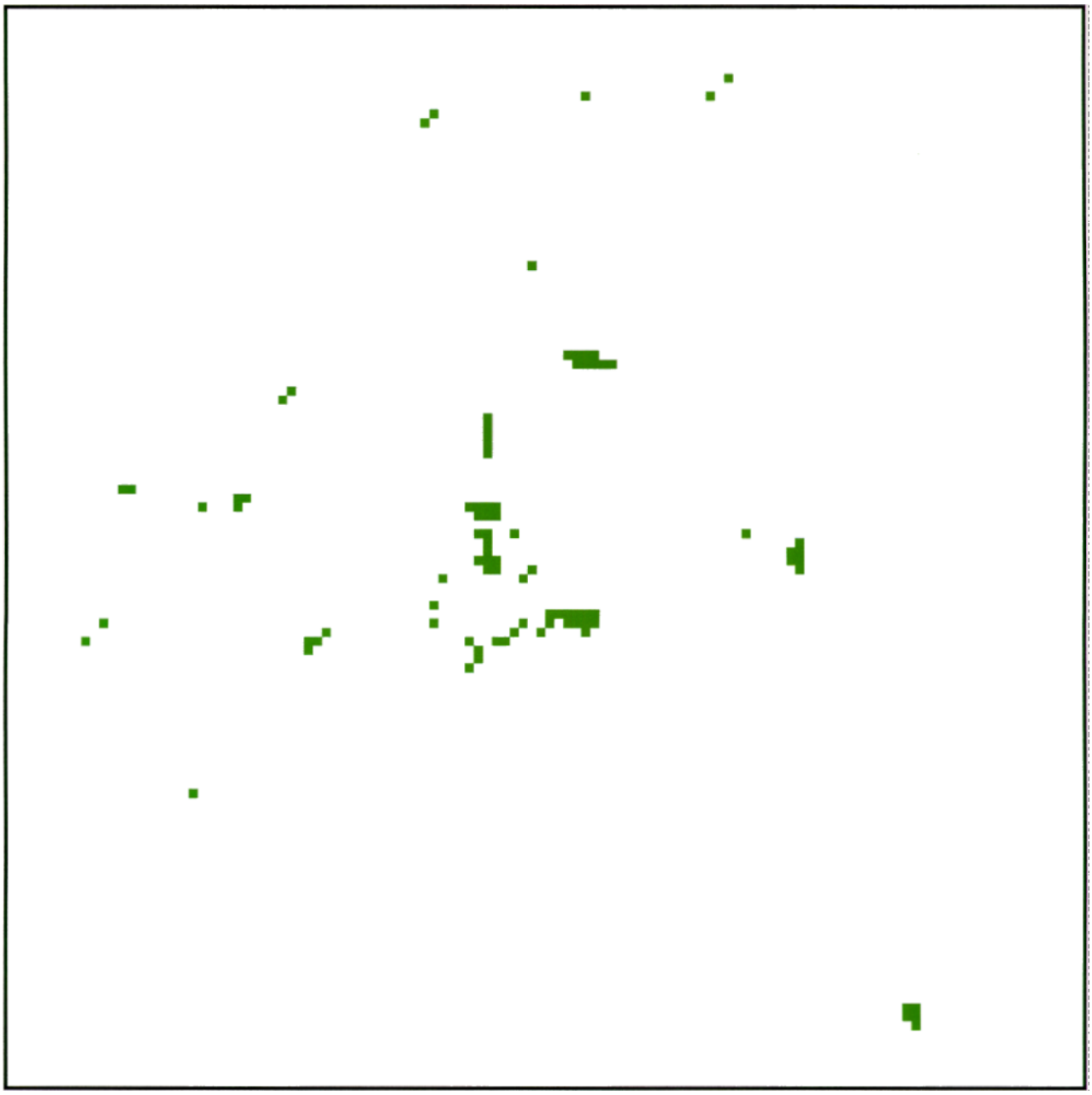


Figure 3.11.—The distribution of persistent emergent herbaceous vegetation indicates the distribution of cells that provide a wetland understory layer of habitat.

Species Possibly Breeding in the Study Area

Twenty-seven species of amphibians and reptiles, 43 species of mammals, and 107 species of birds were identified from breeding bird survey data and by field biologists as probably breeding within the study area. The species are identified in Table 3-1 and are organized by the species-habitat groups (SHG) identified in Appendix C. The species-habitat models for each of the 177 wildlife species are included in Appendix B.

Maps predicting areas of habitat for each of the 177 species were developed using ECOSEARCH. The maps indicate the distribution of cells that provide the habitat characteristics apparently required by the species.

Because a 0.25-ha cell can provide habitat for many species, it is possible to describe the number of species that can use an individual cell as habitat in terms of a "density map". Such "density maps" may suggest areas of high species-richness and may be an indicator of areas of special concern. For example, a herpetofaunal density map for the study area is presented in Figure 3-12. Areas within the central forested swamp and along certain riparian streamers are estimated to be the most favorable habitats for the herpetofaunal community.

The habitat area for a species is calculated from the individual species-habitat maps by summing the number of 0.25-ha cells predicted to be habitat for the species. The total area of habitat for individual species and for individual species-habitat groups is listed in Table 3-1. Habitat areas for SHG are used in developing the "species-habitat group profile" (Figure 3-13). Habitat maps for individual species; density maps for particular taxonomic groups; and predicted habitat areas for individual species, individual species-habitat groups, or the total wildlife community represent baseline data useful in status and trend assessments.

Table 3.1.—Areas of predicted habitat for wildlife species and species-habitat groups on the South Amherst study area before and after a proposed development. The group habitat area value will equal the species value if only a single species is present for a group. The species-habitat groups are those listed in Appendix C.

Species habitat group number	Group value and species within the species-habitat group	Habitat (ha) before development	Habitat (ha) after development	Percent difference
1.	Group value	6,071.5	6,242.5	+2.8
	Eastern chipmunk	2,151.0	2,268.0	+5.4
	Hairy tailed mole	2,290.25	2,300.0	+0.4
	Woodchuck	1,630.25	1,674.5	+2.7
2.	Belted kingfisher	321.0	321.0	0
3.	Group value	7,184.0	6,690.0	-6.9
	Coyote	3,592.0	3,345.0	-6.9
	Red fox	3,592.0	3,345.0	-6.9
4.	Bank swallow	2,064.25	2,400.0	+16.3
5.	Group value	2,030.5	2,078.75	+2.4
	Field sparrow	1,17.75	91.75	-22.1
	Ovenbird	1,504.75	1,607.75	+6.8
	Rufous-sided towhee	408.0	379.25	-7.0
7.	Group value	20,769.25	18,959.25	-8.7
	Black bear	2,165.0	1,588.25	-26.6
	Bobcat	3,592.0	3,199.0	-10.9
	Eastern box turtle	3,358.5	3,110.25	-7.4
	Gray fox	3,569.25	3,175.75	-11.0
	Killdeer	156.5	269.75	+113.25
	Ring-necked pheasant	230.5	136.25	-40.9
	Ruffed grouse	850.75	1,060.25	+24.6
	Turkey vulture	3,592.0	3,345.0	-6.9
	Wild turkey	3,254.75	3,074.75	-5.5

(Continued)

Table 3.1—Continued.

Species habitat group number	Group value and species within the species- habitat group	Habitat (ha) before development	Habitat (ha) after development	Percent difference
12.	Group value	706.0	672.5	-4.7
	House mouse	353.0	336.25	-4.7
	Norway rat	353.0	336.25	-4.7
13.	Group value	5,768.25	5,395.25	-6.5
	Eastern cottontail	2,176.25	2,050.25	-5.8
	Striped skunk	3,592.0	3,345.0	-6.9
14.	Porcupine	2,943.75	2,718.25	-7.7
15.	House finch	592.5	515.5	-13.0
16.	Group value	923.5	919.5	-0.4
	Black-billed cuckoo	163.75	148.0	-9.6
	Solitary vireo	366.25	326.0	-11.0
	Yellow-billed cuckoo	393.5	445.5	+13.2
19.	Brown thrasher	265.5	257.5	-3.0
20.	Prairie warbler	83.5	64.5	-22.8
21.	Group value	9,529.0	9,502.0	-0.3
	European starling	1,730.5	1,746.0	+0.9
	House sparrow	595.0	584.25	-1.8
	Mourning dove	3,369.0	3,300.0	-2.0
	Northern flicker	2,911.0	2,958.5	+1.6
	Rock dove	923.5	913.25	-1.1
22.	Group value	2,284.75	1,986.25	-13.1
	Pine warbler	808.0	699.5	-13.4
	Purple finch	1,476.75	1,286.75	-12.9
25.	Chimney swift	1,783.75	2,127.25	+19.3
29.	Bull frog	511.75	363.0	-29.1
30.	Group value	2,366.25	1,287.75	-45.6
	Green frog	599.25	238.25	-60.2
	Northern leopard frog	678.75	283.25	-58.3
	Pickerel frog	1,088.25	766.25	-29.6
31.	Group value	10,337.75	8,561.25	-17.2
	Eastern American toad	3,446.0	3,206.0	-7.0
	Fowler's toad	1,968.5	1,584.25	-19.5
	Red spotted newt	1,699.5	1,428.25	-16.0
	Spotted salamander	1,248.5	840.25	-32.7
	Wood frog	1,975.25	1,502.5	-23.9
32.	Northern spring peeper	696.75	299.75	-57.0
33.	Gray treefrog	678.75	283.25	-58.3
35.	Group value	198.75	25.75	-87.0
	Louisiana waterthrush	194.75	25.75	-86.8
	Marsh wren	4.0	0	-100.0

(Continued)

Table 3.1—Continued.

Species habitat group number	Group value and species within the species- habitat group	Habitat (ha) before development	Habitat (ha) after development	Percent difference
36.	Group value	658.5	276.0	-58.1
	Ribbon snake	629.25	274.75	-56.3
	Swamp sparrow	21.75	0.75	-96.6
	Virginia rail	7.5	0.5	-93.3
37.	Group value	628.5	266.75	-57.6
	Northern water snake	627.25	264.0	-57.9
	Water shrew	1.25	2.75	+120.0
38.	Star nosed mole	1,084.25	855.75	-21.1
42.	Muskrat	294.5	265.5	-9.8
43.	Beaver	23.75	225.25	+848.4
44.	Group value	3,567.75	3,335.75	-6.5
	Common snapping turtle	814.0	768.5	-5.6
	Eastern (midland) painted turtle	911.0	832.5	-8.6
	Spotted turtle	1,063.25	1,001.0	-5.9
	Stinkpot	779.5	733.75	-5.9
45.	Group value	38,786.75	35,219.75	-9.2
	American woodcock	56.5	51.0	-9.7
	Bobolink	36.25	19.0	-47.6
	Eastern meadowlark	91.75	64.5	-29.7
	Eastern milksnake	3,478.25	3,149.25	-9.5
	Eastern smooth green snake	2,952.25	2,827.75	-4.2
	Hermit thrush	739.0	365.75	-50.5
	Masked shrew	599.5	256.25	-57.3
	Northern black racer	3,540.25	3,318.5	-6.3
	Northern brown snake	3,496.75	3,281.25	-6.2
	Northern red belly snake	3,480.0	3,268.75	-6.1
	Northern ringneck snake	3,064.0	2,780.0	-9.3
	Northern short tailed shrew	789.5	515.0	-34.8
	Redback salamander	2,568.75	2,534.25	-1.3
	Savannah sparrow	76.75	51.75	-32.6
	Smoky shrew	2,572.5	2,539.75	-1.3
	Snowshoe hare	2,995.75	2,734.25	-8.7
	Southern red backed vole	2,963.25	2,704.5	-8.7
	White footed mouse	3,581.5	3,334.5	-6.9
	White throated sparrow	901.5	794.0	-11.9
	Winter wren	802.75	629.75	-21.6
46.	Group value	4,381.25	4,218.5	-3.7
	Eastern garter snake	3,548.0	3,320.75	-6.4
	Spotted sandpiper	833.25	897.75	+7.7
48.	Group value	180.75	133.5	-26.1
	American black duck	39.75	24.5	-38.4
	Canada goose	83.25	72.25	-13.2
	Mallard	57.75	36.75	-36.4
49.	Group value	3,850.25	3,453.0	-10.3
	Common yellowthroat	77.0	32.5	-57.8
	Veery	258.25	95.5	-63.0
	White-tailed deer	3,592.0	3,325.0	-7.4

(Continued)

Table 3.1—Continued.

Species habitat group number	Group value and species within the species- habitat group	Habitat (ha) before development	Habitat (ha) after development	Percent difference
51.	Group value	3,500.0	3,397.5	-2.9
	Black-and-white warbler	1,077.5	1,157.25	+7.4
	Black-throated blue warbler	308.25	155.25	-49.6
	Blue-winged warbler	1,496.25	1,534.0	+2.5
	Chestnut-sided warbler	311.75	269.25	-13.6
	Nashville warbler	306.25	281.75	-8.0
53.	Canada warbler	2,999.75	2,746.5	-8.4
54.	Group value	4,865.0	4,947.25	+1.7
	Meadow jumping mouse	976.0	1,010.25	+3.5
	Meadow vole	1,219.5	1,181.5	-3.1
	Woodland vole	2,669.5	2,755.5	+3.2
55.	Group value	6,301.75	5,779.75	-8.3
	Ermine	2,764.5	2,519.25	-8.9
	Long-tailed weasel	3,537.25	3,260.5	-7.8
56.	Mink	375.25	0	-100.0
58.	Fisher	1,924.25	1,439.75	-25.2
62.	Four toed salamander	630.0	254.75	-59.6
64	Group value	2,823.0	2,599.25	-7.9
	Chipping sparrow	1,708.5	1,727.75	+1.1
	Northern cardinal	1,114.5	871.5	-21.8
65.	Group value	2,786.75	2,428.5	-12.9
	Carolina wren	166.5	101.75	-38.9
	Gray catbird	1,015.25	746.25	-26.5
	House wren	1,605.0	1,580.5	-1.5
66.	Brown creeper	1,792.75	1,654.0	-7.7
67.	Rose-breasted grosbeak	1,189.75	939.25	-21.1
68.	Group value	2,175.5	1,932.75	-11.2
	Least flycatcher	1,604.0	1,502.75	-6.3
	Willow flycatcher	571.5	430.0	-24.8
69.	Tree swallow	647.75	194.5	-70.0
70.	Eastern bluebird	1,619.0	1,624.25	+0.3
71.	Eastern phoebe	1,567.75	1,569.75	+0.1
74.	Alder flycatcher	0	0.75	+
76.	Red-winged blackbird	439.25	334.25	-23.9
78.	Group value	1,935.5	1,815.75	-6.2
	Indigo bunting	431.5	441.25	+2.3
	Northern mockingbird	722.5	652.0	-9.8
	Song sparrow	781.5	722.5	-7.5
79.	Magnolia warbler	134.0	117.5	-12.3

(Continued)

Table 3.1—Continued.

Species habitat group number	Group value and species within the species- habitat group	Habitat (ha) before development	Habitat (ha) after development	Percent difference
81.	Group value	15,042.75	13,522.5	-10.1
	Barred owl	1,545.0	1,351.75	-12.5
	Cooper's hawk	3,590.25	3,184.75	-11.3
	Great-horned owl	3,586.25	3,296.0	-8.1
	Red-tailed hawk	3,592.0	3,305.75	-8.0
	Sharp-shinned hawk	2,729.25	2,384.25	-12.6
83.	Wood duck	259.5	124.25	-52.1
84.	Warbling vireo	884.75	1,013.75	+14.6
86.	Gray squirrel	1,842.75	1,828.0	-0.8
89.	Northern goshawk	2,092.25	1,599.0	-23.6
90.	Common raven	3,210.0	2,949.75	-8.1
94.	Group value	12,272.25	11,401.75	-7.1
	American crow	3,583.0	3,334.5	-6.9
	Broad-winged hawk	1,545.0	1,351.75	-12.5
	Common grackle	1,725.5	1,627.25	-5.7
	Eastern screech owl	2,329.0	2,301.75	-1.2
	Northern saw-whet owl	2,005.5	1,607.0	-19.9
	Wood thrush	1,084.25	1,179.5	+8.8
97.	American robin	3,568.25	3,322.5	-6.9
99.	Group value	24,592.75	22,942.25	-6.7
	Black-capped chickadee	3,052.75	2,791.25	-8.6
	Black-throated green warbler	847.0	668.0	-21.1
	Cedar waxwing	1,511.5	1,425.5	-5.7
	Downy woodpecker	3,312.75	3,065.5	-7.5
	Hairy woodpecker	2,789.25	2,564.75	-8.0
	Northern oriole	1,272.75	1,396.25	+9.7
	Pileated woodpecker	2,518.5	2,208.25	-12.3
	Red-breasted nuthatch	1,284.25	1,017.5	-20.8
	Red-eyed vireo	2,153.5	2,053.75	-4.6
	Scarlet tanager	2,789.25	2,564.75	-8.0
	White-breasted nuthatch	1,803.25	1,827.0	+1.3
	Yellow warbler	1,258.0	1,359.75	+8.1
100.	Group value	12,617.5	11,911.75	-5.6
	American goldfinch	1,272.5	1,303.0	+2.4
	Blue jay	3,492.5	3,236.0	-7.3
	Ruby-throated hummingbird	1,779.25	1,771.5	-0.4
	Southern flying squirrel	2,756.5	2,538.75	-7.9
	Tufted titmouse	3,316.75	3,062.5	-7.7
101.	Group value	26,628.0	25,768.75	-3.2
	Big brown bat	3,600.0	3,461.0	-3.9
	Eastern kingbird	1,852.0	1,803.5	-2.6
	Eastern pipistrelle	3,472.75	3,436.5	-1.0
	Hoary bat	3,600.0	3,470.0	-4.0
	Little brown myotis	3,472.75	3,436.5	-1.0
	Northern long-eared bat	3,430.5	3,256.25	-5.1
	Red bat	3,600.0	3,457.0	-4.0
	Silver-haired bat	3,600.0	3,461.0	-3.9

(Continued)

Table 3.1—Continued.

Species habitat group number	Group value and species within the species- habitat group	Habitat (ha) before development	Habitat (ha) after development	Percent difference
102.	American kestrel	1,442.0	1,440.25	-0.1
103.	Group value	7,371.0	7,038.5	-4.5
	American redstart	1,435.75	1,472.75	+2.6
	Eastern wood-pewee	3,263.5	3,024.75	-7.3
	Great crested flycatcher	2,671.75	2,541.0	-4.9
104.	Yellow-rumped warbler	1,302.5	1,032.25	-20.7
105.	Red squirrel	2,756.5	2,538.75	-7.9
108.	Great blue heron	273.75	130.5	-52.3
109.	Barn swallow	1,310.75	1,825.0	+39.2
110.	Green heron	328.0	121.25	-63.0
111.	Brown-headed cowbird	3,569.75	3,323.5	-6.9
112.	Virginia opossum	3,156.75	2,905.75	-8.0
113.	Raccoon	2,084.75	2,103.0	+0.9
		295,880.75	272,539.5	-7.9

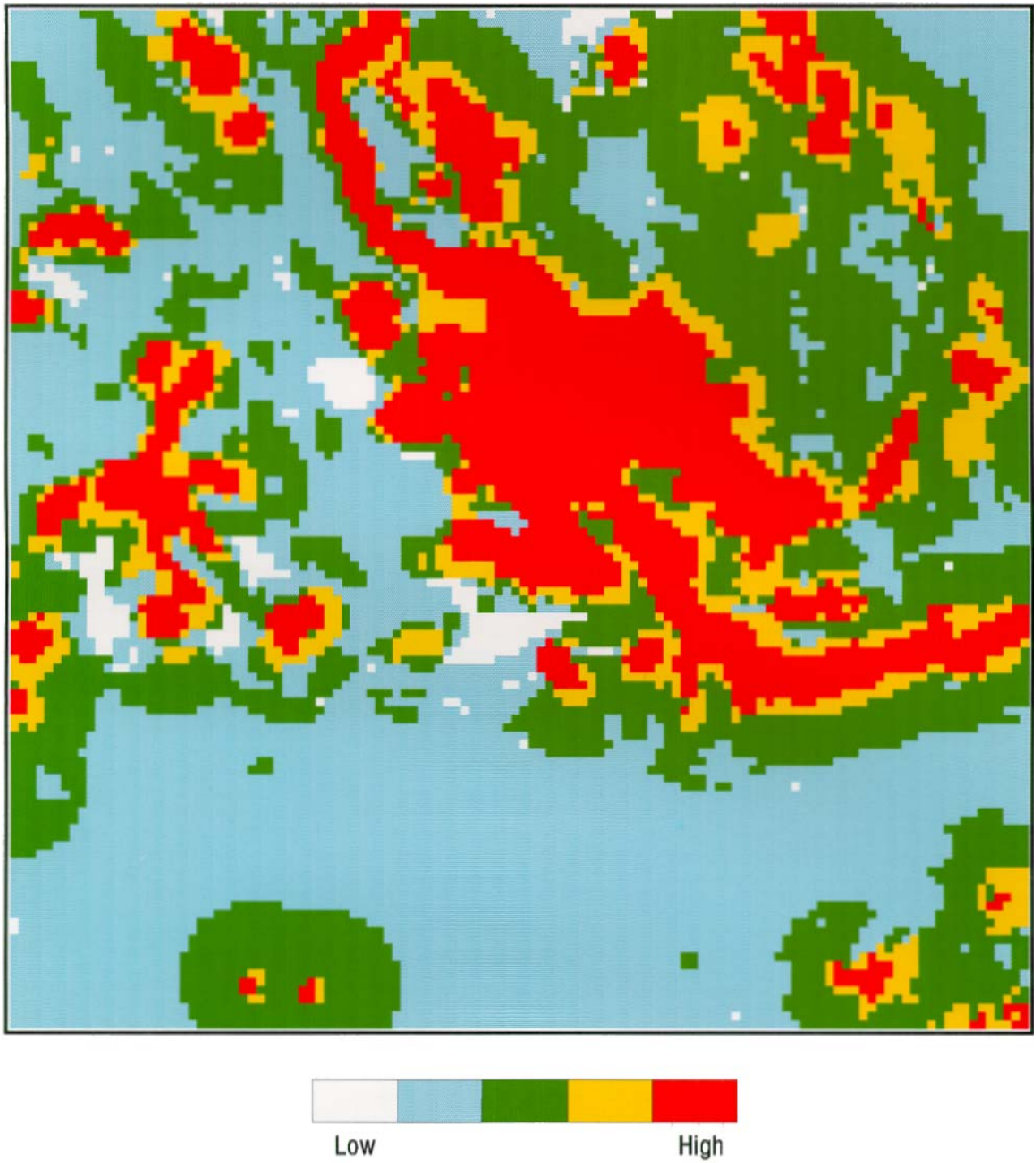


Figure 3-12.—Different portions of the Massachusetts study area provide habitats for differing numbers of amphibians and reptiles. This “density map” indicates that the central forested swamp and some riparian streamers provide habitats for more of these species than do other habitat areas. Scale is based on increments of 5 species, with high representing > 20 species.

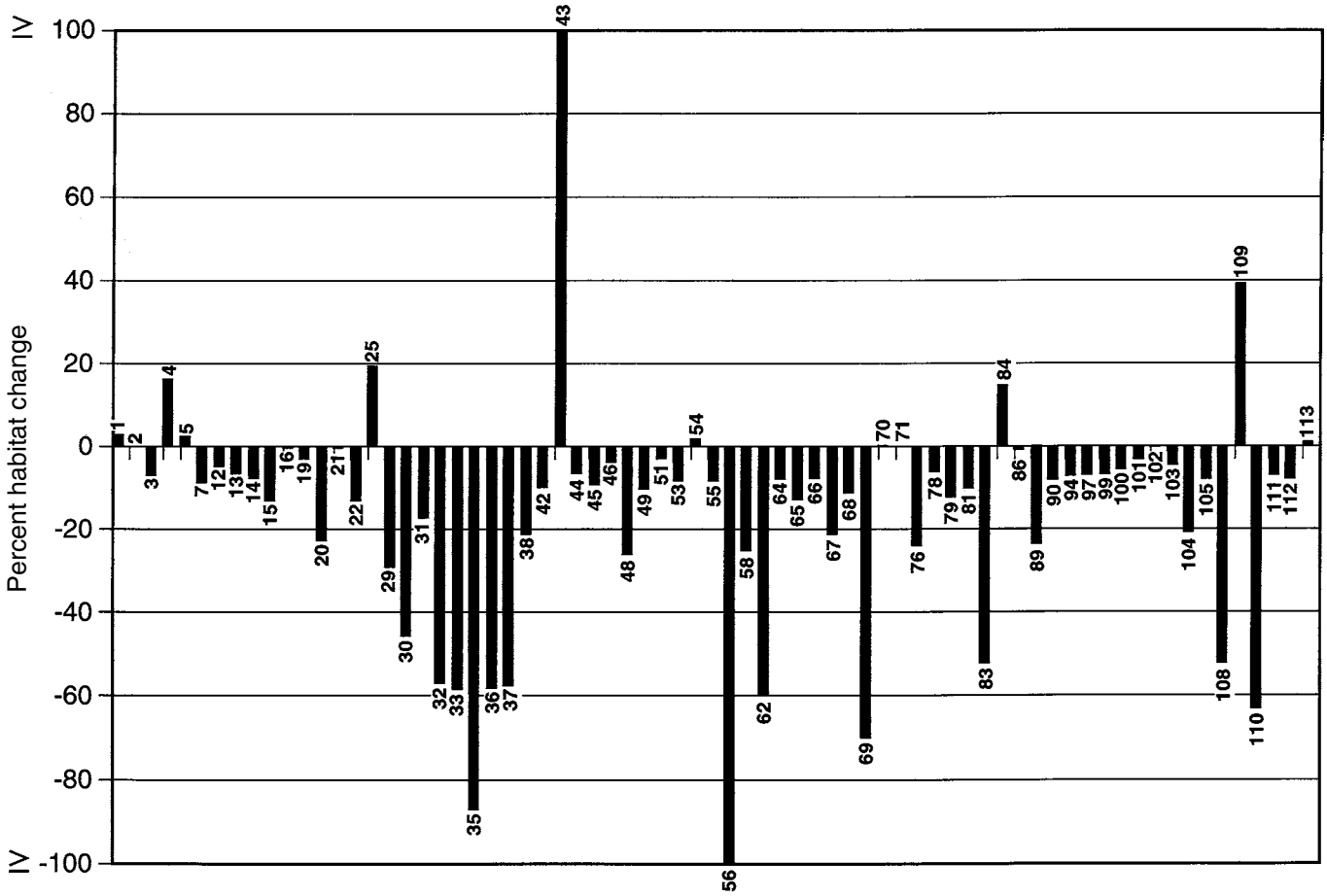


Figure 3-13.—Species-habitat group profile for the South Amherst study area. Bars indicate the direction and magnitude with which predicted habitat areas under the postdevelopment condition differ from habitat areas predicted under the predevelopment condition. Numbers at the end of the bar identify each species-habitat group. Data from Table 3.1.

Performing a Biological Impact Assessment

ECOSEARCH can be used to assess the impact of proposed land-use change scenarios that affect one or more of the four habitat data layers — topography, soils, water regimes, and vertical structure. Many types of land-use change affect the vertical structure of landscapes. Forest management is a prescribed manipulation of structure, and much urban and suburban development is an unprescribed manipulation of structure. A variety of wetland modifications affect water regimes and sometimes also soil conditions. For example, consider a change to the Massachusetts study area that would significantly alter the habitat structure within the central forested swamp. The proposed development would change much of the palustrine woodland to a 220-ha lake, a contiguous 160-ha greenland supporting a golf course, and a buffer of upland forest that will contain 1-ha homesites.

More specifically the structural changes to the predevelopment landscape include increases of 157 ha in the area of broad-leaved deciduous upland trees, 105 ha in the area of mowed herbaceous vegetation, and 220 ha in the deep water zone of a permanently flooded lake. The structural changes also include reductions of 114 ha of needle-leaved evergreen upland trees, 55 ha of agricultural crops, 126 ha of broad-leaved deciduous wetland trees, 70 ha of needle-leaved evergreen wetland trees, and 51 ha in broad-leaved deciduous wetland shrubs. The changes to water regimes (Figure 3-14) and vertical structure (Figures 3-15 to 3-23) within the area of proposed development are obvious and extreme. The changes to recorded soil conditions are that the lake area would be covered by permanent water, and the new golf course would be developed on modified soils labeled as “well drained B1”. It is assumed that no change occurs to topography.

The area of habitat that might exist for individual wildlife species, should the development occur, also can be estimated using ECOSEARCH. The distribution and quantity of postdevelopment habitats are shown in Figures 3-24 to 3-29 and in Table 3-1. A postdevelopment “faunal density” map was developed to illustrate how the proposed development might impact an important segment of the wildlife community. For example, the “faunal density” map predicting the use of the “developed” area by the herpetofaunal community (Figure 3-30) indicates that the central area that was a forested swamp and very important habitat (Figure 3-12) is now an area of much reduced importance as habitat for the herpetofaunal community.

Areas of habitat for members of individual species-habitat groups are listed in Table 3-1, and those areas can be compared before and after the proposed habitat modification to determine the impact of the proposed development. If the areas of habitat for individual species are totaled for predevelopment and postdevelopment conditions, 7.9 percent loss in total habitat area would be caused by the proposed development. A comparison of how different species-habitat groups are advantaged or disadvantaged by the development is represented graphically in Figure 3-13, as a “species-habitat group response profile”. This profile provides a visual display of the direction and degree of change in the quantity of habitat available to different SHG should the development occur. Bars in the profile that indicate very large changes frequently represent SHG composed of one or only a few species that frequently have unique habitat requirements. Likely causes why a habitat change might advantage or disadvantage a particular species can be suggested by studying the variables listed for individual species-habitat models (Appendix B). The species-habitat profile emphasizes the complexity of the response by the wildlife community to a major habitat change and the need to understand that response in developing planning and mitigation proposals.

A comparison of maps predicting areas and distribution of habitat for a species before and after a proposed habitat change provides a way to estimate the impacts of a development upon individual species. Eleven species would gain at least 100 ha of habitat if the proposed development were to occur (Table 3-1). A summary of some of these impacts follows. The number in parentheses following each species name refers to the SHG number listed in Table 3-1. The increases in estimated habitat area for the ovenbird (5) are due to the increase in the area of deciduous woodland near the lake development, the gains for the eastern chipmunk (1), ruffed grouse (7) and warbling vireo (84) are due to increases in deciduous forest and forest edges; and habitat gains for the northern oriole (99) and the yellow warbler (99) are due to increases in edge between decidous forest, the understory layer of the golf course and the lakeshore. Increased beaver (43) habitat is caused by the juxtaposition of lake shoreline and deciduous trees on the lake banks, and enhanced killdeer (7) habitat seems due to the presence of a mowed upland grassland represented by the new golf course. Increases in available habitat for the bank swallow (4), chimney swift (25), and barn swallow (109) are due to their extension of foraging activities over lake water and the golf course clearings. Twenty-two other species are predicted not to be adversely impacted or to realize small gains in habitat area should the development occur. The gains are frequently due to the conversion, outside the lake margins, of wetland to upland habitats.

It is predicted that 144 species will be adversely impacted by the proposed development (Table 3-1) with 96 of these species losing at least 100 ha of habitat. Twenty-eight species lost at least 20 percent of their predevelopment habitat area because they utilized a variety of wetland structures and conditions present within the Lawrence Swamp complex but absent in and around the newly formed lake. Habitat modification would presumably cause the loss of temporary and semi-permanent water regimes in ponds and pools that provide important breeding habitat for amphibians. It would cause the loss of the following habitats: wooded wetlands within the swamp, riparian streamers passing into and through the swamp, small patches of marshes and wet meadows, various types of edge habitats, and wet or moist woodlands influenced by the hydrology of the swamp.

The following wildlife species (SHG in parentheses) should be of major concern to biologists and managers because their specific habitat requirements would be substantially modified by the development: bullfrog (29), green frog (30), northern leopard frog (30), pickerel frog (30), spotted salamander (31), wood frog (31), northern spring peeper (32), gray treefrog (33), Louisiana waterthrush (35), eastern ribbon snake (36), northern water snake (37), star-nosed mole (38), hermit thrush (45), masked shrew (45), northern short-tailed shrew (45), winter wren (45), veery (49), black-throated blue warbler (51), mink (56), four-toed salamander (62), northern cardinal (64), gray catbird (65), rose-breasted grosbeak (67), tree swallow (69), red-winged blackbird (76), wood duck (83), great blue heron (108), and green heron (110).

In addition, 116 other species will each lose varying amounts of habitat because of the conversion of forest habitats to lake and golf course development (Table 3-1).

Species-habitat maps for six species presented in Figures 3-24 to 3-29 show how areas and distributions of habitats can be expected to change because of the proposed development. Figure 3-24 depicts habitat for the eastern chipmunk and shows increases in habitat due to increases in deciduous forest and in forest edges around the development. Figure 3-25 suggests increases in habitat for killdeer because of the likelihood that the proposed golf course will be suitable habitat. Figure 3-26 for the bullfrog, Figure 3-27 for the northern leopard frog, and Figure 3-28 for the mink indicate that the habitat predicted to exist in the postdevelopment condition is moderately reduced for the bullfrog, substantially reduced for the northern leopard frog, and totally lost for the mink because the new lake surface and the reduced wet woodlands near the lake no longer provide suitable habitat for the species. Figure 3-29 for the green heron indicates that habitat is diminished after development because of the loss of shallow water and shoreline trees especially in the area of the proposed golf course.

The comparison of areas of estimated habitat before and after proposed habitat modifications represents an impact assessment or a biological risk assessment. It is the biological cost or benefit of the proposed habitat change.

In summary, ECOSEARCH can describe the present condition (the area estimated to be habitat for species at the present time), and changes that are likely to occur to the distribution of a wildlife species or to the wildlife community, if changes are made to the water regime or to the vertical habitat structure of a landscape. This impact assessment is a reactive assessment: “What will happen if someone does something to a landscape?” We illustrate in the next chapter how ECOSEARCH also can be used in a planning mode, which is a proactive analysis to determine “how habitat variables should be changed to enhance the value of the landscape for particular wildlife species or for the wildlife community.”

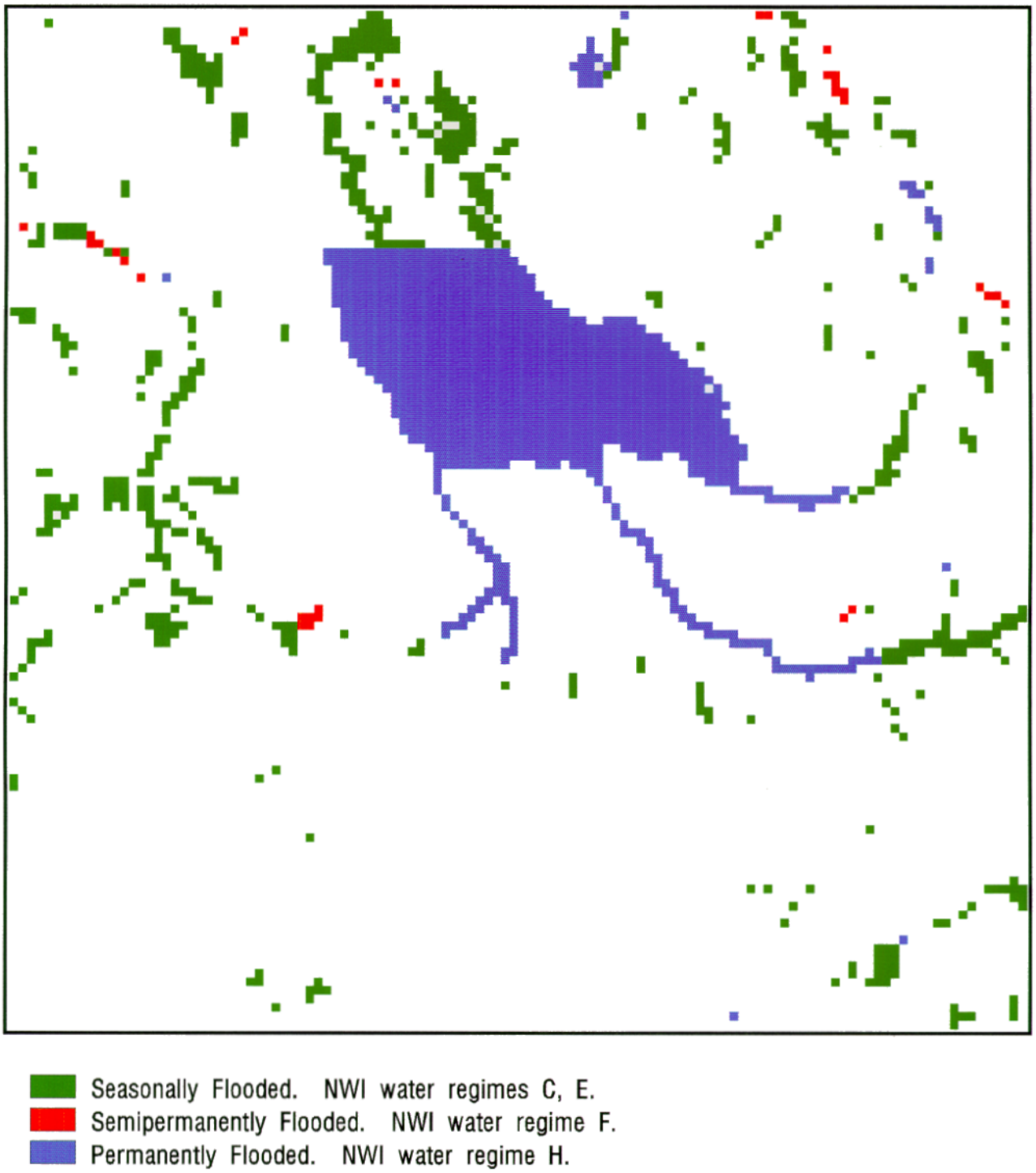
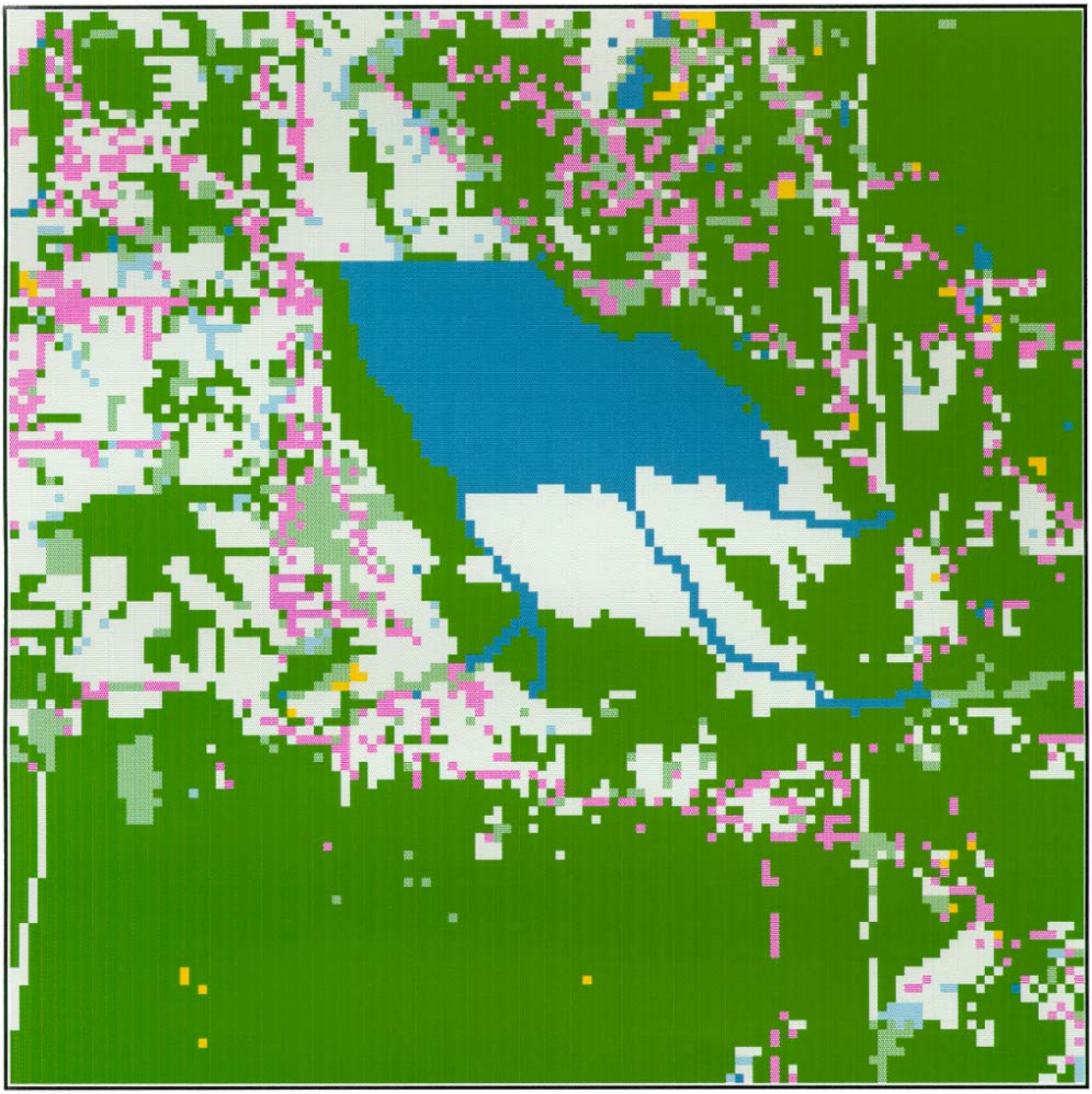


Figure 3.14.—Water regimes within the Massachusetts study area after the proposed development.



Tree Canopy. Intercept points 1-4, 41-44.
Shrub Midstory. Intercept points 11-14, 51-54.
Upland Understory. Intercept points 24-26.
Wetland Understory. Intercept points 62, 64-65.
Human Structures. Intercept points 7, 17, 27, 47, 57, 67.
Water. Intercept points 81-83.
Barren or Rock Covered Surface. Intercept points 21-23.

Figure 3-15.—A representation of the vertical structure of vegetation within the Massachusetts study area after development. Note the large central lake and the adjoining upland understory to be developed into a golf course. Details of habitat structure occur in Figures 3-16 to 3-25.

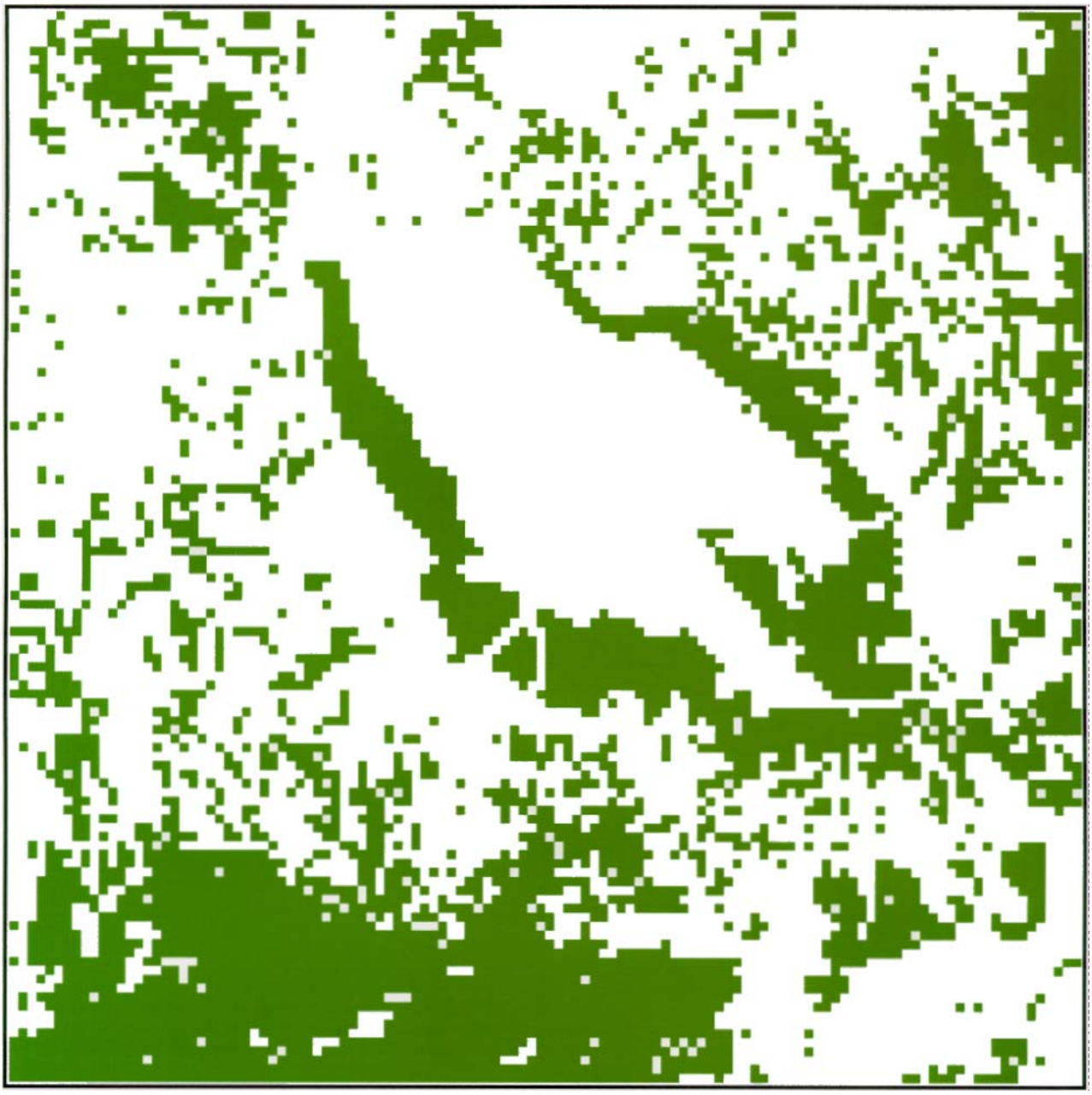


Figure 3-16.—The distribution of broad-leaf deciduous upland trees on the study area after the proposed development. Habitat layers are as described in Figure 3-4.

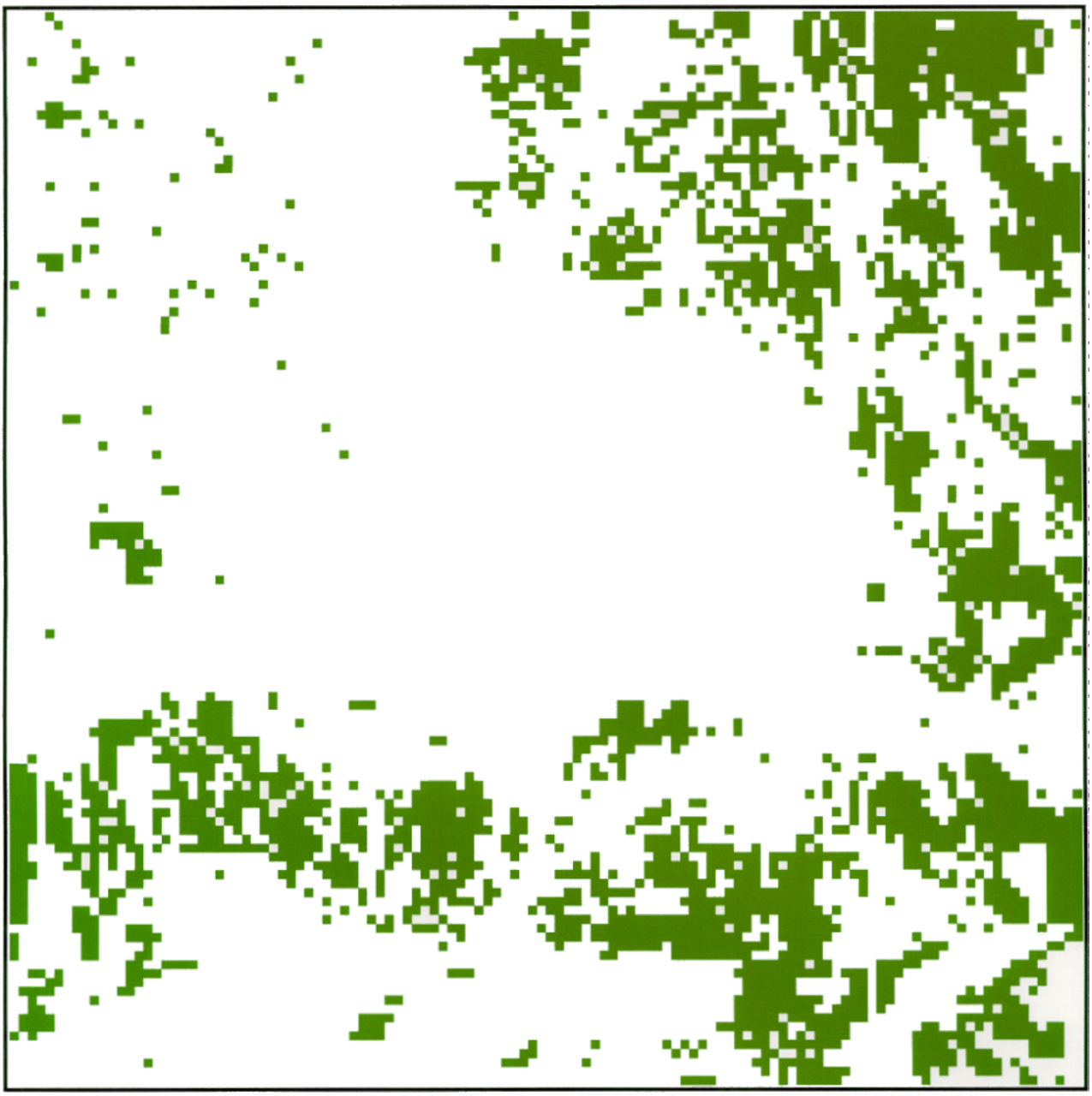


Figure 3-17.—The distribution of needle-leaf evergreen upland trees on the study area after the proposed development. Habitat layers are as described in Figure 3-5.

Figure 3-18.—The distribution of broad-leaf deciduous upland shrubs on the study area after the proposed development. Habitat layers are as described in Figure 3-6.

Figure 3-19.—The distribution of herbaceous vegetation on the study area after the proposed development. Habitat layers are as described in Figure 3-7.

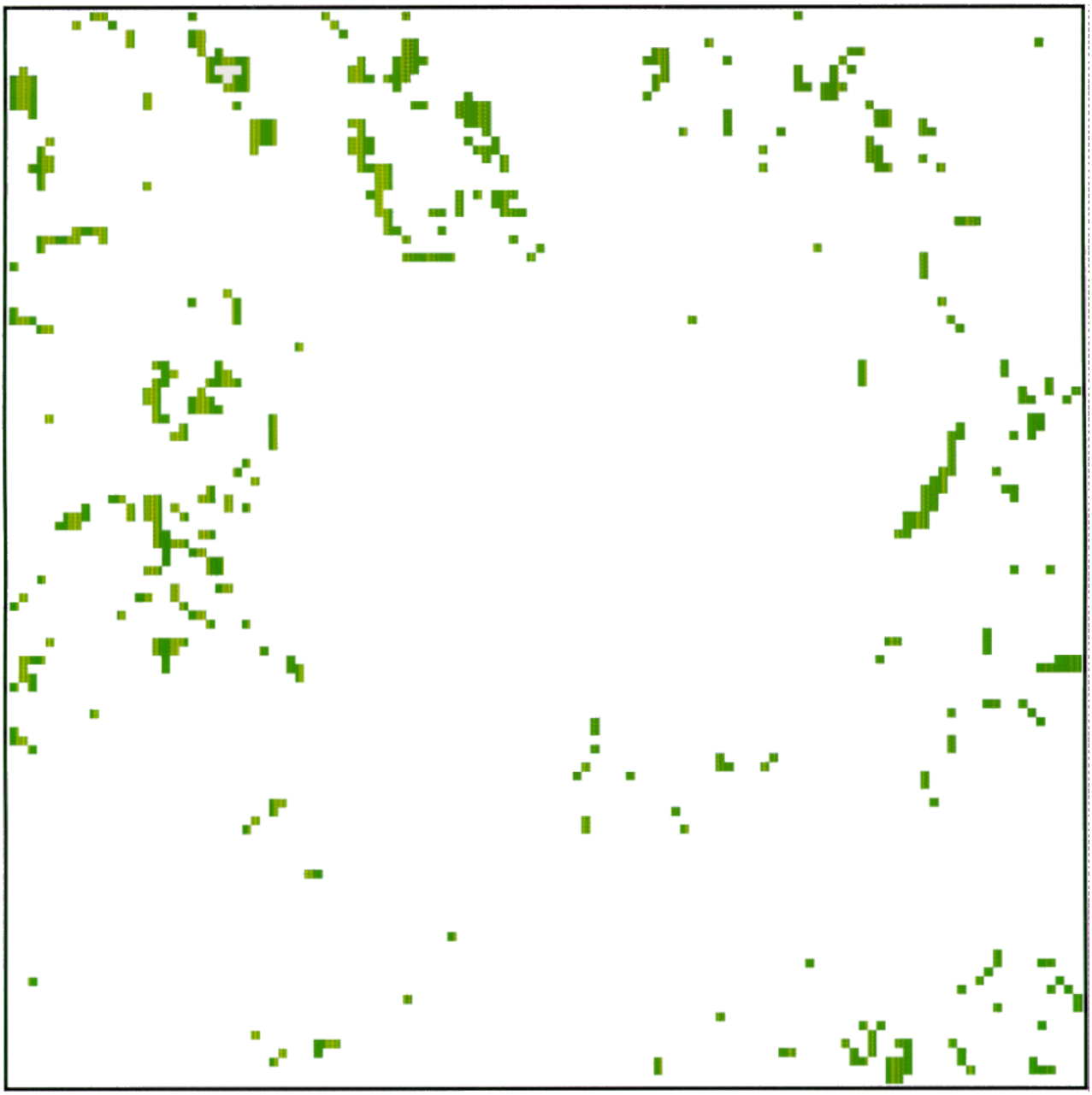


Figure 3-20.—The distribution of broad-leaf deciduous wetland trees on the study area after the proposed development. Habitat layers are as described in Figure 3-8.

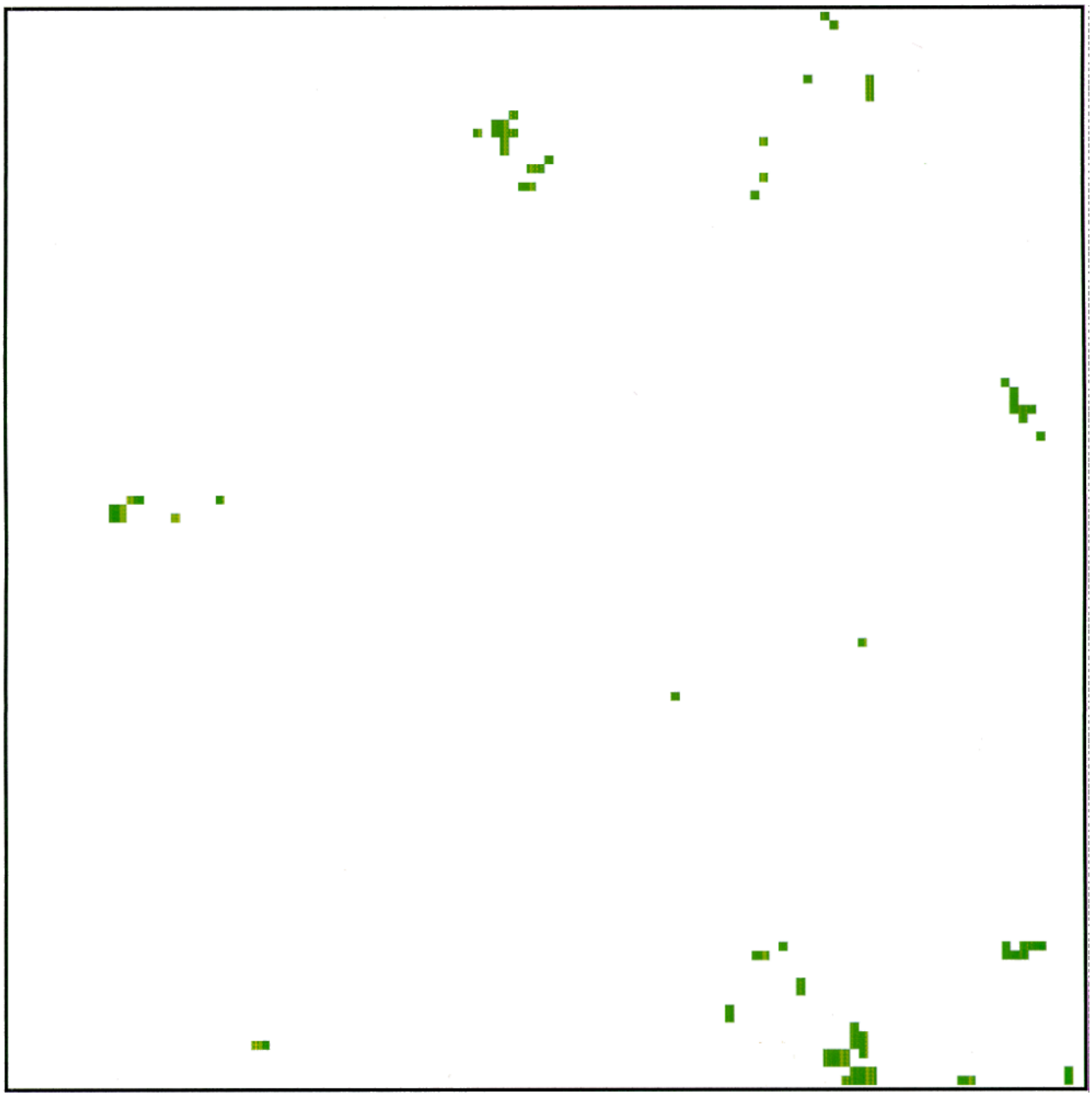


Figure 3-21.—The distribution of needle-leaf evergreen upland trees on the study area after the proposed development. Habitat layers are as described in Figure 3-9.

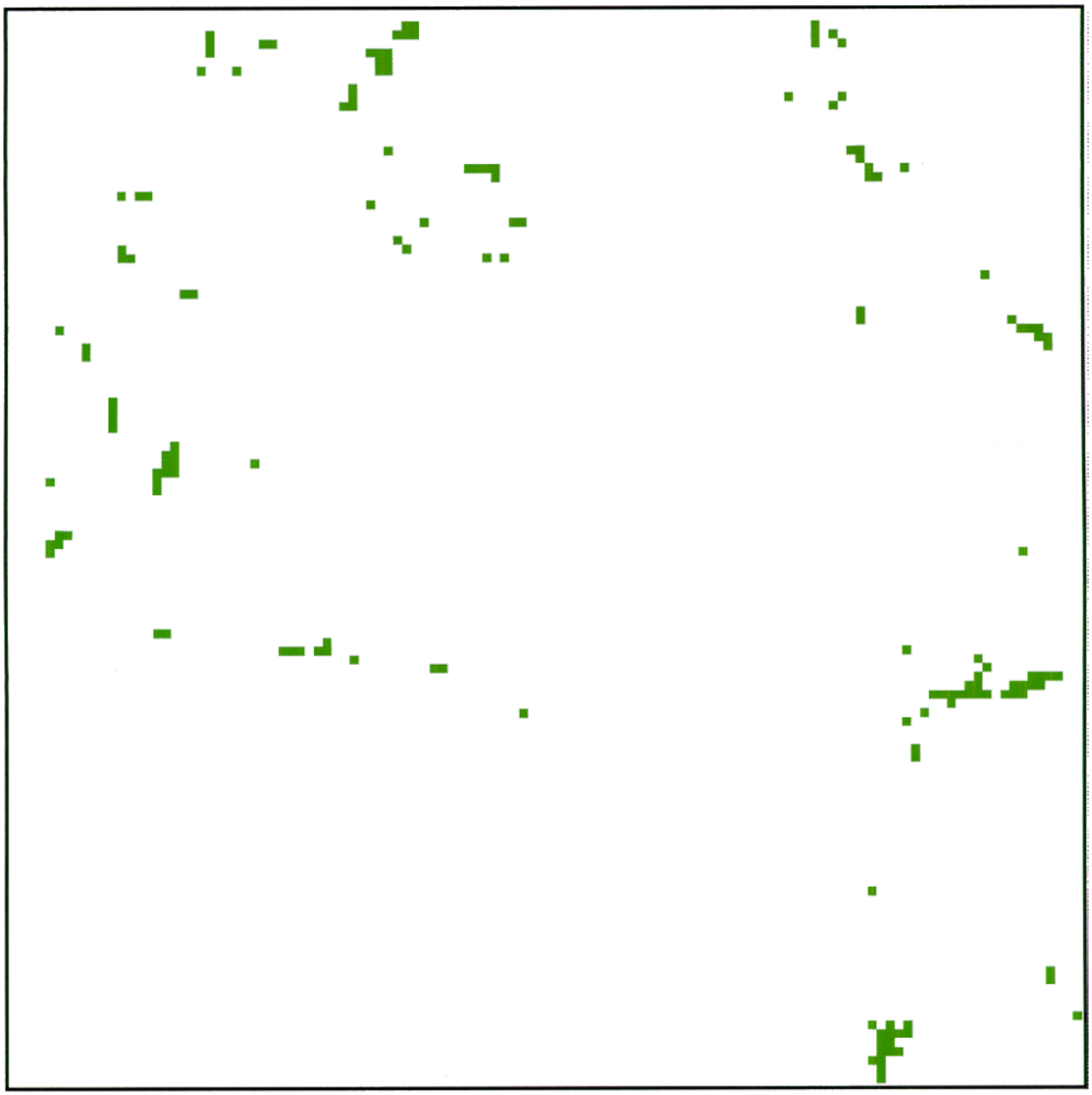


Figure 3-22.—The distribution of broad-leaf deciduous wetland shrubs on the study area after the proposed development. Habitat layers are as described in Figure 3-10.

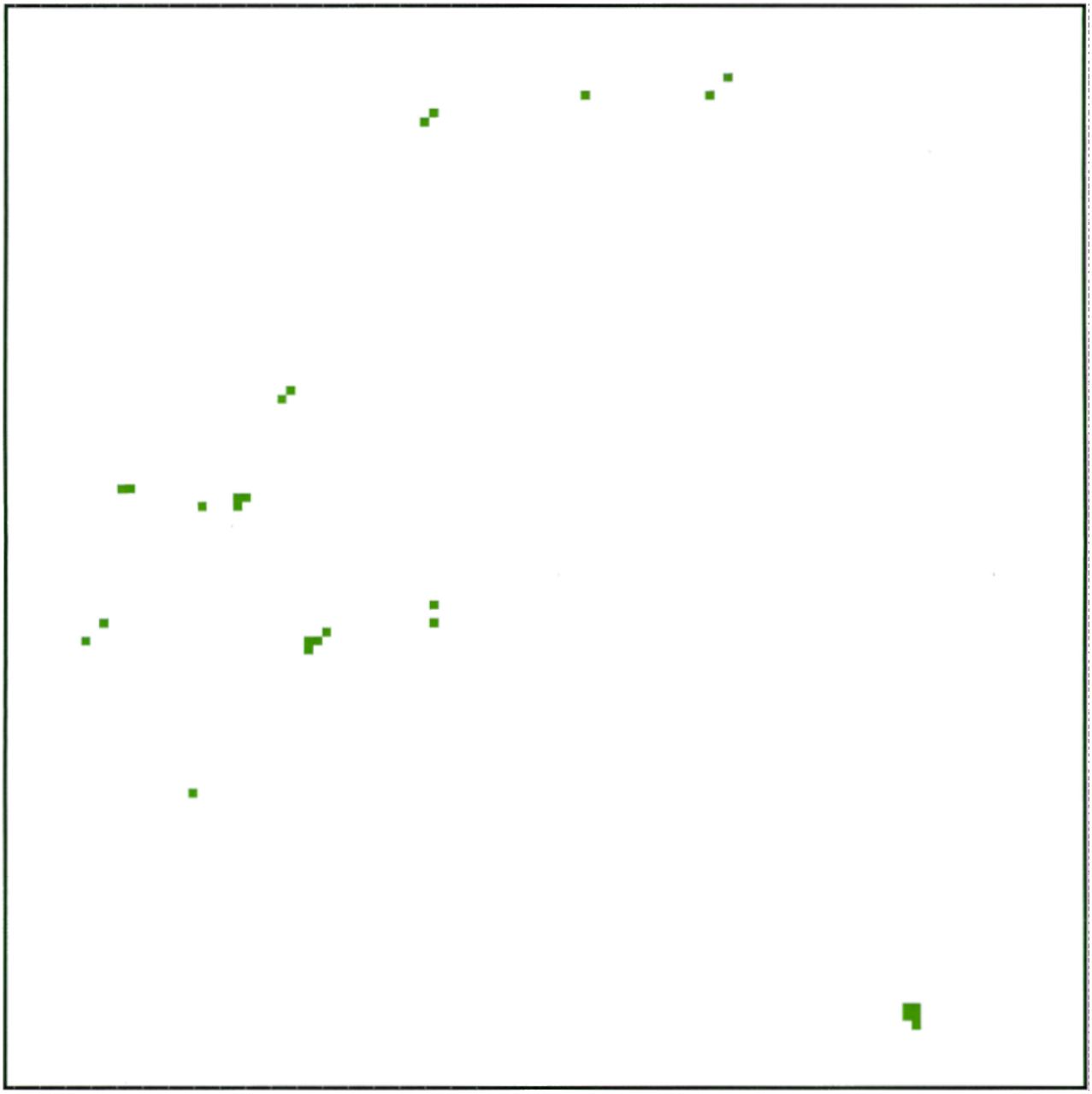


Figure 3-23.—The distribution of persistent emergent herbaceous vegetation on the study area after the proposed development. Habitat layers are as described in Figure 3-11.

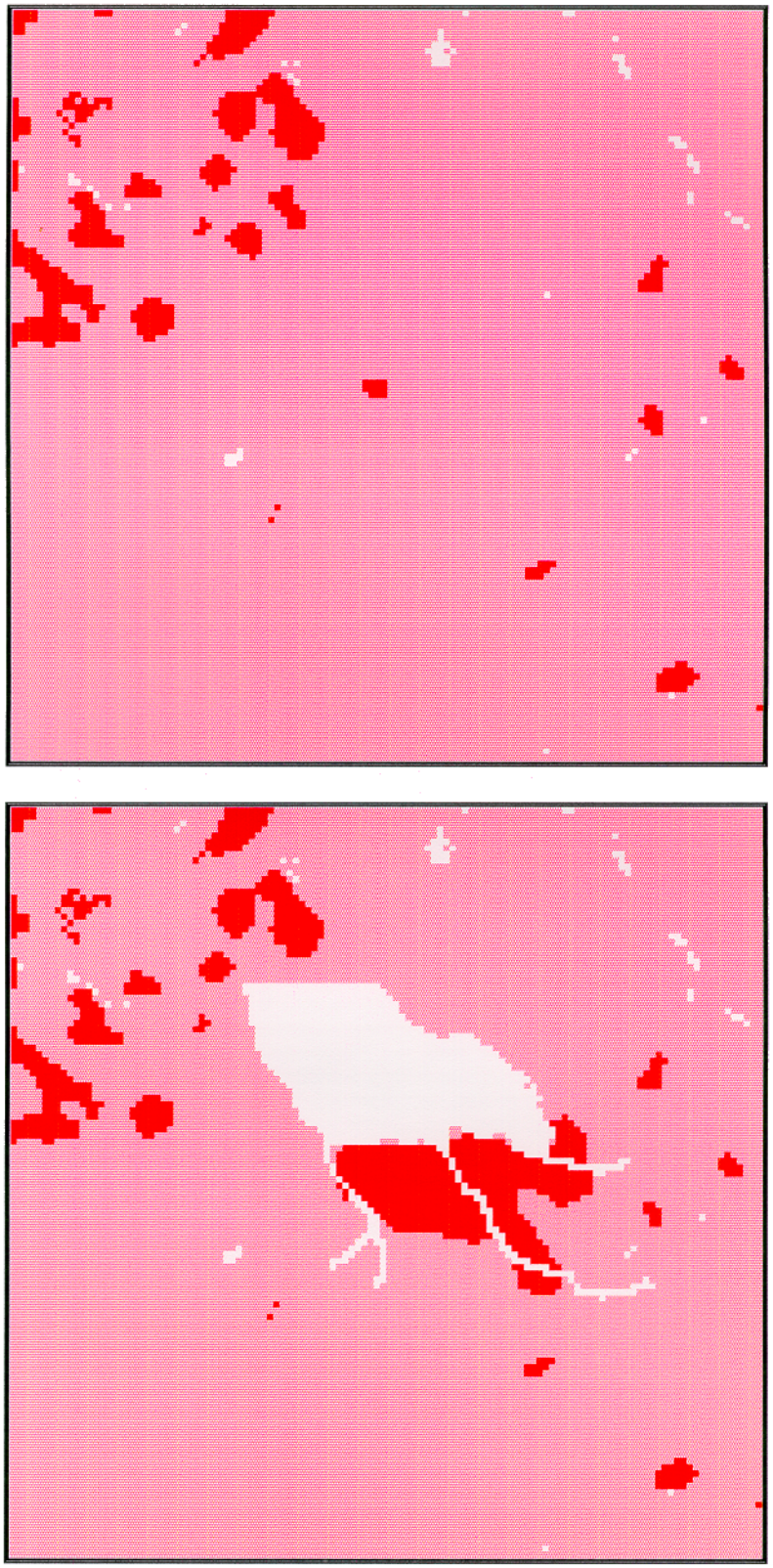


Figure 3-24.—Estimated areas of habitat (red) for the eastern chipmunk (SHG 1) on the Massachusetts study area before and after a proposed development. Note gain in habitat due to increase in forest and forest edges near the development. White represents various wetlands.

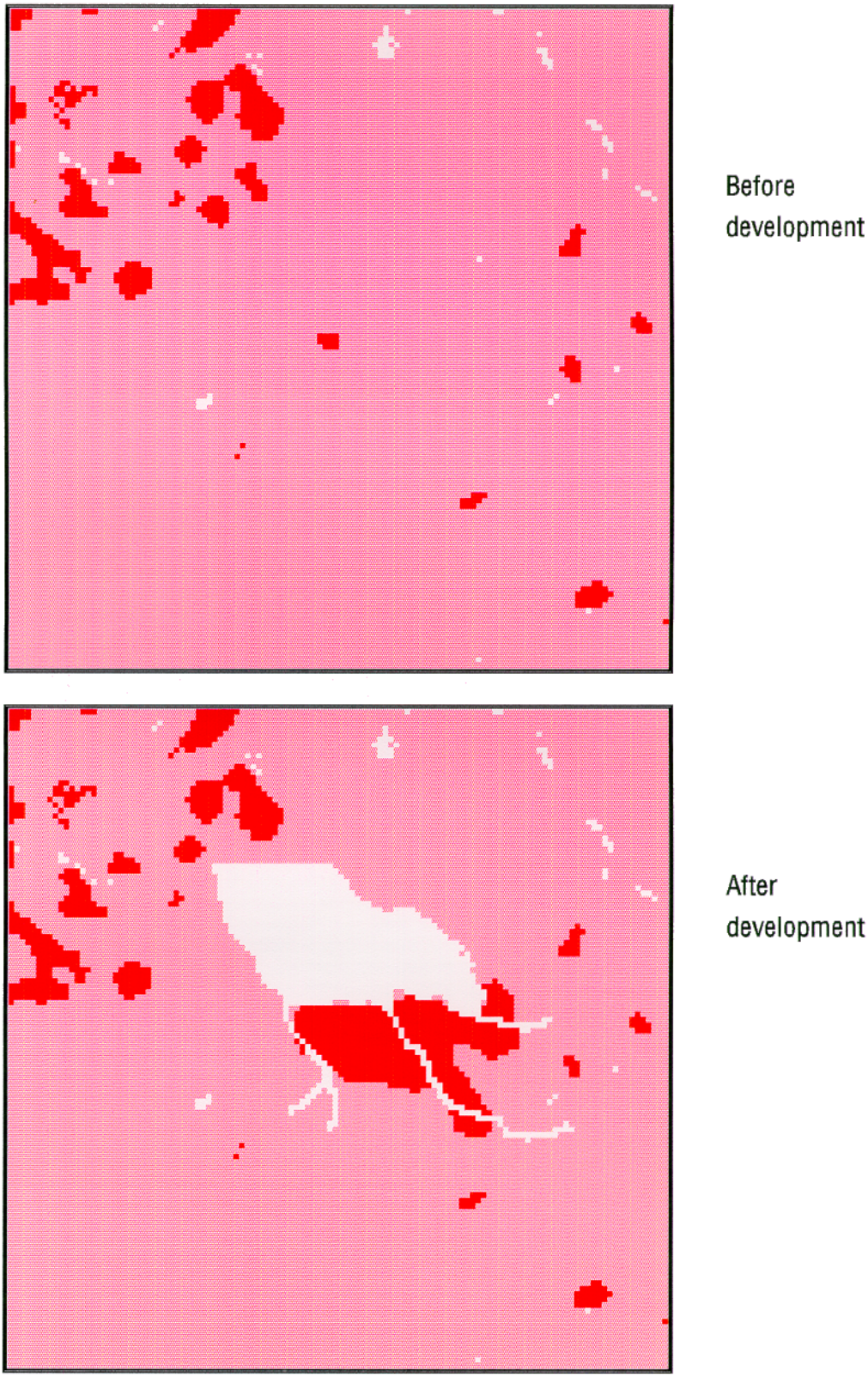


Figure 3-25.—Estimated areas of habitat (red) for the killdeer (SHG 7) on the Massachusetts study area before and after a proposed development. Note gain in habitat due to the inclusion of the proposed golf course as suitable habitat. White represents various wetlands.

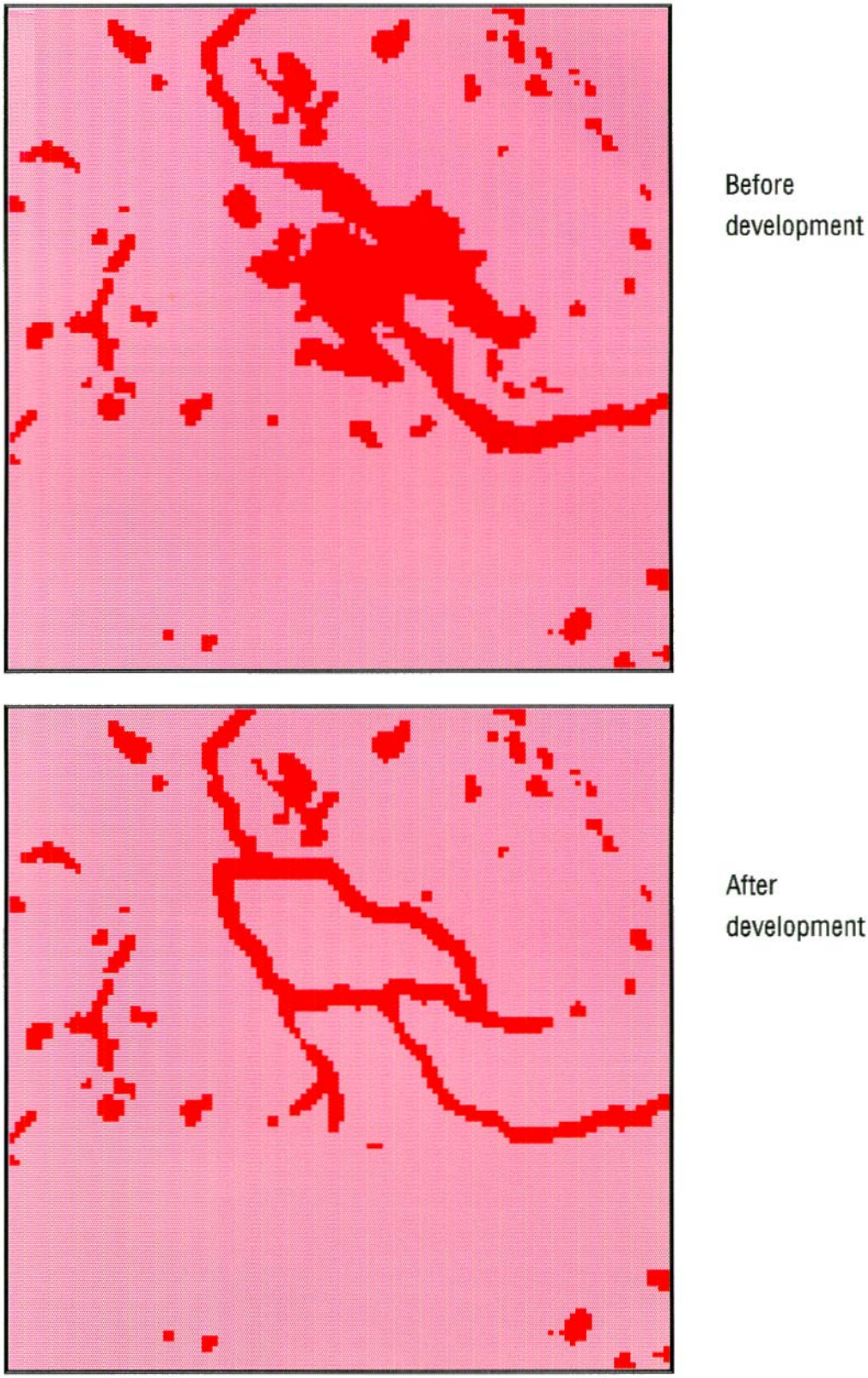


Figure 3-26.—Estimated areas of habitat (red) for the bullfrog (SHG 29) on the Massachusetts study area before and after a proposed development. Note loss in habitat because the species occurs only near the shoreline of large bodies of water.

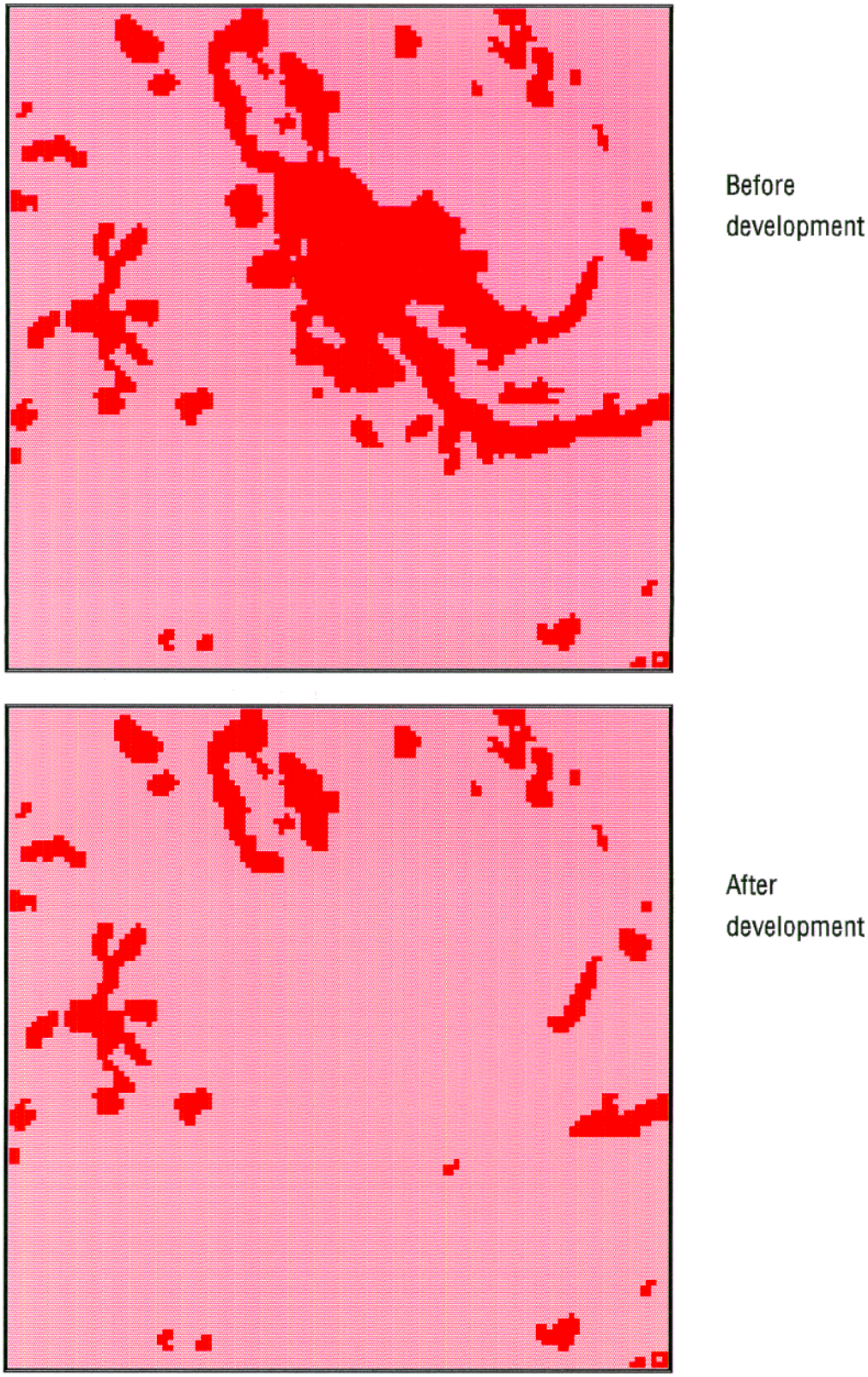
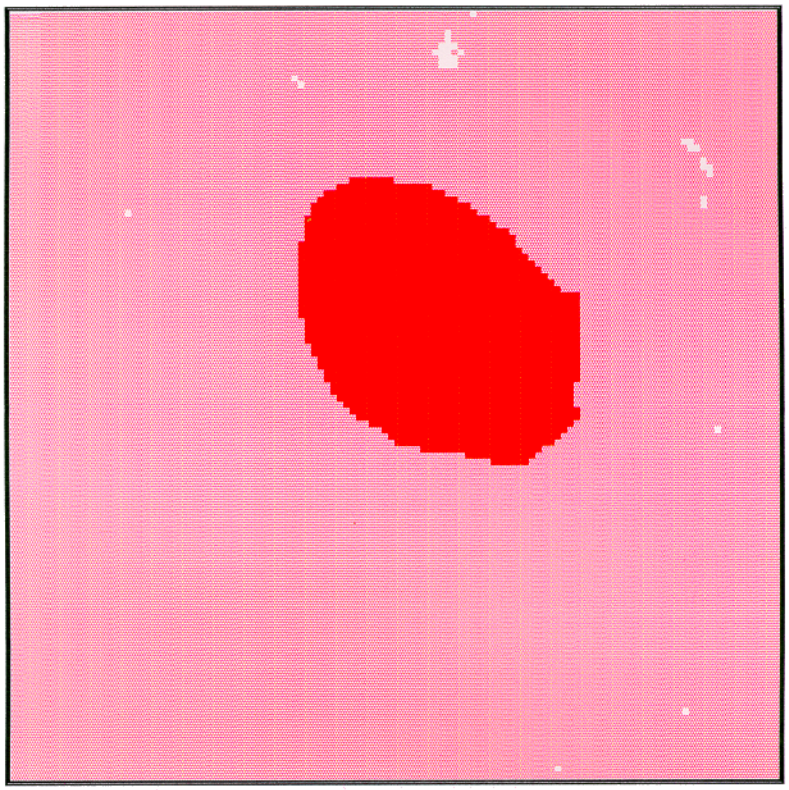


Figure 3-27.—Estimated areas of habitat (red) for the northern leopard frog (SHG 30) on the Massachusetts study area before and after a proposed development. Note loss in habitat because the species inhabits the margin of shallow water bodies and contiguous moist woodlands.



Before development

After development

Figure 3-28.—Estimated areas of habitat (red) for the mink (SHG 56) on the Massachusetts study area before and after a proposed development. Note total loss of habitat because of the loss of an extensive block of forested wetland habitat. White represents various wetlands.

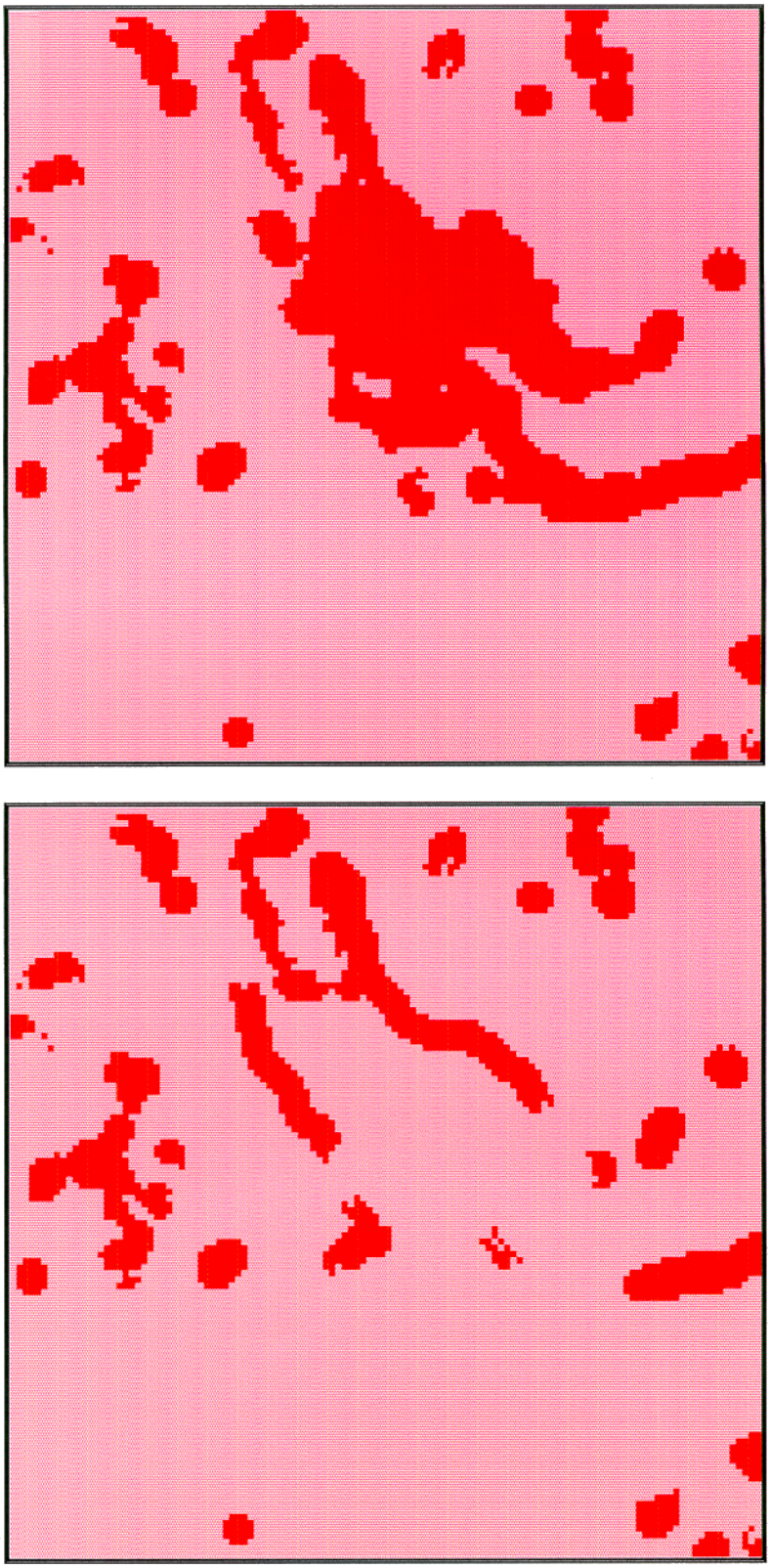


Figure 3-29.—Estimated areas of habitat (red) for the green heron (SHG 110) on the Massachusetts study area before and after a proposed development. Note loss in habitat because of the loss of shallow water and of trees in the area of the proposed golf course.

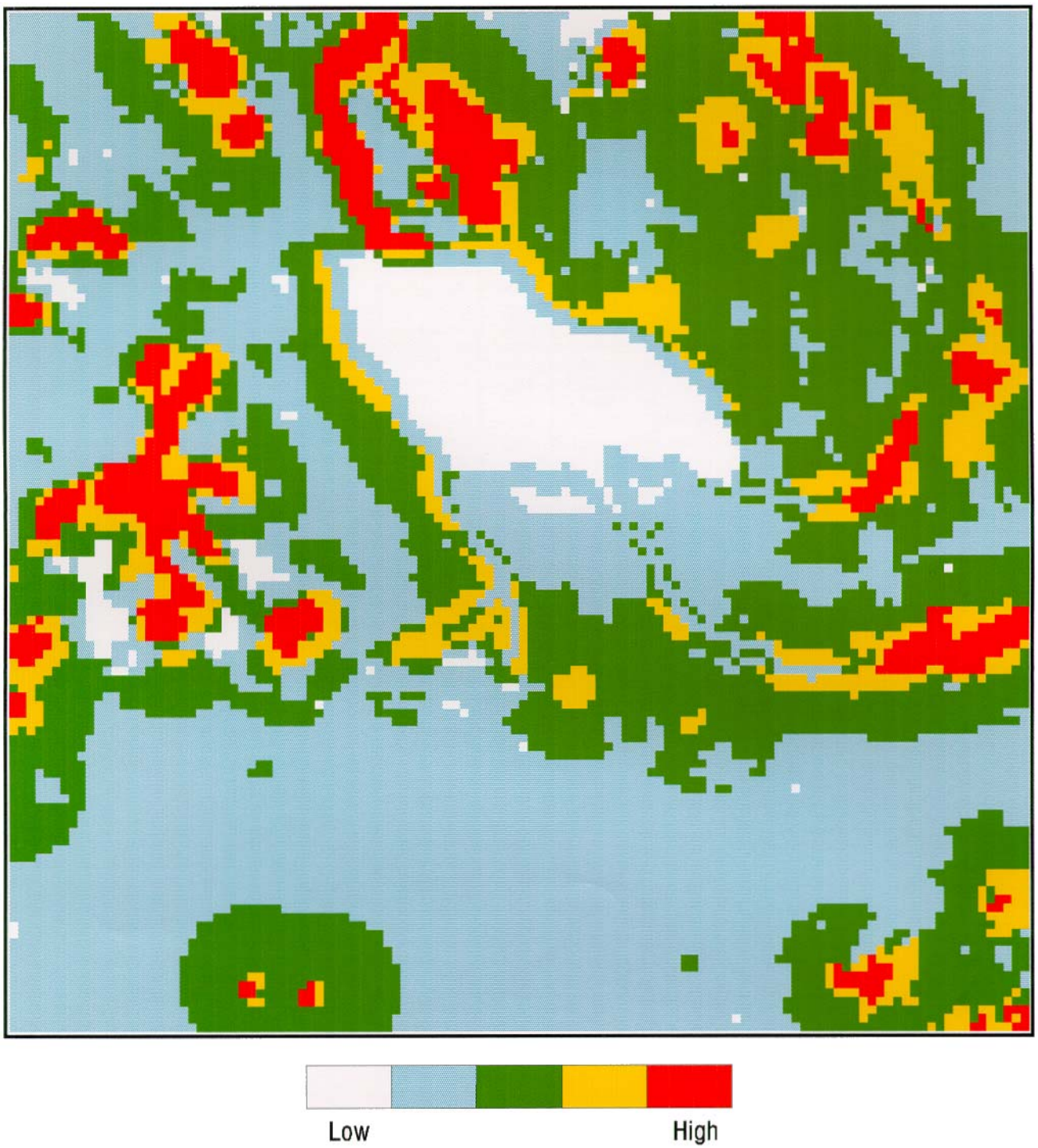


Figure 3-30.—This “faunal density” map for amphibians and reptiles, after the proposed development has occurred, indicates that the former central forested swamp area is now an area of much reduced importance for this segment of the wildlife community. The interpretation of relative density is as for Figure 3-12.

Chapter 4. Developing a Management Plan

ECOSEARCH also can be used to develop management plans that favor or disfavor a species, and to determine how those management plans might impact other members of the wildlife community. Habitat management plans utilize the relevant species-habitat model variables and strive to order, sequence, or pattern the placement of habitat features so the eventual landscape pattern will advantage or disadvantage the species in the desired manner. This capability to develop management plans and to evaluate their impacts should be important to the refuge, forest, or park manager charged with wildlife management responsibilities.

We describe a management plan for the American woodcock (*Scolopax minor*) on a portion of the Moosehorn National Wildlife Refuge (MNWR) located in northeastern Maine on the Canadian border (Baring Unit). The management plan is derived from the woodcock species-habitat model listed on page B-11 in Appendix B. We then use ECOSEARCH to predict areas that would provide habitat favorable for woodcock should the habitat management plan be implemented. The Baring Unit is actively managed to produce woodcock habitat and substantial information about the actual distribution of woodcock exists for the area. Thus, we are able to compare the locations of areas predicted by ECOSEARCH to be woodcock habitat with actual woodcock locations as determined by telemetry. The comparison checks the capability of ECOSEARCH to predict areas of habitat useful to a wildlife species and the utility of ECOSEARCH in developing habitat management plans. Finally, we predict the impacts of the prescribed habitat management plans on the total wildlife community that might exist on the study area. This describes the cost or benefit to the wildlife community of a particular management action designed to favor a single species.

The MNWR was established in 1936 to benefit the continental population of American woodcock, and since 1979 it has been the site of an intensive research and management effort to enhance woodcock productivity and survival. Results from this research have been published in several papers, including Dwyer et al. (1988), Longcore and Sepik (1993), Straw et al. (1994), and McAuley et al. (1996). These research results have influenced the development of our woodcock model and our habitat management plan.

Much of the MNWR was covered by a mature, second-growth forest interspersed with natural and man-made water bodies, meadows, and blueberry fields before active management was begun in 1979. A practice of producing small clearcuts, totaling 40 to 60 ha per year, was begun on a 6,673-ha study area in 1979 resulting in the present condition of an uneven-aged forest comprised of a series of even-aged blocks of a few deciduous tree species. Habitat management recommendations on the MNWR include suggestions that land managers should maintain about 25 percent of their land in early successional habitat by producing small clearcuts in mature forests on a 40-year rotation, and small clearcuts in shrublands on a 20-year rotation (McAuley et al. 1996). Our management prescription is based on a series of prescribed clearcuts performed on a 20-year rotation.

Habitat Requirements of Woodcock on the MNWR

Woodcock migrate to the latitude of MNWR, usually in late March, where reproduction and brood rearing eventually occur. Prenesting behavior includes courtship behavior at singing grounds that occur in forest openings or in fields. These forest openings or fields also often serve as nocturnal roosts throughout the late spring, summer, and early autumn until woodcock depart in early November. Nest sites occur in shallow depressions on the ground within habitats characterized as dense stands of early growth hardwoods on good soils that support an abundance of earthworms. These dense hardwood stands also serve as brood habitats and as diurnal cover and often occur within 150 m of the singing grounds (Straw et al. 1994). Reverted farm lands with dense early succession woody cover on moderately drained, fine-textured soils provide good habitat for woodcock. Throughout time, a clearcut in such habitats, can provide a nocturnal roost site and singing ground, then nesting, brood-rearing and diurnal habitat, and ultimately non-productive habitat for woodcock as succession proceeds (Straw et al. 1994). Optimizing timber operations for woodcock involves entering a forest every 5 to 10 years to cut small areas adjacent to previous cuts to juxtapose habitat elements critical for woodcock (Straw et al. 1994).

Prediction of Woodcock Habitat on the MNWR

The habitat management prescription for woodcock is derived from the woodcock species-habitat model (page B-11 in Appendix B), which is interpreted in Table 4-1. Table 4-1 also identifies habitat conditions that become the bases for developing the prescription for woodcock management. The woodcock model indicates that the species, in New England, uses two different habitats (**x** and **y**) that are not necessarily contiguous. The management prescription identifies **x** habitats as early forest successional stages with dense shrubs and young trees in understory and midstory layers that are located on soils likely to provide abundant earthworm biomasses. Management strives to manipulate structure so these **x** habitats will be available to provide nesting, brood rearing, foraging, and cover habitats for woodcock. Management then strives to provide favorable blocks of **y** habitats within 200 m of the **x** habitats. The **y** habitats consist of open areas with no or limited midstory and/or overstory structures that provide singing grounds and nocturnal habitats for woodcock. The vertical structures within both **x** and **y** habitats are manipulated by management, but the soil characteristics, determining the location of **x** habitats, effectively bound the woodcock management prescription.

Table 4-1.—The habitat management prescription for woodcock is derived from the species-habitat model for woodcock (p. B-11 in Appendix B). The interpretation of the species-habitat model is similar to the model explanation provided in Figure 2-1.

Species-habitat model code	Habitat management plan
(**3.c,e:e) -** column II for habitat block **X**	Habitat for the species consists of two habitat blocks (**x** and **y**) that are not necessarily contiguous (code **3**). The **c,e** before the colon, indicates that block **x** requires a particular vegetative structure (**e**) on certain specified soil types (**c**). Block **y**, described following the colon, also requires a particular vegetative structure (**e**).
[**G-N**] - column II for habitat block **x**	Indicates that permanently flooded landscapes are non-habitats for the species.
(**2**) - column III for habitat block **x**	Indicates that habitat block **x** can occur in habitat patches as small as **2** ha.
9 - column Va for habitat block **x**	ECOSEARCH will search a neighborhood of nine 0.25-ha cells to predict the adequacy of a landscape as **x** habitat for woodcock.
0.3 - column Vb for habitat block **x**	At least 30 percent of the 9 neighborhood cells (at least three 0.25-ha cells or 0.75 ha) need to have the soil types and vertical structure indicated in columns VII and IX.
B1, C1, D1 - column VII for habitat block **x**	Areas that provide suitable **x** habitats occur on nonrocky soils that are likely to provide a substantial earthworm biomass. These soils are classified as either well drained or moderately well drained (**B1**), poorly drained (**C1**), or very poorly drained (**D1**). The potential location of areas suitable as **x** habitat is bounded by the location of soil types **B1, C1,** and **D1**, and the location of suitable **x** habitat in the management prescription is also bounded by the location of soil types **B1, C1,** and **D1** on the MNWR (see below).
11ab,24ab,51ab,62a - column IX for habitat block **x**	Early successional woody or brushy cover growing on suitable soils provides **x** habitat for the species. The management prescription uses woodland management practices to provide this required vegetative structure on areas identified as having suitable soils.
Bz=4 - column X	The second habitat block (**y**) needs to be within four 50-m cell lengths (200 m) of habitat block **x**.
(**2**) - column III for habitat block **y**	Indicates that habitat block **y** can also occur in habitat patches as small as **2** ha.
9 - column Va for habitat block **y**	ECOSEARCH will search neighborhoods of nine 0.25-ha cells that are within 200 m of an **x** habitat, to predict the utility of a land area as **y** habitat for woodcock.
0.3 - column Vb for habitat block **y**	At least 30 percent of the 9 neighborhood cells (a minimum of 3 cells or 0.75 ha) will need to have the structure described in column Va classified as **y** habitat.
25a-c,26a - column IX for habitat block **y**	Herbaceous cover in areas with no or limited midstory and overstory cover provides suitable blocks of **y** habitat, if located within 200 m of suitable blocks of **x** habitat.

The management prescription developed in this example is based on three important habitat characteristics: (1) the location of permanent water bodies indicating landscapes that are “out-of-bounds” for the species; (2) the location of suitable soils that are assumed to bound the location of potential habitat for woodcock by bounding the location of an essential food source; and (3) certain patterns of vertical structure that provide a variety of cover requirements.

The location of permanent water bodies and other wetland types on the Baring Unit of the MNWR, classified according to the NWI wetland classification system, is shown in Figure 4-1.

Soil types and soil drainage classes for the area were digitized from a paper map that was created by the U.S. Natural Resources Conservation Service in 1970. A map depicting the location of nonrocky soils that are well drained, poorly drained, and very poorly drained was developed to indicate areas likely to provide a favorable earthworm biomass for woodcock (Figure 4-2). The location of these soils bounded the forest cutting prescription that was developed to provide favorable patterns of habitat structure, as described in the woodcock model.

A description of the vertical structure of the vegetation community on the study area was made from the photo interpretation of large-scale (approximately 1:7920) black-and-white aerial photography using the techniques described in Chapter 3. A dot grid overlay was produced so that dots represented 50-m intervals on the ground, and this overlay defined points where vegetative structure was classified according to the descriptors listed in Table 2-4, also as described in Chapter 3.

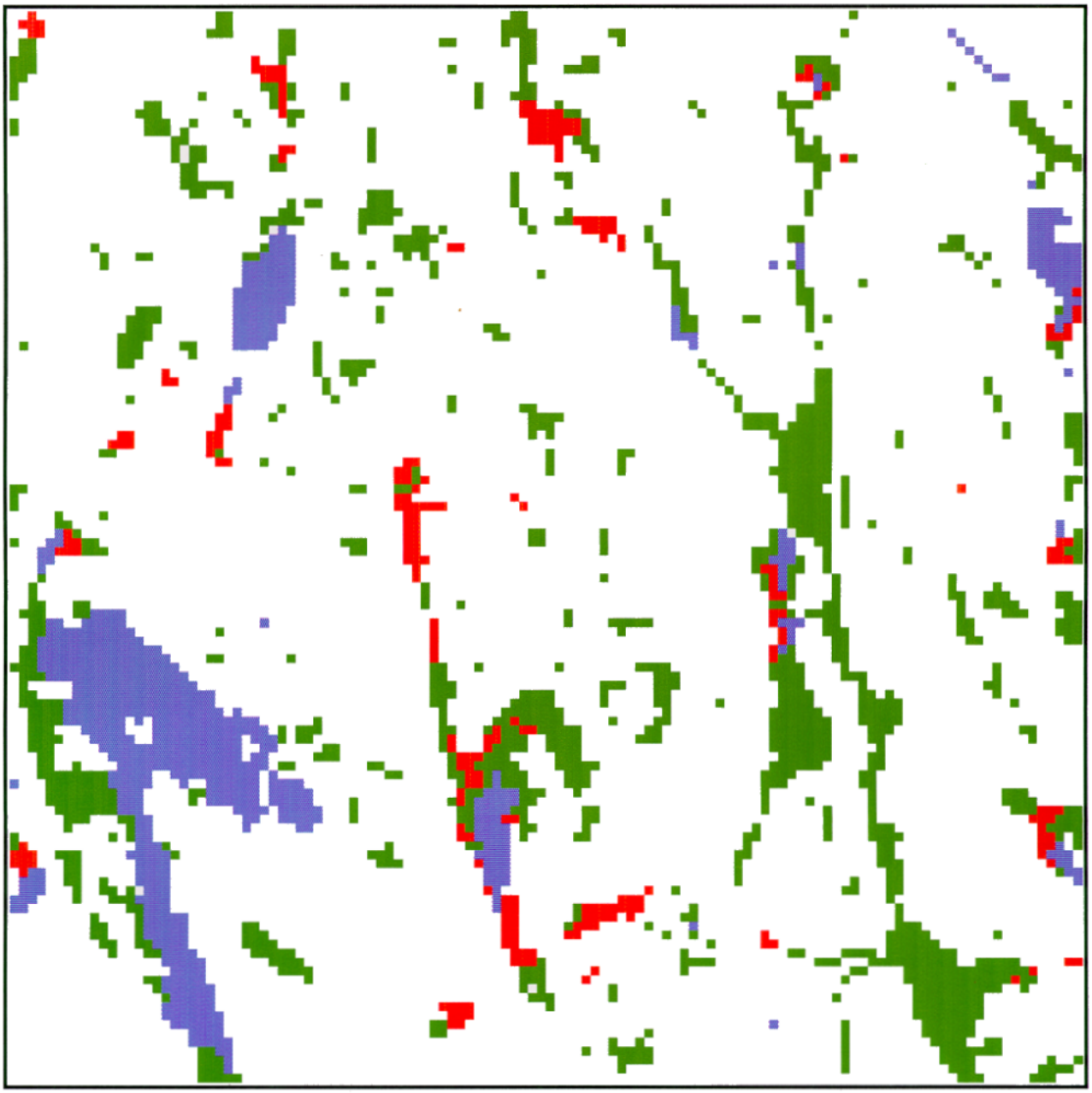
No topographic map is included herein because no major topographic distinctions occurred on this low-relief area.

Five age classes (A-E) that represent forest successional stages are listed in Table 4-2. Age class A, which consists of cleared lands 0 to 5 years after cutting, was assumed to have a high value as singing grounds but a low value as nesting habitat. Age class B represents brushy regeneration at 6 to 10 years after cutting, and age class C represents small trees providing a midstory canopy at 11 to 15 years after cutting. Both B and C habitat conditions have relatively low values as singing habitat but high values as nesting habitats. Age class D represents pole-sized hardwoods, at 16 to 20 years after cutting, that have no value as singing grounds and only moderate value as nesting habitats. Habitat comprised of older (>21 years after cutting) and larger trees (age class E) had low value as nesting habitat and no value as singing grounds. The management prescription developed in this example only considered age classes A-D in Table 4-2 because of the very limited utility of the more mature timber stands as woodcock habitat. Consequently, the forest cutting prescription in this example is based on a 20-year cutting rotation, accomplished on landscape units with suitable soils, where contiguous habitat blocks are cut at 5-year intervals.

The management prescription strives to efficiently arrange the variables in the species-habitat model to maximize or at least enhance the habitat area suitable for the species. Our management prescription superimposed eleven 64-ha blocks on that portion of the Baring Unit with soils deemed most favorable for woodcock foraging (Figure 4-3). Each block contained 16 units each 4 ha in area, and these 4-ha units became treatment or cutting units with A, B, C, or D (Table 4-2) age-class patterns sequenced in a prescribed manner. The sequencing occurred so that units that provided nesting cover would border units providing potential singing grounds. The location of cells with the A age class successional pattern, and of cells with old fields, herbaceous vegetation in upland and wetlands areas as determined by the point sampling vegetation analysis, is displayed in Figure 4-4. The location of cells with the B age class successional pattern, and of cells determined to have short, brushy woodland vegetation as determined by the point sampling vegetation analysis, is displayed in Figure 4-5. The location of cells with the C age class successional pattern, and of cells providing a hardwood scrub-shrub midstory as determined by the point sampling vegetation analysis, is displayed in Figure 4-6. The location of cells with the D age class successional pattern is displayed in Figure 4-7. The change that would occur to the present habitat structure, should the management prescription occur, would be the conversion of about 250 ha of “mature” forest providing an upland tree canopy layer to very early forest successional stages providing upland understory structures (Table 4-3). Also, some cells presently providing midstory and understory structures would be modified, and successional stages would be arranged into the specific patterns depicted in Figures 4-4 to 4-7.

Table 4-2.—The utility of forest successional stages to woodcock.

Vertical habitat structure	Relative use as singing grounds	Relative use as nest sites	Relative age of successional stage
A. Old field, mowed field	High	Low	0-5 years
B. Short woody regeneration	Low	High	6-10 years
C. Hardwood shrub-scrub midstory	Low	High	11-15 years
D. Pole-sized hardwoods	None	Moderate	16-20 years
E. > Pole-sized hardwoods	None	Low	>21 years



Seasonally Flooded. NWI water regimes C, E.
Semipermanently Flooded. NWI water regime F.
Permanently Flooded. NWI water regime H.

Figure 4-1.—A complex series of wetlands occurs on the MNWR study area. See “Chapter 2, VIII. Water regimes” for further explanation of key.

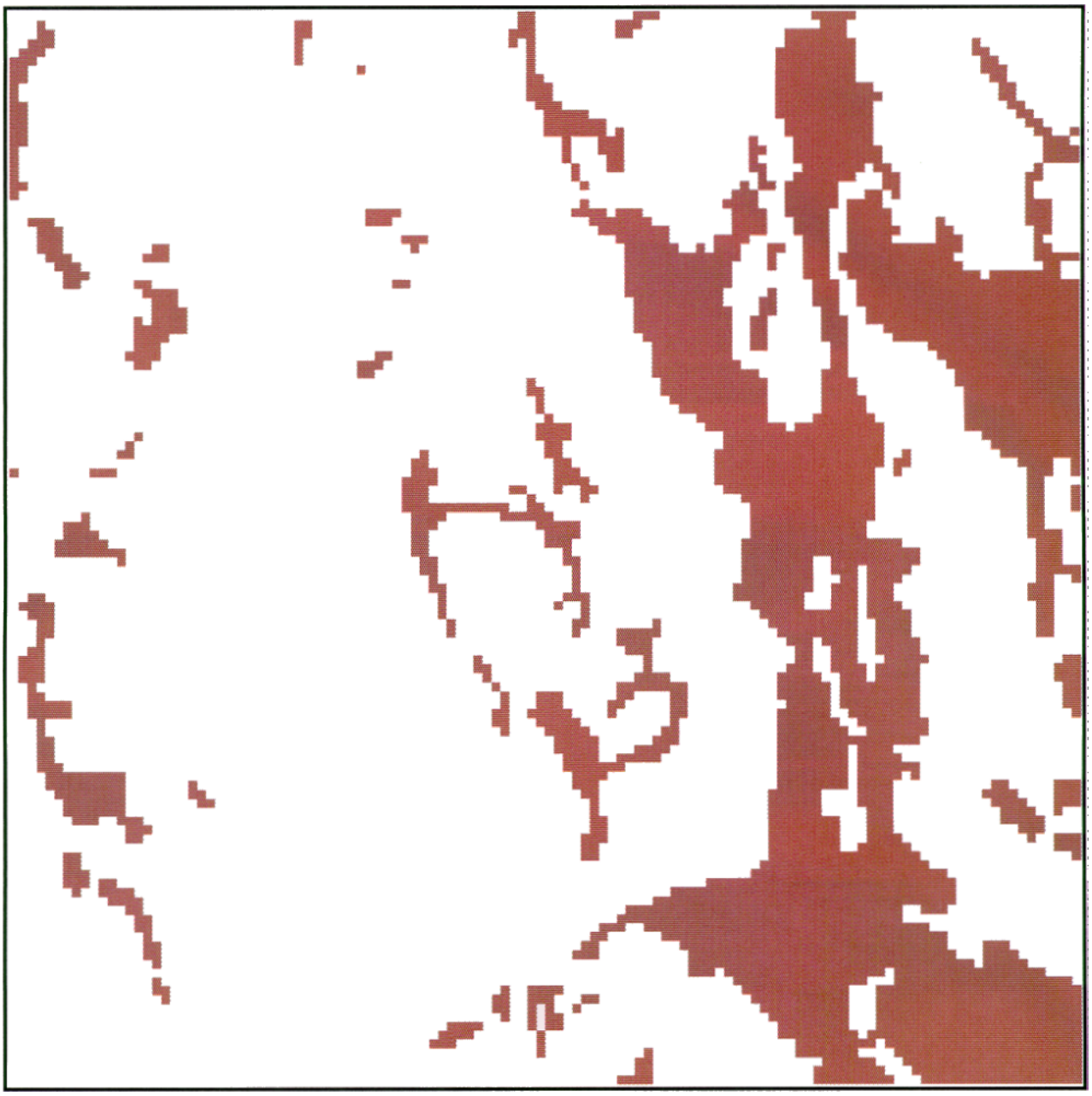


Figure 4.2.—The distribution of non-rocky well-drained, poorly drained, and very poorly drained soils on the MNWR study area.

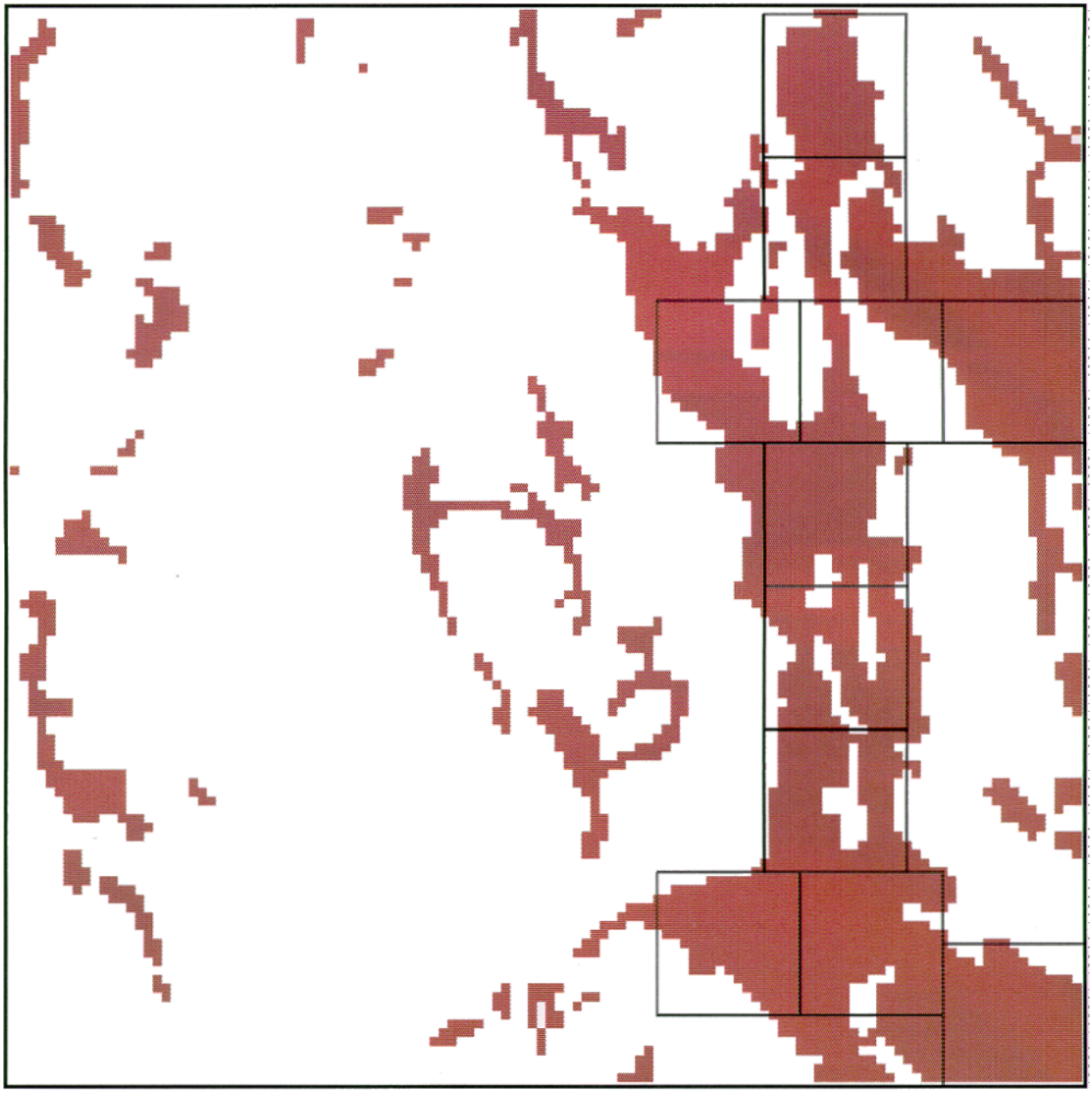


Figure 4-3.—The distribution of eleven 64-ha habitat management blocks on the MNWR study area overlain on a map of suitable soil types.

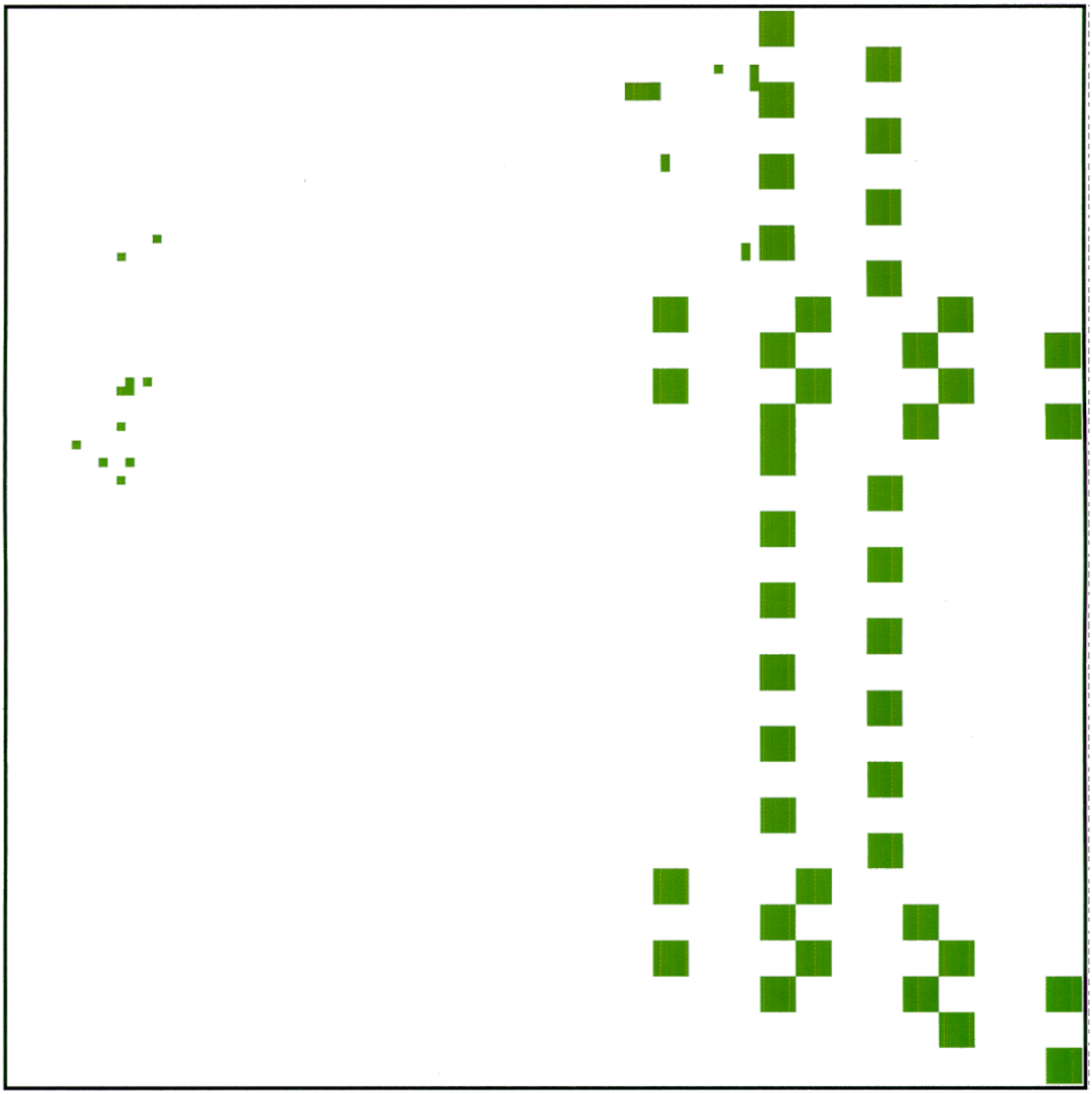


Figure 4.4.—The distribution on the MNWR study area of prescription management patches conforming to age class A in Table 4-2. Other cells providing herbaceous vegetation in upland and wetland understory layers of habitat, as determined by the point sampling vegetation analysis, are also indicated on this figure.

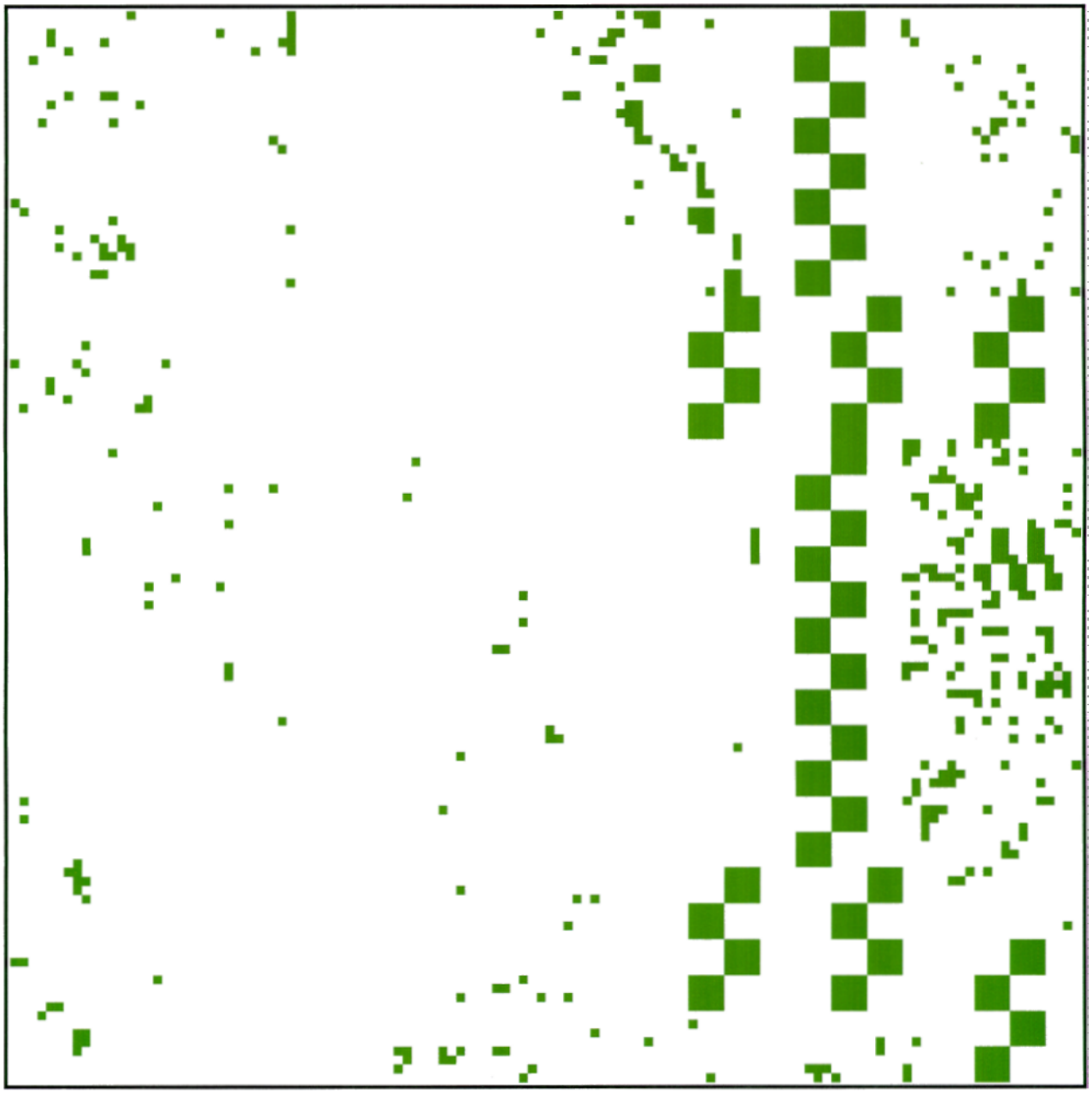


Figure 4.5.—The distribution on the MNWR study area of prescription management patches conforming to age class B in Table 4-2. Other cells providing short, brushy woodland vegetation, as determined by the point sampling vegetation analysis, are also indicated on this figure.

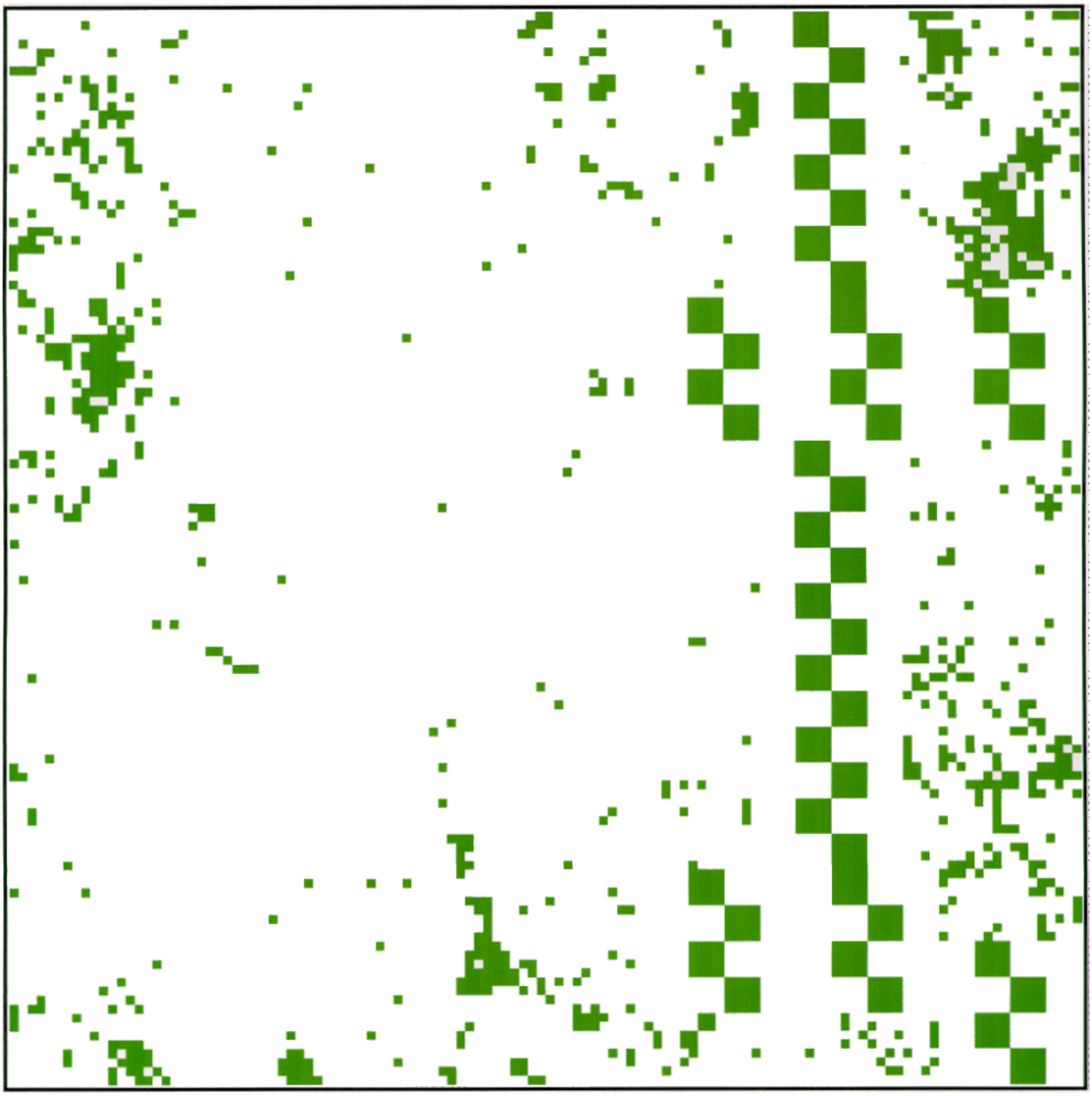


Figure 4.6.—The distribution on the MNWR study area of prescription management patches conforming to age class C in Table 4-2. Other cells providing a hardwood shrub-scrub midstory, as determined by the point sampling vegetation analysis, are also indicated on this figure.

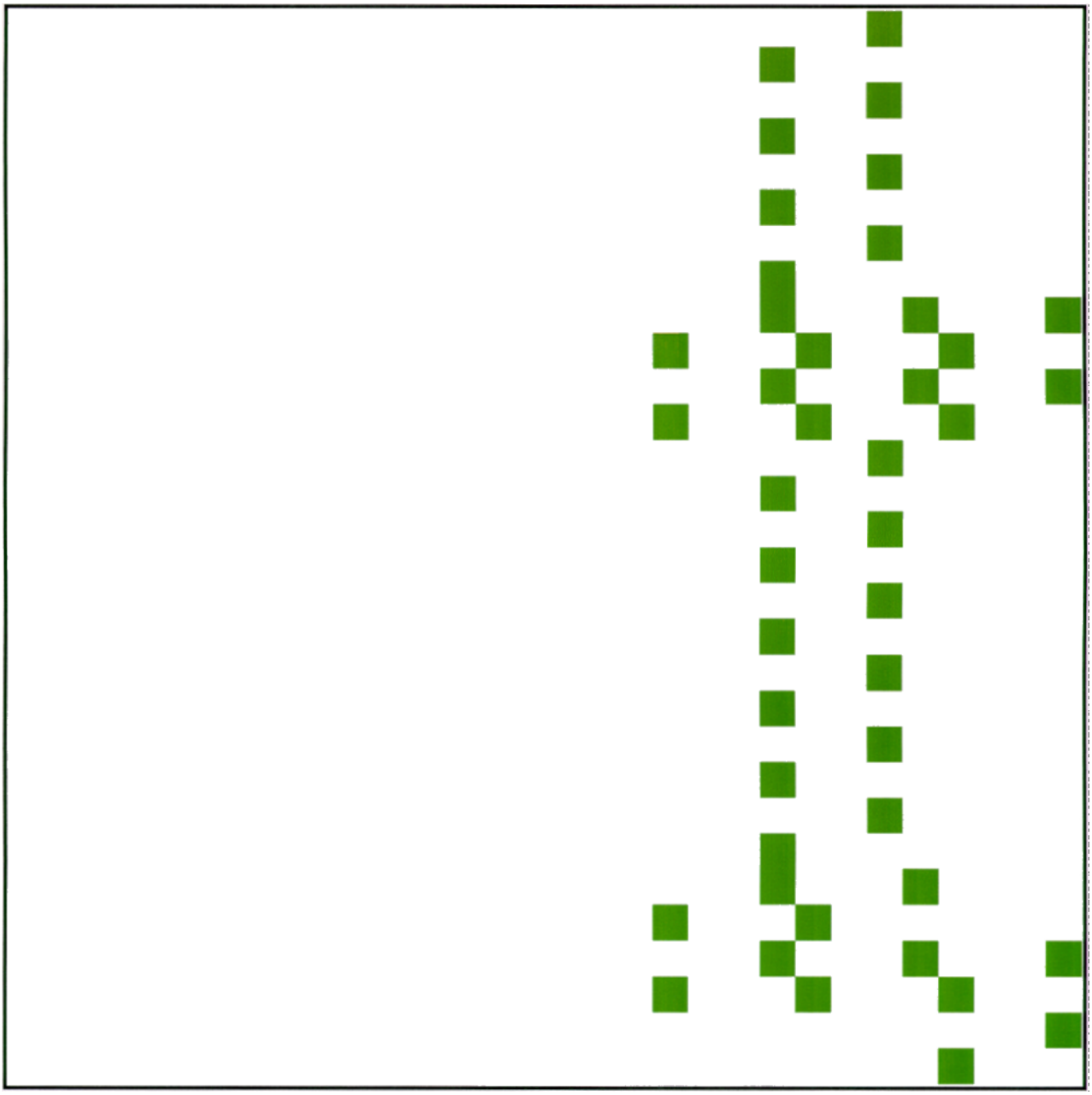


Figure 4.7.—The distribution on the MNWR study area of prescription management patches conforming to age class D in Table 4-2. These patches consist of pole-sized hardwoods.

Table 4-3.—Areas of habitat and other structures, expressed in terms of areas of habitat layers, before and after possible implementation of a woodcock habitat prescription.

Habitat layer	Area (ha) before prescription	Area (ha) after prescription
Upland overstory	2,310.5	2,078.0
Upland midstory	423.25	444.5
Upland understory	202.25	452.0
Wetland overstory	187.25	185.25
Wetland midstory	125.25	101.75
Wetland understory	173.75	170.0
Water surface	177.75	168.5
	3,600.0	3,600.0

ECOSEARCH was then used to predict areas of woodcock habitat that might occur if the management prescription was implemented. This predicted habitat area is shown in Figure 4-8. Actual woodcock management on the study area has produced a series of clearcut blocks and strips, ≥ 10 years old, totaling about 650 ha (McAuley et al. 1996) located near the northeastern and southeastern edges of the Moosehorn study area. Woodcock use of these manipulated areas, as determined by telemetry, is indicated in Figure 4-9, which shows actual telemetric locations of predicted woodcock habitat. A substantial overlap exists despite the fact that ECOSEARCH built a management prescription on the basis of a species-habitat model. Field observations indicate a response to habitat manipulations that were directed by other procedures and priorities.

The biological cost or benefit of the management prescription for woodcock can be estimated by predicting areas of habitat for different species-habitat groups, with and without the proposed management prescription in place. These estimated areas of habitat are described in Table 4-4, which summarizes data from the distribution maps prepared for the 18 species of amphibians and reptiles, 136 species of birds, and 24 species of mammals potentially occurring on the Baring Unit of the MNWR. Implementing the habitat management prescription would produce reduced areas of forest habitat and increased areas of clearings or openings featuring early forest successional conditions. Species that utilize early successional clearings and forest:understory edges are expected to benefit from the management prescription for woodcock, while species dependent on extensive blocks of forest habitat are disadvantaged by implementation of the management prescription. The significant changes to habitat include the loss of coniferous forest, the conversion of coniferous forest to early successional hardwood seral stages, the development of areas of understory cover associated with early forest successional stages, and the development of forest:understory edge habitats. Evaluating the impacts of the proposed management plan on the wildlife community is advisable before implementing a proposed management prescription. ECOSEARCH does not provide the evaluation, rather it provides the information needed to evaluate and modify the design of a management prescription.

If areas of habitat for individual species or species-habitat groups are totaled and compared for conditions before and after the implementation of the management prescription, then it becomes evident (Table 4-4) that there is no net gain or loss in total habitat area due to the implementation of the management prescription. The loss of habitat for forest interior species is matched by habitat gains for species requiring forest edges or openings. Individual species-habitat groups, however, do vary in their response to the implemented habitat prescription. A summary of some of these impacts follows for species whose habitat areas on the Baring Unit study area would be changed by ≥ 100 ha. The number in parentheses following each species name refers to the SHG number listed in Table 4-4. The species comprising the different SHG are listed in Appendix C.

A substantial portion of the Baring Unit is comprised of a mature, second-growth forest composed of stands of spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) with mixed hardwoods (McAuley et al. 1996). Eighteen species — (ovenbird (5), black bear (7), porcupine (14), redback salamander (45), Canada warbler (53), fisher (58), brown creeper (66), barred owl (81), northern goshawk (89), broad-winged hawk (94), northern saw-whet owl (94), blackburnian warbler (98), hairy woodpecker (99), pileated woodpecker (99), scarlet tanager (99), yellow-bellied sapsucker (99), northern flying squirrel (100), and the eastern wood-pewee (103) — would likely lose at least 100 ha of habitat because of the reduction in areas of forest canopy, and 25 additional species would likely lose at least 100 ha of habitat because they utilize blocks of coniferous forest, which is the forest habitat that is to be reduced. These species are the solitary vireo (16), pine grosbeak (17), pine warbler (22), purple finch (22), white-winged crossbill (22), red crossbill (23), winter wren (45), spruce grouse (52), palm warbler (53), black-backed woodpecker (66), boreal chickadee (66), Swainson's thrush (67), evening grosbeak (85), Merlin (87), bay-breasted warbler (99), black-throated green warbler (99), Cape May warbler (99), golden-crowned kinglet (99), northern parula (99), red-breasted nuthatch (99), gray jay (100), pine siskin (100), ruby-crowned kinglet (100), yellow-rumped warbler (104), and the red squirrel (105).

The production of clearcuts in accordance with the management prescription, substantially increases the quantity of forest:understory and midstory edge, which increases areas of habitat for the eastern chipmunk (1), rufous-sided towhee (5), ruffed grouse (7), whip-poor-will (10), black-billed cuckoo (16), yellow-billed cuckoo (16), dark-eyed junco (45), hermit thrush (45), white-throated sparrow (45), chipping sparrow (64), house wren (65), least flycatcher (68), indigo bunting (78), warbling vireo (84), common grackle (94), northern oriole (99), Philadelphia vireo (99), yellow warbler (99), American goldfinch (100), eastern kingbird (101), American kestrel (102), American redstart (103), great crested flycatcher (103), and the raccoon (103).

Early successional stages following the prescribed clearcuts may provide habitats that vary from clearings to old field communities and provide habitat for the woodchuck (1), field sparrow (5), European starling (21), American woodcock (45), Lincoln's sparrow (45), northern short-tailed shrew (45), savannah sparrow (45), spotted sandpiper (46), American black duck (48), blue-winged teal (48), mallard (48), chestnut-sided warbler (51), Nashville warbler (51), Tennessee warbler (51), meadow jumping mouse (54), meadow vole (54), and the song sparrow (78).

Certain aerial feeders — bank swallow (4), chimney swift (25), little brown myotis (101), barn swallow (109) and cliff swallow (109) — are expected to extend their foraging activities over the forest openings developed to fulfill the management prescription.

The species-habitat group profile in Figure 4-10 provides a visual display of the direction and degree of change in the quantity of habitat available to different SHG of the wildlife community if the woodcock management prescription is implemented. Bars in the profile that indicate very large changes frequently represent species-habitat groups composed of one or only a few species. Frequently these species-habitat groups represent species with unique habitat requirements, and the profile depiction will demonstrate how these species of special interest might fare if a proposed habitat modification occurs. The general appearance of a profile can suggest whether a proposed habitat change is likely to be positive or negative to segments of the wildlife community. For example, the modest habitat modification proposed to enhance woodcock management enhanced habitat for "edge" and "forest opening" species and was disadvantageous to "closed forest species".

The profile in Figure 4-10 can be compared to the species-habitat profile developed to summarize the impact of a change in the water regime on the wildlife community (Figure 3-13). That profile indicated that many species would be negatively impacted if the wetland modification occurred.

Maps predicting areas of habitat before and after implementation of the proposed management prescription illustrate the data base used in the compilation of Table 4-4 and Figure 4-10. The map sets also suggest how habitat variables affect distribution patterns and how changing structural conditions associated with the implementation of the proposed woodcock management plan would affect the areas of habitat available to individual species.

The distribution patterns for the red-breasted nuthatch (Figure 4-11) indicate the reductions in habitat areas caused by the loss of coniferous forest. The distribution patterns for the American kestrel (Figure 4-12) and the woodchuck (Figure 4-13) indicate increases in areas of habitat due primarily to increases in edge habitats and in clearings following the prescribed clearcuttings. The predicted distribution patterns for the bank swallow (Figure 4-14) indicate likely increases in habitat because this aerial feeder is expected to forage over the new openings produced by the prescribed clearcuts.

Distribution maps for individual species can be evaluated in detail to suggest more subtle impacts from a proposed management activity. For example, values in Table 4-4 suggest the habitat modification to increase the quantity of woodcock habitat is not predicted to adversely impact aquatic species like the bull frog or mink frog (SHG 29) or the pied-billed grebe (SHG 34) but is predicted to adversely impact available habitat for species requiring a wetland:vegetative structure interface like the green frog, northern leopard frog and pickerel frog (SHG 30), the blue spotted salamander, eastern American toad, red spotted newt and the wood frog (SHG 31) and the northern spring peeper (SHG 32). The minor changes to available habitat for the northern leopard frog, should the woodcock management prescription be implemented, are illustrated in Figure 4-15. This kind of assessment could lead a manager to modify the management prescription to, for example, restrict clearcutting within 50 m of a wetland so species requiring a wetland:vegetative structure interface would be less adversely impacted.

Thus, ECOSEARCH can be used to develop a management prescription, to help predict the utility of that management prescription, to predict the impact on the wildlife community from implementing that management prescription, and to suggest modifications to the management prescription that might enhance its utility or minimize any undesirable impacts.

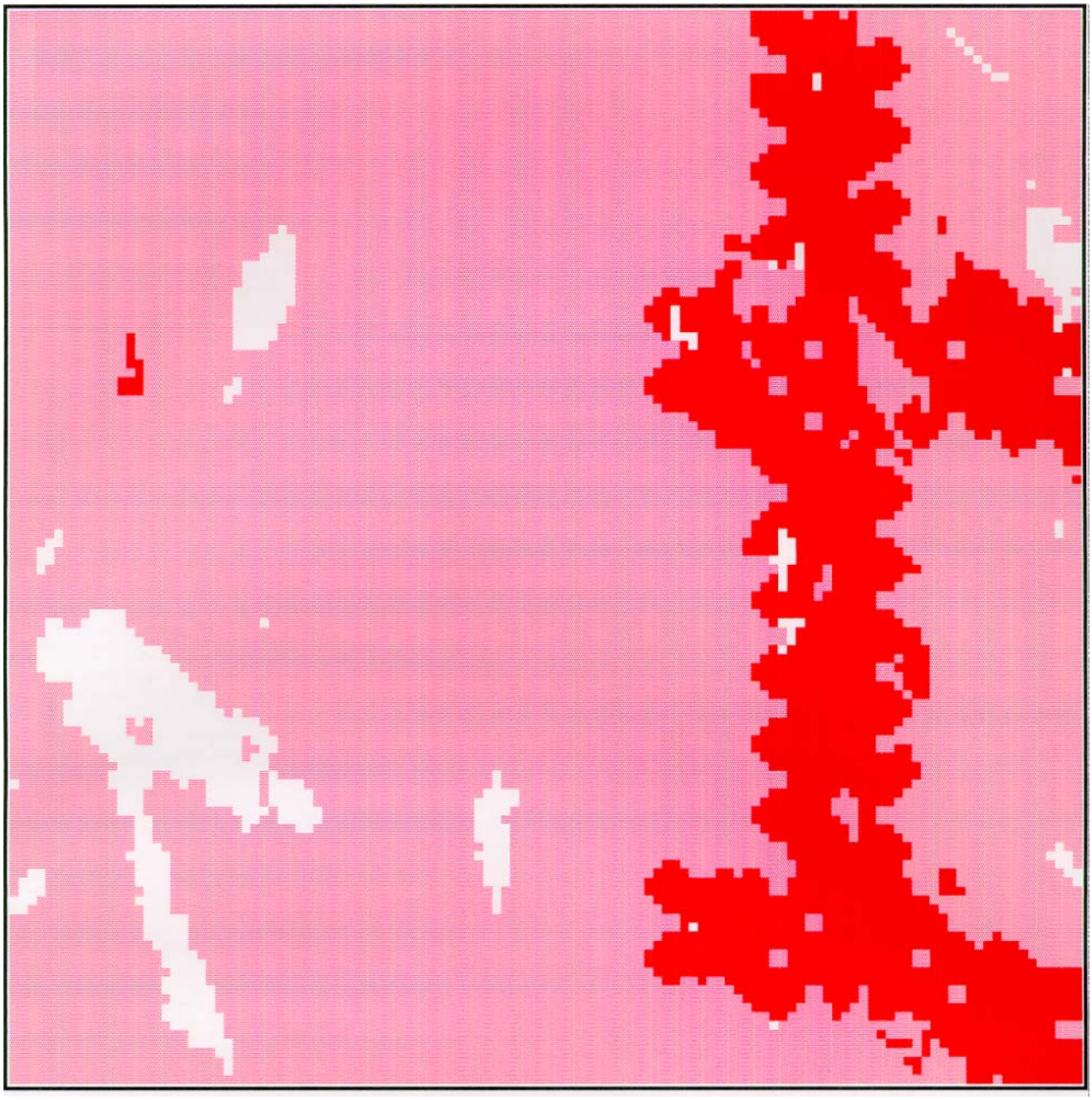


Figure 4.8.—Estimated areas of habitat for woodcock on the Baring Unit of the MNWR after implementation of the woodcock management prescription. White areas represent permanent water and red areas represent areas predicted to be woodcock habitat.

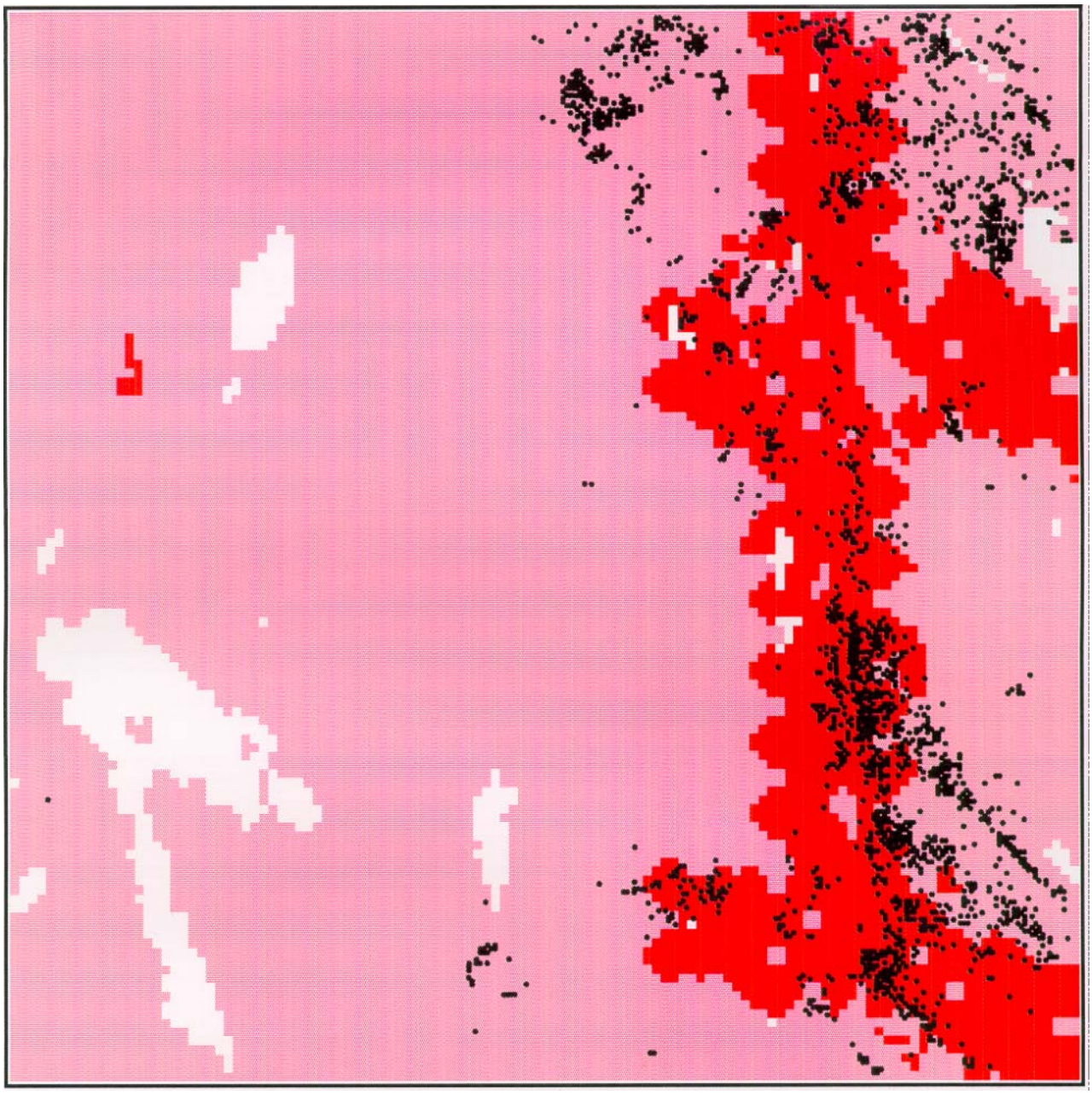


Figure 4.9.—Telemetric locations of woodcock, 1986-1989, on the same landscape unit of the MNWR that is shown in Figure 4-8.

Table 4.4.—Areas of predicted habitat for wildlife species and species-habitat groups on the MNWR study area before and after a proposed habitat management prescription is implemented. The group value will equal the species value if only a single species is present within a group.

Species Habitat Group (SHG) Number	Group value and species within the species-habitat group	Habitat (ha) before change	Habitat (ha) after change	Percent difference
1.	Group value	1,466.25	2,466.0	+68.2
	Eastern chipmunk	708.25	1,171.25	+65.4
	Hairy tailed mole	685.0	631.75	-7.8
	Woodchuck	73.0	662.5	+807.5
2.	Group value	6,845.5	6,845.5	0
	Coyote	3,422.75	3,422.75	0
	Red fox	3,422.75	3,422.75	0
4.	Bank swallow	407.0	1,418.5	+248.5
5.	Group value	3,123.75	3,960.0	+26.8
	Field sparrow	201.75	727.75	+260.7
	Horned lark	2.0	4.25	+112.5
	Ovenbird	2,445.5	2,105.75	-13.9
	Rufous-sided towhee	469.0	1,033.0	+120.3
	Vesper sparrow	5.5	89.25	+1,522.7
7.	Group value	6,801.5	6,051.5	-11.0
	Black bear	3,324.5	2,444.25	-26.5
	Bobcat	3,422.75	3,422.75	0
	Killdeer	0.75	0	-
	Ruffed grouse	53.5	184.5	+244.9
9.	Green-winged teal	80.0	374.75	+368.4
10.	Whip-poor-will	32.25	533.25	+1,553.5
12.	House mouse	5.0	5.0	0
13.	Striped skunk	3,422.75	3,422.75	0
14.	Porcupine	3,275.0	2,915.25	-11.0
16.	Group value	3,647.75	4,091.0	+12.2
	Black-billed cuckoo	769.25	1,019.75	+32.6
	Solitary vireo	1,658.0	1,415.0	-14.7
	Yellow-billed cuckoo	1,220.5	1,656.25	+35.7
17.	Pine grosbeak	3,121.25	2,580.75	-17.3
19.	Blackpoll warbler	12.5	12.5	0
21.	Group value	5,959.0	6,275.75	+5.3
	European starling	84.25	433.0	+413.9
	House sparrow	11.5	4.5	-60.9
	Mourning dove	3,288.25	3,220.5	-2.1
	Northern flicker	2,575.0	2,615.0	+1.6
	Rock dove	0	2.75	+
22.	Group value	6,219.0	4,929.25	-20.7
	Pine warbler	601.5	231.0	-61.6
	Purple finch	3,076.0	2,591.0	-15.8
	White-winged crossbill	2,541.5	2,107.25	-17.1
23.	Red crossbill	2,541.5	2,107.25	-17.1
25.	Chimney swift	142.25	423.25	+197.5
26.	Common nighthawk	15.0	0	-100.0
29.	Group value	1,014.75	1,014.75	0
	Bull frog	789.0	789.0	0

Continued

Table 4.4—Continued

Species Habitat Group (SHG) Number	Group value and species within the species-habitat group	Habitat (ha) before change	Habitat (ha) after change	Percent difference
	Mink frog	225.75	225.75	0
30.	Group value	3,036.5	2,868.25	-5.5
	Green frog	591.75	523.75	-11.5
	Northern leopard frog	650.5	571.25	-12.1
	Pickerel frog	1,794.25	1,773.25	-1.2
31.	Group value	11,959.5	12,058.0	+0.8
	Blue spotted salamander	1,534.25	1,511.75	-1.5
	Eastern American toad	3,480.75	3,443.25	-1.1
	Red spotted newt	3,151.75	3,085.75	-2.1
	Spotted salamander	519.0	819.75	+57.9
	Wood frog	3,273.75	3,197.5	-2.3
32.	Northern spring peeper	689.25	603.25	-12.5
34.	Pied billed grebe	471.25	471.25	0
35.	Group value	163.0	130.25	-20.1
	Marsh wren	9.25	5.25	-43.2
	Northern water thrush	153.75	125.0	-18.7
36.	Group value	335.0	254.5	-24.0
	Common snipe	193.5	156.5	-19.1
	Swamp sparrow	112.5	80.75	-28.2
	Virginia rail	29.0	17.25	-40.5
37.	Northern water snake	542.25	446.5	-17.7
38.	Group value	656.25	644.25	-1.8
	Sora	32.75	20.75	-36.6
	Star-nosed mole	623.5	623.5	0
39.	American bittern	8.25	3.25	-60.6
40.	Wilson's warbler	146.0	146.25	+0.2
41.	Yellow-bellied flycatcher	128.75	112.25	-12.8
42.	Muskrat	89.0	789.0	0
43.	Beaver	40.75	76.5	+87.7
44.	Group value	967.0	967.0	0
	Common snapping turtle	483.5	483.5	0
	Eastern (midland) painted turtle	483.5	483.5	0
45.	Group value	29,265.25	30,478.0	+4.1
	American woodcock	38.25	625.0	+1,534.0
	Bobolink	0	47.75	+
	Dark-eyed junco	2,056.75	2,245.5	+9.2
	Hermit thrush	1,002.25	1,454.75	+45.1
	Lincoln's sparrow	841.25	1,155.0	+37.3
	Masked shrew	366.25	330.5	-9.8
	Northern redbelly snake	3,388.5	3,342.25	-1.4
	Northern ringneck snake	3,363.5	3,367.0	+0.1
	Northern short-tailed shrew	286.25	498.25	+74.1
	Redback salamander	3,201.5	3,039.25	-5.1
	Savannah sparrow	0.25	140.5	+56,100.0
	Snowshoe hare	3,388.75	3,289.25	-2.9
	Southern red backed vole	3,351.75	3,258.75	-2.8
	White footed mouse	3,393.25	3,393.25	0
	White-throated sparrow	1,824.75	2,023.25	+10.9

Continued

Table 4.4—Continued

Species Habitat Group (SHG) Number	Group value and species within the species-habitat group	Habitat (ha) before change	Habitat (ha) after change	Percent difference
	Winter wren	2,762.0	2,268.0	-17.9
46.	Group value	3,443.5	3,638.5	+5.7
	Eastern garter snake	3,416.25	3,370.5	-1.3
	Spotted sandpiper	27.25	268.0	+883.5
48.	Group value	1,175.0	1,795.0	+52.8
	American black duck	312.75	504.0	+61.2
	Blue-winged teal	395.75	571.75	+44.5
	Canada goose	117.25	129.75	+10.7
	Mallard	349.25	589.5	+68.8
49.	Group value	3,910.75	3,927.0	+0.4
	Common yellowthroat	234.0	183.5	-21.6
	Mourning warbler	186.0	247.25	+32.9
	White-tailed deer	3,422.75	3,422.75	0
	Veery	68.0	73.5	+8.1
50.	Moose	3,600.0	3,600.0	0
51.	Group value	1,497.75	3,151.75	+110.4
	Black-and-white warbler	17.0	156.5	+820.6
	Black-throated blue warbler	3.0	98.	+3,175.0
	Chestnut-sided warbler	651.75	1,043.5	+60.1
	Nashville warbler	674.5	1,126.75	+67.0
	Tennessee warbler	151.5	726.75	+379.7
52.	Spruce grouse	2,008.75	1,693.0	-15.7
53.	Group value	6,592.25	5,918.0	-10.2
	Canada warbler	3,403.5	3,303.5	-2.9
	Palm warbler	3,188.75	2,614.5	-18.0
54.	Group value	7,540.0	8,406.75	+11.5
	Deer mouse	3,367.5	3,361.75	-0.2
	Meadow jumping mouse	347.0	751.75	+116.6
	Meadow vole	428.75	897.75	+109.4
	Woodland jumping mouse	3,396.75	3,395.5	0
55.	Group value	6,794.25	6,768.75	-0.4
	Ermine	3,373.25	3,347.75	-0.8
	Long tailed weasel	3,421.0	3,421.0	0
56.	Mink	156.5	129.25	-17.4
57.	River otter	58.5	58.5	0
58.	Fisher	1,981.0	1,451.5	-26.7
59.	Ring-necked duck	265.75	149.75	-43.7
61.	American coot	471.25	471.25	0
64.	Chipping sparrow	1,491.0	1,833.5	+23.0
65.	Group value	1,894.75	2,434.75	+28.5
	Gray catbird	1,695.25	1,599.75	-5.6
	House wren	199.5	835.0	+318.5
66.	Group value	8,311.5	6,886.75	-17.1
	Black-backed woodpecker	3,195.75	2,562.75	-19.8
	Boreal chickadee	3,098.75	2,498.25	-19.4
	Brown creeper	2,017.0	1,825.75	-9.5

Continued

Table 4.4—Continued

Species Habitat Group (SHG) Number	Group value and species within the species-habitat group	Habitat (ha) before change	Habitat (ha) after change	Percent difference
67.	Group value	4,963.25	4,368.0	-12.0
	Rose-breasted grosbeak	2,325.5	2,179.75	-6.3
	Swainson's thrush	2,637.75	2,188.25	-17.0
68.	Least flycatcher	686.75	1,085.25	+58.0
69.	Tree swallow	431.0	701.25	+62.7
71.	Eastern phoebe	207.0	836.75	+304.2
72.	Rusty blackbird	352.75	253.0	-28.3
74.	Alder flycatcher	25.0	11.25	-55.0
76.	Red-winged blackbird	300.75	302.75	+0.7
78.	Group value	1,653.5	2,555.25	+54.5
	Indigo bunting	757.0	1,269.5	+67.7
	Song sparrow	896.5	1,285.75	+43.4
79.	Magnolia warbler	800.25	691.75	-13.6
81.	Group value	15,178.75	14,942.25	-1.6
	Barred owl	1,612.0	1,356.75	-15.8
	Cooper's hawk	3,422.5	3,422.5	0
	Great horned owl	3,416.75	3,417.75	0
	Red-tailed hawk	3,313.0	3,344.25	+0.9
	Sharp-shinned hawk	3,414.5	3,401.0	-0.4
81.	Bald eagle	57.25	57.25	0
83.	Wood duck	595.0	600.0	+0.8
84.	Warbling vireo	19.5	339.75	+1,642.3
85.	Evening grosbeak	3,186.0	2,614.0	-18.0
86.	Gray squirrel	156.0	400.0	+156.4
87.	Merlin	3,062.75	2,290.75	-25.2
89.	Northern goshawk	3,294.5	2,374.0	-27.9
90.	Common raven	3,422.75	3,385.25	-1.1
94.	Group value	8,832.25	8,023.0	-9.2
	American crow	3,327.25	3,250.25	-2.3
	Broad-winged hawk	1,577.75	1,345.75	-14.7
	Common grackle	671.0	861.75	+28.4
	Northern saw-whet owl	3,239.25	2,408.75	-25.6
	Wood thrush	17.0	156.5	+820.6
97.	American robin	3,360.25	3,319.25	-1.2
98.	Blackburnian warbler	2,385.5	1,985.5	-16.8
99.	Group value	39,387.25	37,216.25	-5.5
	Bay-breasted warbler	2,762.0	2,268.75	-17.9
	Black-capped chickadee	3,403.25	3,394.75	-0.3
	Black-throated green warbler	2,385.5	1,985.5	-16.8
	Cape May warbler	3,186.0	2,614.0	-18.0
	Cedar waxwing	1,566.25	1,497.0	-4.4
	Downy woodpecker	3,385.5	3,378.5	-0.2
	Golden-crowned kinglet	1,736.0	1,480.25	-14.7
	Hairy woodpecker	3,088.25	2,765.75	-10.4
	Northern oriole	391.5	924.25	+136.1
	Northern parula	2,421.5	2,005.0	-17.2

Continued

Table 4.4—Continued

Species Habitat Group (SHG) Number	Group value and species within the species-habitat group	Habitat (ha) before change	Habitat (ha) after change	Percent difference
	Philadelphia vireo	1,491.0	1,739.5	+16.7
	Pileated woodpecker	2,926.0	2,329.25	-20.4
	Red-breasted nuthatch	3,004.25	2,449.75	-18.5
	Red-eyed vireo	722.75	1,038.5	+43.7
	Scarlet tanager	3,083.5	2,763.25	-10.4
	White-breasted nuthatch	41.5	274.25	+560.8
	ellow-bellied sapsucker	3,007.75	2,714.5	-9.7
	Yellow-throated vireo	109.0	505.25	+363.5
	Yellow warbler	675.75	1,088.25	+61.0
100.	Group value	17,995.5	16,835.25	-6.4
	American goldfinch	868.5	1,253.75	+44.4
	Blue jay	3,413.5	3,413.5	0
	Gray jay	3,331.75	2,700.0	-19.0
	Northern flying squirrel	2,882.5	2,578.0	-10.6
	Pine siskin	3,325.25	2,754.75	-17.2
	Ruby-crowned kinglet	3,117.75	2,631.25	-15.6
	Ruby-throated hummingbird	1,056.25	1,504.0	+42.4
101.	Group value	2,467.75	3,417.75	+38.5
	Eastern kingbird	687.75	1,149.75	+67.2
	Little brown myotis	1,780.0	2,268.0	+27.4
102.	American kestrel	463.75	1,130.25	+143.7
103.	Group value	7,562.25	7,786.5	+3.0
	American redstart	609.5	1,088.5	+78.5
	Eastern wood-pewee	3,190.75	2,983.25	-6.5
	Great crested flycatcher	635.75	1,118.5	+75.9
	Olive-sided flycatcher	3,126.25	2,596.75	-16.9
104.	Yellow-rumped warbler	3,186.0	2,614.0	-18.0
105.	Red squirrel	3,007.75	2,714.5	-9.7
106.	Osprey	57.25	57.25	0
108.	Great blue heron	1,817.75	1,779.25	-2.1
109.	Group value	83.75	483.0	+476.7
	Barn swallow	0	291.0	+
	Cliff swallow	83.75	192.00	+129.3
110.	Green heron	1,224.25	1,196.75	-2.2
111.	Brown-headed cowbird	3,388.5	3,342.25	-1.4
113.	Raccoon	1,368.25	1,600.75	+17.0
		283,503.25	283,099.5	-0.1

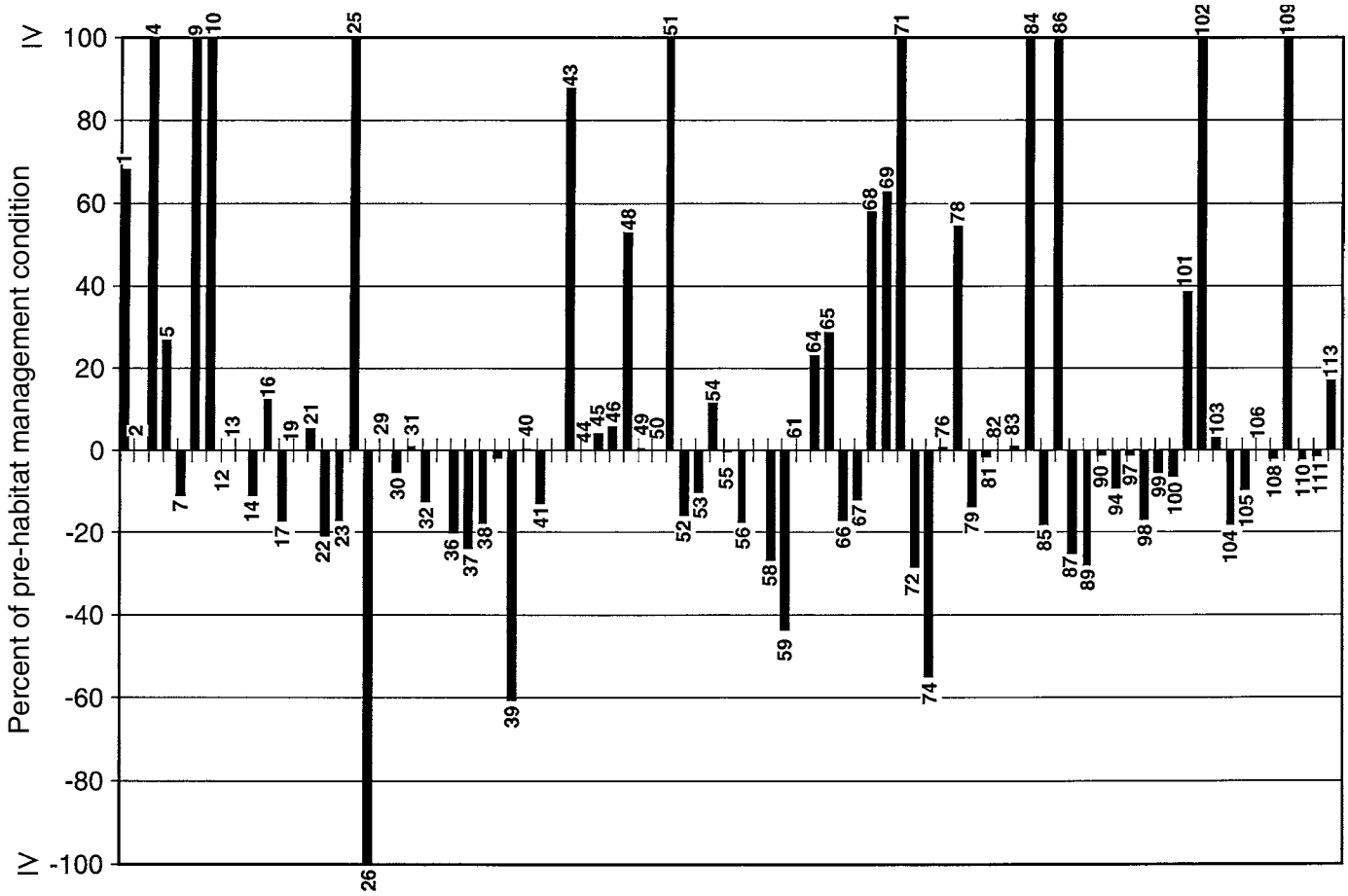


Figure 4-10.—Species-habitat group profile for the MNWR study area. Bars indicate the direction and magnitude with which predicted habitat areas under the posthabitat management condition differ from habitat areas predicted under the prehabitat management condition. Numbers at the end of the bar identify the species-habitat group. Data are from Table 4.4.

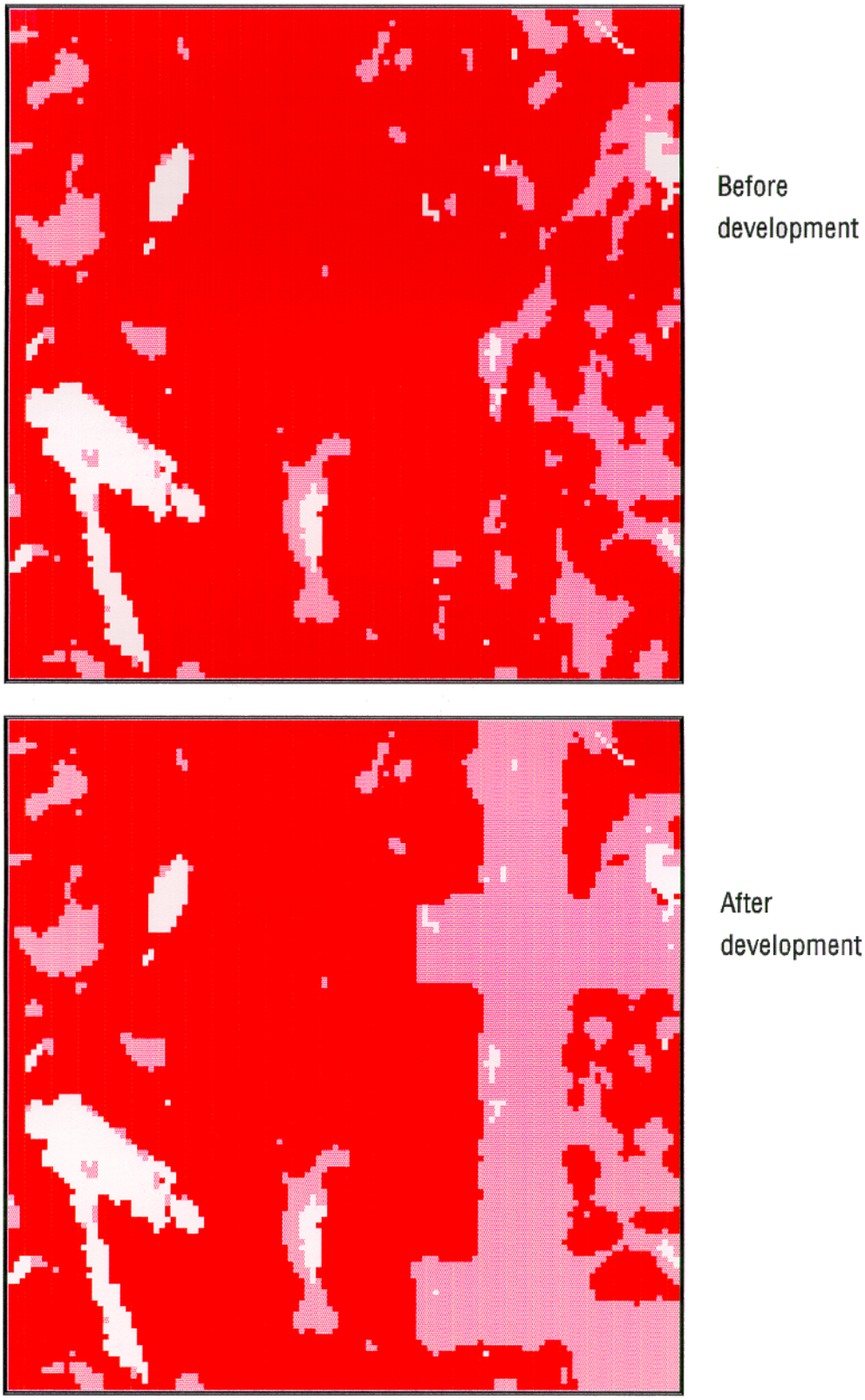
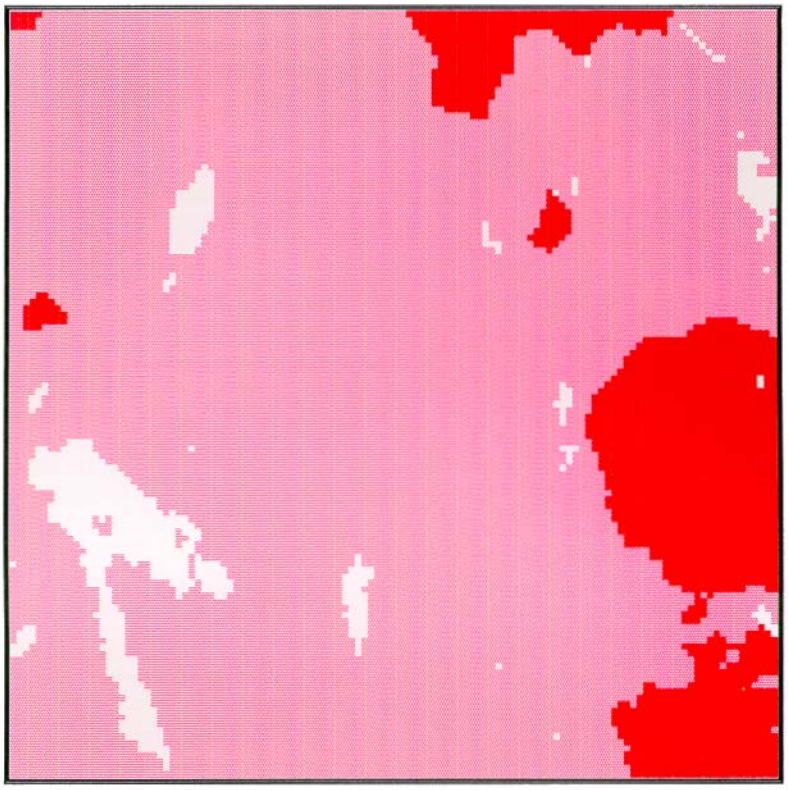
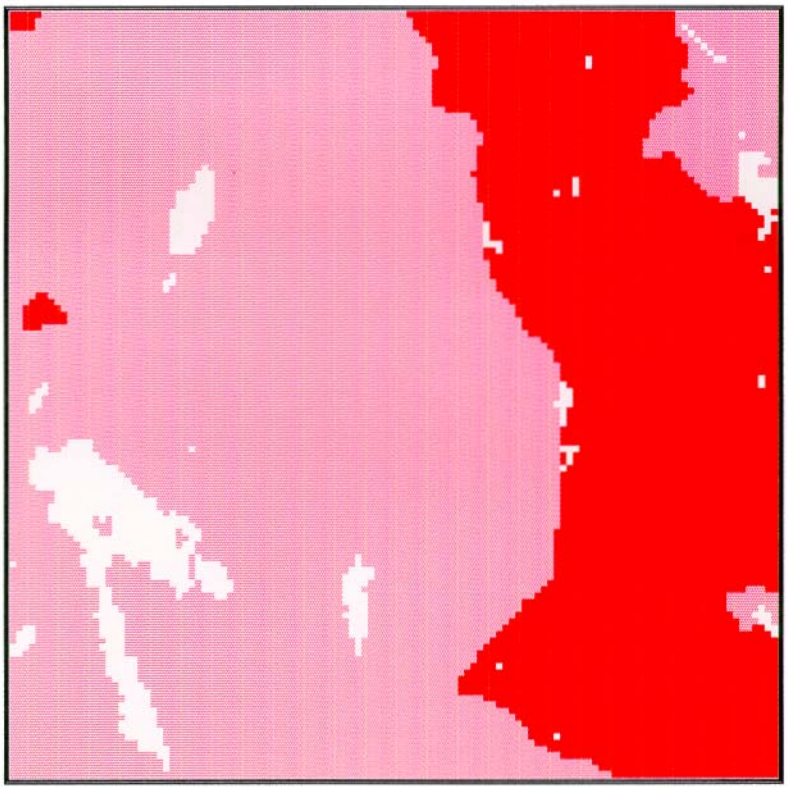


Figure 4-11.—Estimated areas of habitat (red) for the red-breasted nuthatch (SHG 99) on the MNWR before and after implementation of a management prescription. Note loss of habitat area caused by the clearcutting of small blocks of coniferous forest. White represents various wetlands.



Before development



After development

Figure 4-12.—Estimated areas of habitat (red) for the American kestrel (SHG 102) on the MNWR before and after implementation of a management prescription. Note gain in habitat because of the increase in edge habitats created by clearcutting small blocks of coniferous forest. White represents various wetlands.

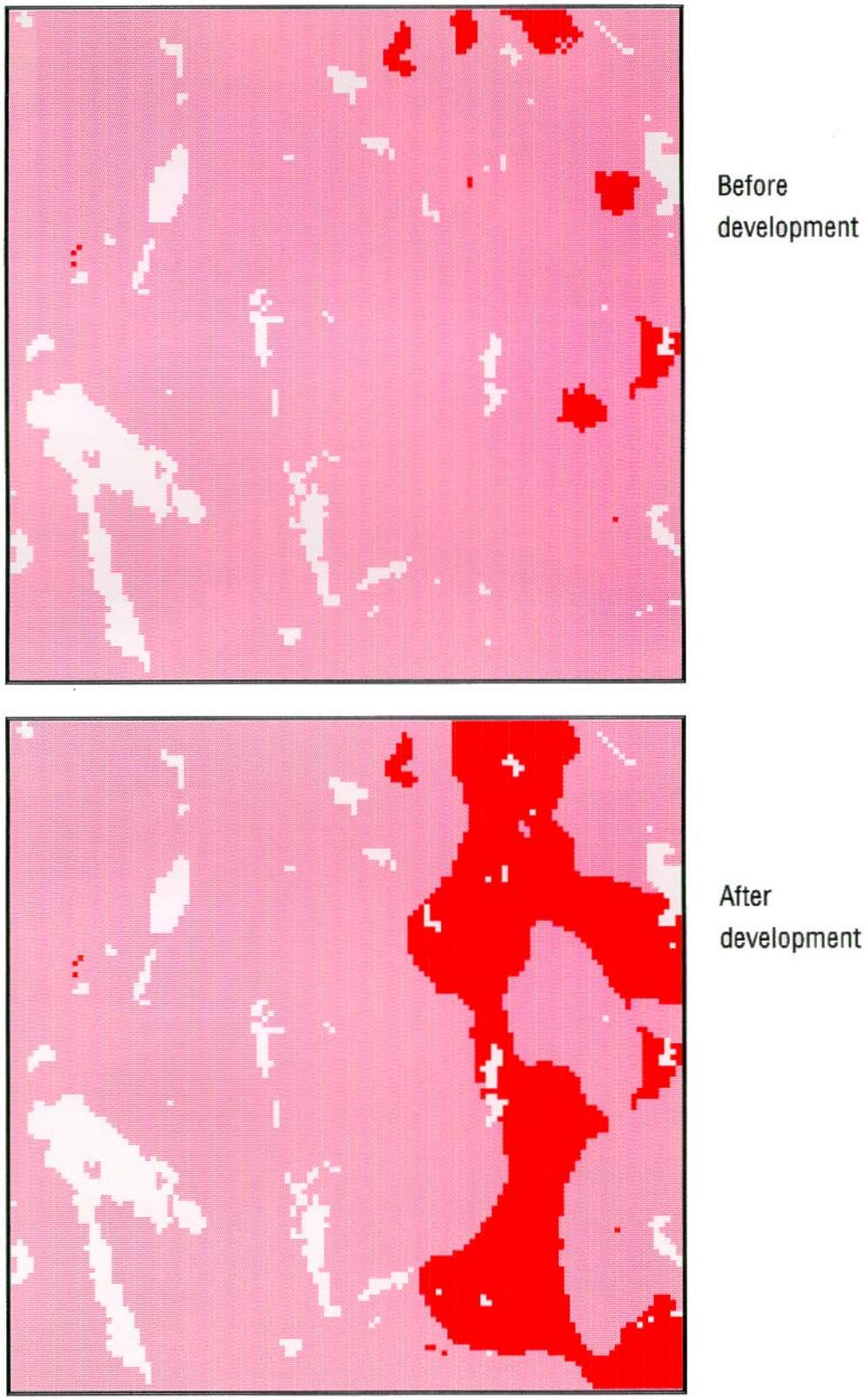


Figure 4-13.—Estimated areas of habitat (red) for the woodchuck (SHG 1) on the MNWR before and after implementation of a management prescription. Note gain in habitat because of the production of clearings caused by clearcutting small blocks of coniferous forest. White represents various wetlands.

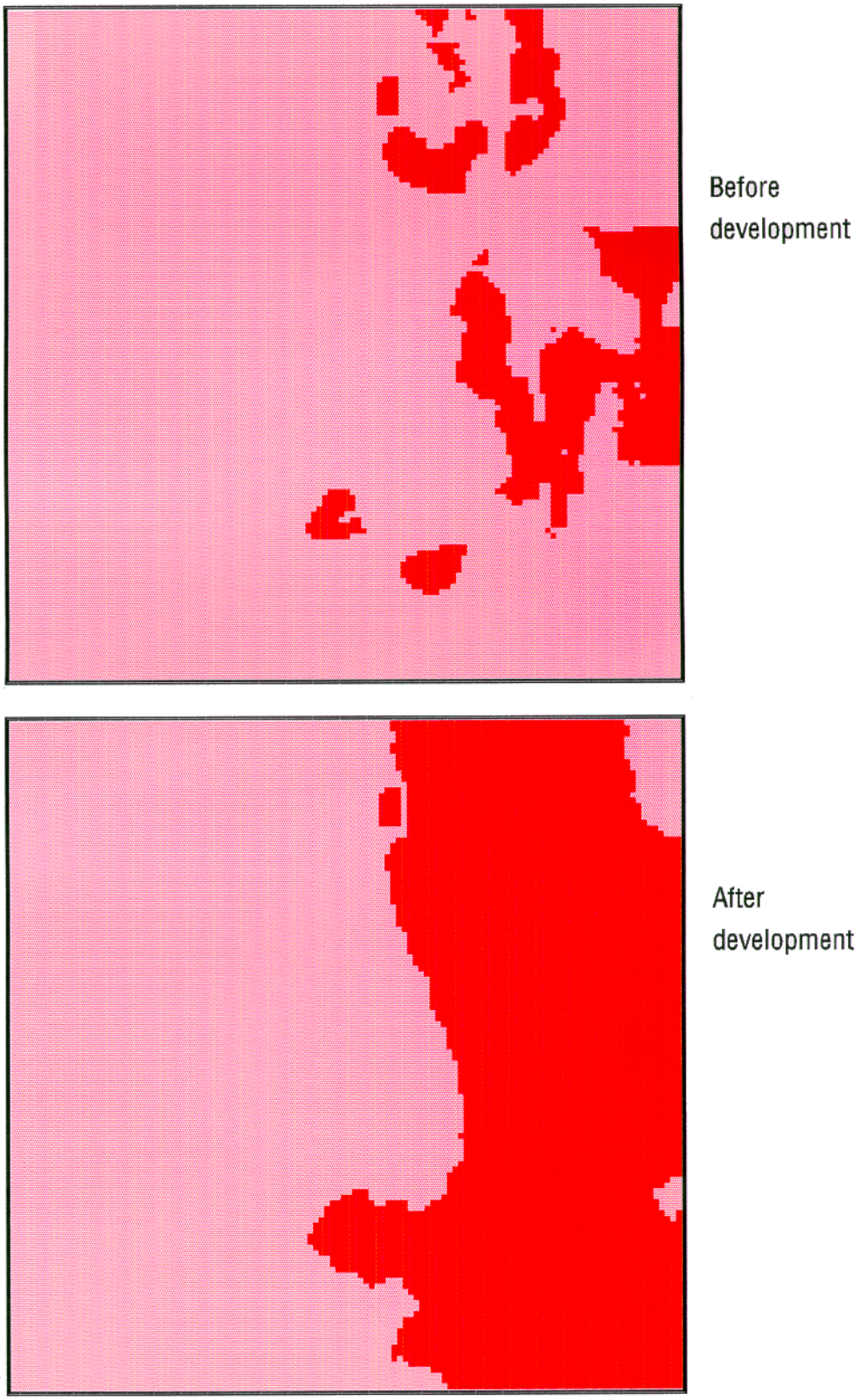
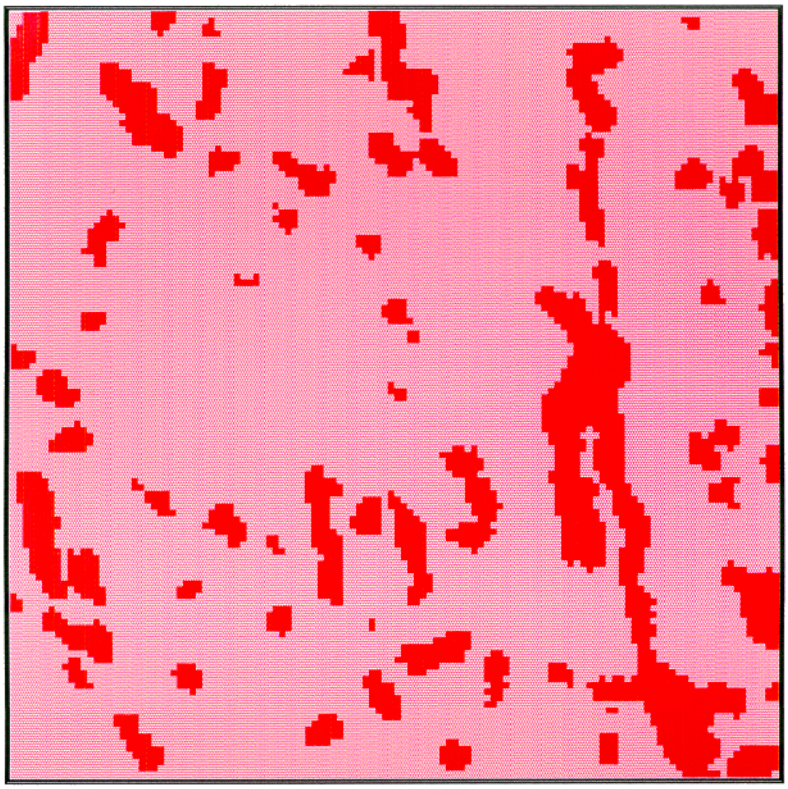
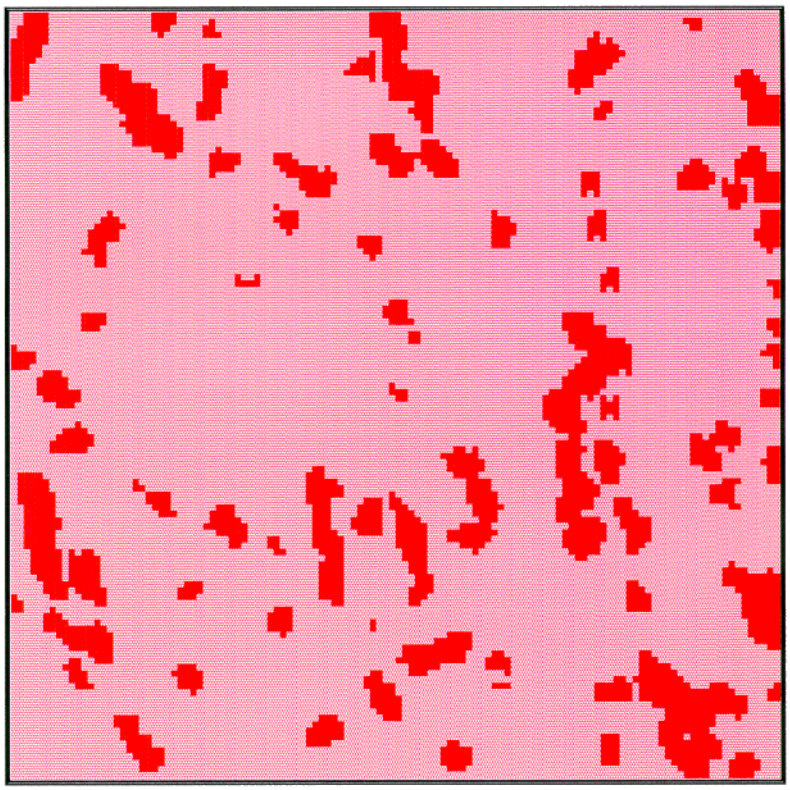


Figure 4-14.—Estimated areas of habitat (red) for the bank swallow (SHG 4) on the MNWR before and after implementation of a management prescription. Note gain in habitat because this aerial feeder forages over clearings created by clearcutting small blocks of coniferous forest.



Before development



After development

Figure 4-15.—Estimated areas of habitat (red) for the northern leopard frog (SHG 30) on the MNWR before and after implementation of a management prescription. Note the small loss of habitat area presumably caused by a loss in wetland vegetation structure borders.

Chapter 5. Assessing Management Options

The examples in Chapters 3 and 4 indicate the use of ECOSEARCH in evaluating impacts caused by changes to water regimes and habitat structure on a small portion of a land unit. In this chapter, we illustrate the use of ECOSEARCH to evaluate large-scale habitat management prescriptions. We compare predicted areas of wildlife habitat that might occur on the Kilkenny Wildlife Management Area (KWMA) of the White Mountain National Forest in northern New Hampshire should different management prescriptions be implemented.

Five management actions listed in Table 5-1 are compared in this evaluation to estimate their possible impact on the vertebrate wildlife community. Option **A** estimates the area of wildlife habitat predicted under present management conditions. Option **B** estimates the area of wildlife habitat predicted when the woody vegetation on the KWMA was allowed to attain successional climax. Option **C** estimates the area of wildlife habitat predicted when all upland and wetland woody vegetation was clearcut and the vegetation communities were returned to very early successional stages. Option **D** estimates the area of wildlife habitat predicted when all upland overstory and midstory vegetation was clearcut to within 50 m of all seasonal, semi-permanent and permanent water bodies and wetlands on the KWMA, and climax woody vegetation was retained within the wetland areas. Option **E** estimates the areas of wildlife habitat predicted under conditions similar to those of option D except that the clearcut extends to within 200 m of the identified wetlands.

The assessments reported in this chapter were developed for a 3,600-ha portion of the 21,200-ha KWMA of the White Mountain National Forest. DeGraaf and Angelstam (1993) describe the KWMA as comprising the most northernmost portion of the White Mountain National Forest and an area that contains soils that are typically stony, sandy, and acidic. The KWMA is considered to be completely forested with no history of agriculture. The predominant forest cover types are northern hardwoods (*Acer saccharum*, *Betula alleghaniensis*, *Fagus grandifolia*) (60%) with conifers (*Picea rubens* and *Abies balsamea*) (25%). Paper birch (*Betula papyrifera*) and quaking aspen (*Populus tremuloides*) are common associates of all types (DeGraaf and Angelstam 1993). Common shrubs in the midstory include striped maple (*Acer pennsylvanicum*), mountain ash (*Sorbus aucuparia*), mountain maple (*A. spicatum*), and hobblebush viburnum (*Viburnum alnifolium*) with a sparse to moderate understory consisting of various herbaceous and woody plants, mosses, and ferns.

The KWMA supports primarily mature stands that grew after widespread unregulated logging in the late 1800's and extensive fires in 1903. Even-age management has been practiced since about 1960. The forest is comprised of 87 percent mature forest, 5 percent poletimber, and 8 percent regeneration/sapling with stand sizes that are 5 to 80 ha and clearcuts that do not exceed 16 ha (DeGraaf and Angelstam 1993).

Extensive surveys have been accomplished on the KWMA by USDA Forest Service personnel, and the study area has been described in terms of Ecological Land Types (ELT), which are units of land that share common biological and physical features and that provide well-known successional patterns on unique soil materials. The purpose of the Forest Service ecological classification effort was to provide a mechanism to relate all management plans and activities on the study area to the inherent capability of the land. In ECOSEARCH we use the ELT information as (1) a descriptor of soils information and present cover types, and (2) a predictor of successional climax, which is management option **B** (Table 5-1) in our assessment.

Habitat Conditions for the Different Management Options

The four data layers — topography, soil particle size and drainage class, water regimes, and vertical habitat structure — were developed and digitized to provide a habitat data base to enable the development of species-habitat maps. The study area is a 3,600-ha block within two 7.5 minute topographic quadrangles — the east half of the Pliny Range and West Milam, within the New Hampshire Lewiston degree block.

Topographic gradients for the study area were traced from the appropriate U.S. Geological Survey (USGS) maps. Figure 5-1 indicates the topographic break at an elevation of 516 m, which is an arbitrary descriptor of mid-mountain slope elevations.

Soil characteristics were inferred from the Forest Service's ELT classification maps, which are based on 1:25000-scale

Table 5-1.—Management prescriptions simulated on the KWMA

Option	Prescription
A	Present condition
B	Upland and wetland forest climax
C	Clearcut upland and wetland forests
D	Clearcut uplands to within 50 m of seasonal, semi-permanent and permanent wetlands. Wetlands have climax vegetation
E	Same as D except clearcuts extend to within 200 m of wetlands.

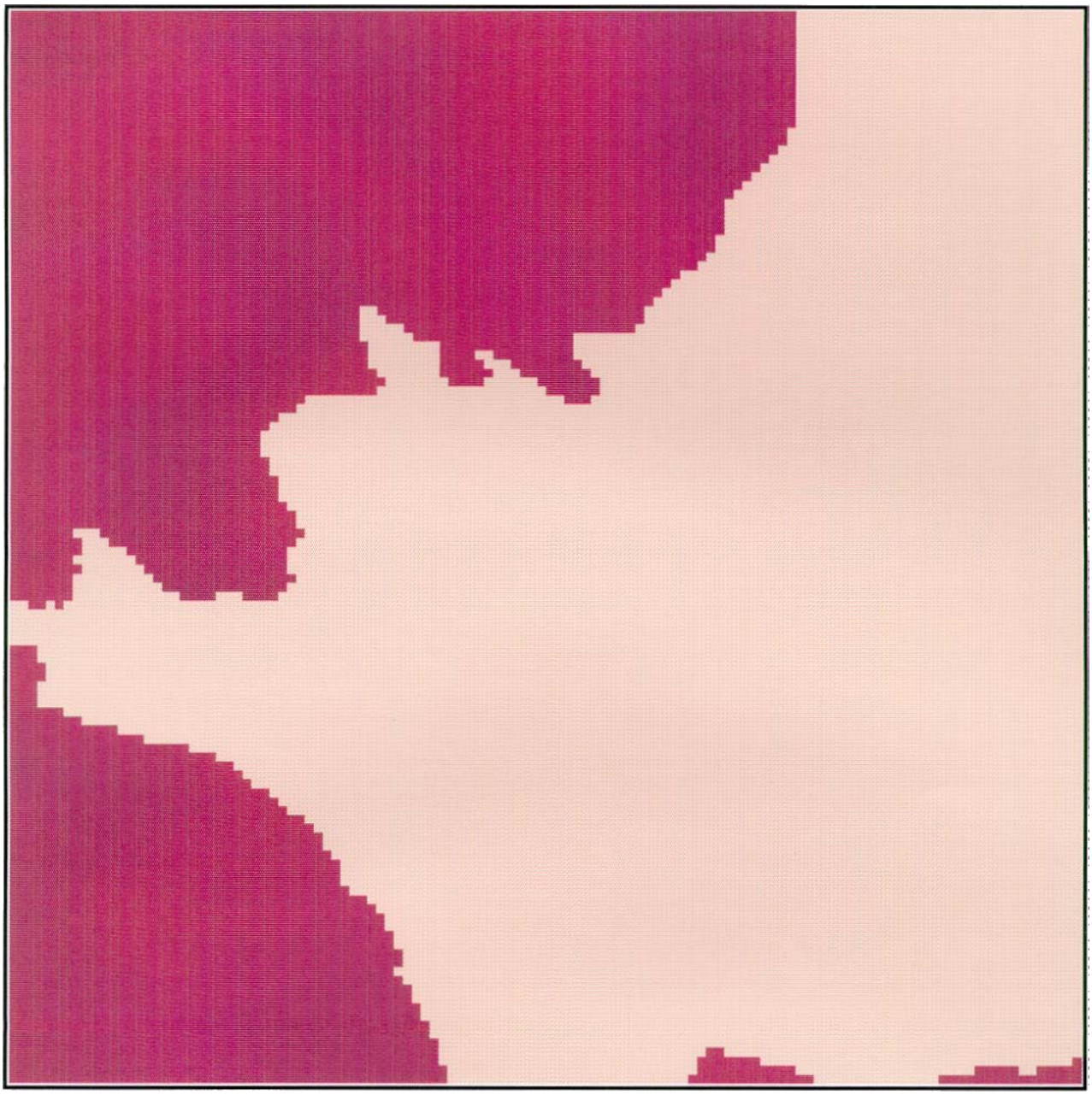


Figure 5.1.—Topography on the KWMA study area. Light shading indicates lower slopes and valleys up to an elevation of 516 m.

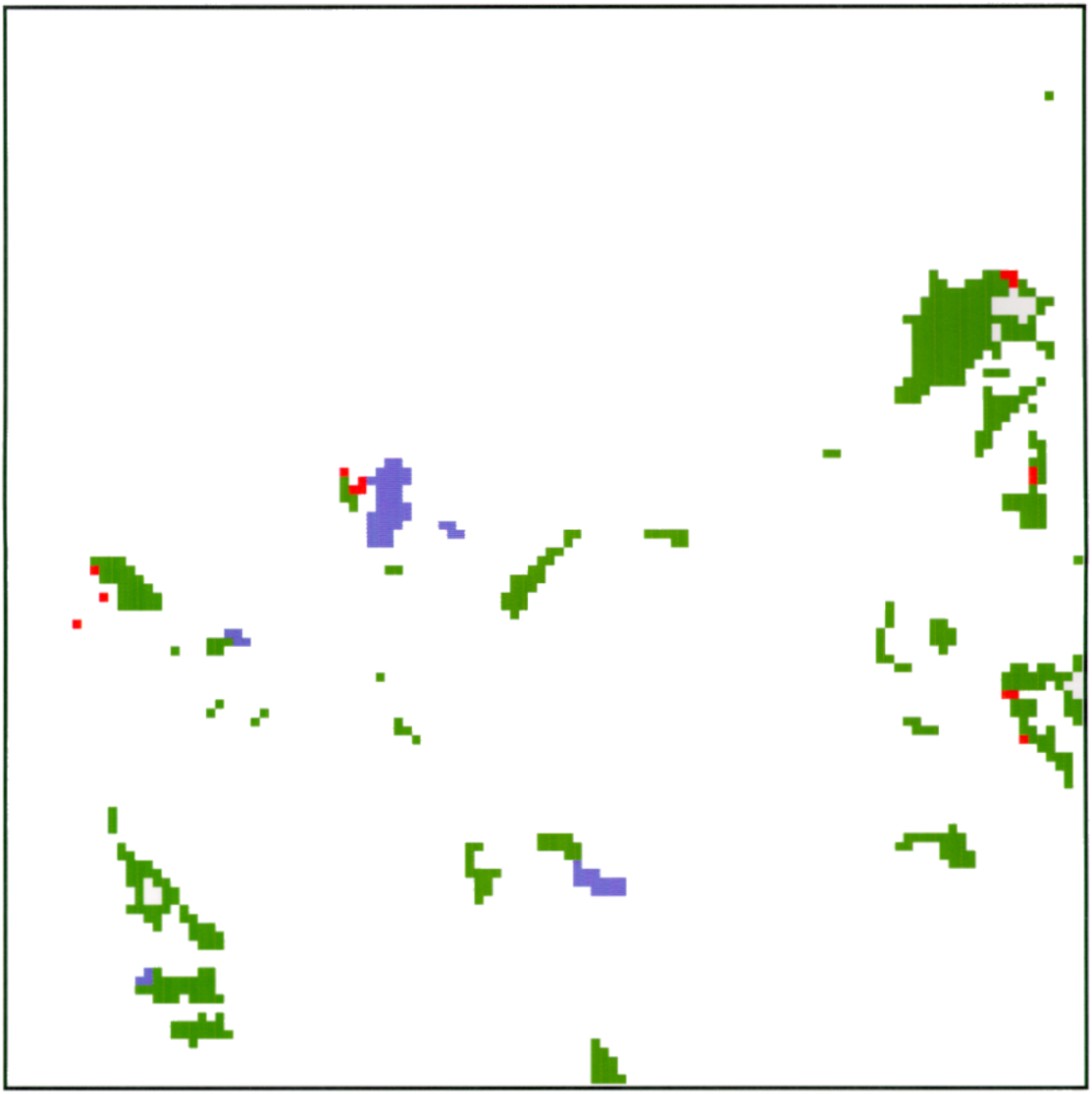
USGS quadrangle maps and an accompanying data base. The ELT data base contains information about physical attributes such as geomorphology; soil characteristics such as permeability, drainage classes, and particle size; and biological attributes such as present vegetation associates in the understory, midstory, and overstory layers; and major and accessory species likely to occur in the climax vegetation. The generalized map indicating the location of excessively drained and somewhat excessively drained rocky soils (A2); well-drained and moderately well-drained, finely grained soils (B1); and well-drained and moderately well-drained rocky soils (B2) on the study area is shown in Figure 5-2.

The location of wetland and deepwater habitats was determined from 1:58000-scale color infrared photography of the study area that was interpreted and classified according

Figure 5-2.—A general soils map for the KWMA study area indicating location of A2, B1, and B2 soil types. See “Chapter 2, VII. Soil types” for further explanation of key.

to the U.S. Fish and Wildlife Service’s official wetland classification system (Cowardin et al. 1979) following standard NWI mapping conventions (NWI 1990). Further data manipulations were similar to those described in Chapter 3 for the production of NWI maps. Figure 5-3 represents the wetland classification map for the study area.

The characterization of vertical habitat structure was accomplished by a point intercept appraisal similar to the procedures described in Chapter 3. Species-habitat distribution maps were developed for each management option using the following habitat structure data and data for the other three layers.



Seasonally Flooded. NWI water regimes C, E. See Chapter 2.
Semipermanently Flooded. NWI water regime F.
Permanently Flooded. NWI water regime H.

Figure 5-3.—Water regimes on the KWMA study area. See “Chapter 2, VIII. Water regimes” for further explanation of key.

Management Option A

The distribution of vegetative structures for the KWMA study area is shown in Figures 5-4 to 5-10.

Management Option B

The presumed climax associations were estimated from the ELT classifications prepared by the USDA Forest Service for the White Mountain National Forest. We assumed that a common climax association occurred throughout an ELT.

Certain ridgetops, knolls, and steep side-slopes at moderately high elevations; certain valley walls and floors and mountain slopes at moderately high elevations; certain mountain slopes and broad basin remnants at moderate to moderately high elevations; and certain lower slopes, basins, and intervales at low elevations are each projected in the ELT classification to have a red spruce — balsam fir climax association. In addition, certain knolls and side slopes at moderately low elevations are projected to have a red spruce — beech climax with hemlock and balsam fir as major accessory species. Some locations at lower elevations near streams are additionally projected to have a hemlock, red spruce, and balsam fir climax association. Portions of the study area within these ELT's were assumed to have a needleleaf evergreen tree cover in climax. The location of the upland needleleaf overstory climax vegetation is represented in Figure 5-11, and the location of the wetland needleleaf overstory climax vegetation is represented in Figure 5-12.

Certain ridges and steep mountain slopes at moderate elevations; certain mountain slopes and intervales at moderate and low elevations; certain mountain slopes at moderate to low elevations; certain mountain slopes and intervales at moderately low elevations; and certain broad basin-like areas and intervales on lower mountain slopes are projected to have a sugar maple, beech climax. Portions of the study area within these ELT's were assumed to have a broadleaf deciduous tree cover in climax. The location of the upland broadleaf deciduous tree climax vegetation is shown in Figure 5-13, and the location of the wetland broadleaf deciduous tree climax vegetation is shown in Figure 5-14.

Management Option C

As stated in Chapter 4, a series of small clearcuts can be crafted to fulfill a management prescription without affecting the total net area of habitat within a study area, even though individual species-habitat groups might be impacted to different degrees. In management option C, we evaluate the impact on the wildlife community that would occur if the total study area were clearcut and the total non-aquatic surface area were returned to early woodland succession with woody regeneration occurring in the understory layer.

Management Option D

This management option is a variation of option **C**. An extensive clearcut extends to within 50 m of seasonal, semi-permanent, and permanent wetland boundaries, and climax vegetation is retained within the wetland borders and within the 50-m border around the wetlands. Forest climax vegetation is determined as in management option B. The clearcut portions of the study are returned to an early woodland successional stage with woody regeneration occurring in the understory layer. The location of the water bodies, forested wetlands, and the 50-m upland border around the wetlands is indicated in Figure 5-15.

Management Option E

This management option is a variation of option **D**. The only change is that 200 m of upland forest is retained as a border around the several wetlands. The location of the water bodies, forested wetlands, and the 200-m upland border around the wetlands is indicated in Figure 5-16.

Impact of Management Options A-E on Wildlife Habitat

Forest Service scientists provided lists of species known or expected to occur on the KWMA study area. ECOSEARCH was used to estimate the distribution and areas of habitat expected for each of the identified wildlife species under the determined and estimated habitat conditions represented by management options A-E. The identity of the 159 species and the predicted areas of habitat for each species are listed in Table 5-2.

There are 159 different stories that could be told about the way individual species responded to the different habitat conditions represented by the five management options. Stories would describe how forest edge and interior species have habitat areas that are devastated by the large clearcut and how other species have habitat requirements that are advantaged by the broad expanse of early successional habitat. Our assessment, however, is intended to demonstrate the impacts of large-scale habitat change on the community habitat. The community habitat, defined as the sum of the habitat area that is predicted to be present for each of the 159 species, is calculated for each management option in Table 5-2. The community habitat is slightly larger for option **A** than for option **B,** and all management options provide substantially more community habitat than is present under the large clearcut of option **C**.

Species-habitat group profiles are presented in Figures 5-17 to 5-20 to compare areas of predicted habitat for each SHG under management options **B** to **E** with those under option **A**. There are two patterns in the four SHG profiles. The profile for option **B** in Figure 5-17 is the most complex: SHG that require forest openings and forest edges are negatively impacted, and forest interior dwelling species are advantaged. The SHG profiles for management options **C**, **D,** and **E** are variations on a common theme. The profile for option **C** is consistent with the hypothesis that those species requiring open habitats or which are ubiquitous in their habitat selections are either advantaged or not affected by expansive forest clearing, but those species requiring habitat criteria provided by forest interiors, forest edges, or forest openings are adversely impacted by the large clearcut. The provision of upland forest borders and wetland vegetation within wetland areas somewhat ameliorates the impact from the

large clearcut. The impact patterns in Figures 5-19 and 5-20 are generally similar to those in Figure 5-18, but the degree of impact is somewhat lessened for management option **D** (Figure 5-19), and is moderated for option **E** (Figure 5-20).

As stated in Chapter 2, the structure of habitats can be considered in terms of habitat layers. Frequently, biodiversity increases as habitat layers are added to a landscape because additional habitat niches will be present as vertical complexity increases. It is possible to approximate this relationship using the predicted species habitat information (Table 5-2) and a crude measure of habitat volume where the understory or surface vegetation ($\leq$1 m) has one layer, midstory vegetation (>1, $\leq$ 6 m) has two layers, and overstory vegetation (>6 m) has three layers. A regression analysis (Figure 5-21) indicated that 26 ha of wildlife habitat on the KWMA are lost or gained for every ha of habitat-layer that is lost or gained ($F = 114$; $df = 1,3$; $P = 0.002$).

Large clearcuts simplify habitat structure by removing the overstory and midstory layers causing a reduction in predicted wildlife, community habitat. This relationship can also be approximated using predicted species habitat (Table 5-2). As expected, the regression analysis (Figure 5-22) indicated that 54 ha (about 2 times the 26 ha per layer estimate) of wildlife habitat are lost or gained for every ha of forest that is lost or gained ($F = 63$; $df = 1,3$; $P = 0.004$).

It is important to remember that the planned management prescription (a series of small [4 ha] clearcuts) described in Chapter 4 caused no net loss in the quantity of community wildlife habitat predicted to be present on that management site. Habitat loss to forest interior species seemed to be balanced by habitat gained for forest edge and forest opening species. Apparently, small clearcuts can be wildlife habitat neutral, whereas larger clearcuts have an immediate impact on wildlife habitat. Thus, the challenge to the multiple-use oriented forest and land manager: (1) develop wildlife management goals to either favor the wildlife community or individual species of special interest or concern; and (2) develop management prescriptions to provide suitable habitats to achieve those goals. ECOSEARCH aids in the design and evaluation of those prescriptions so adverse impacts to wildlife habitats can be minimized or averted when prescriptions are implemented.

Future Directions

ECOSEARCH is based on the concept that species are associated with distinct habitat layers and that species habitat can be predicted from species-habitat models and geographic data interpreted at a grid of point-intercepts (Short et al. 1996). Species also can be arbitrarily assigned to specific Species-Habitat Groups (SHG) based on the habitat layers used for feeding and breeding. Accordingly, all species within a particular SHG should be similarly impacted by changes in the existing habitat layers.

In the future, the quality of remotely sensed data will increase as pixel size shrinks, computer speed increases, and new instruments and methodologies provide new metrics of environmental variation. As these data sources are developed, prediction of species occurrence will move from natural-history models to statistical models where the probability of occurrence of each species will be predicted from various geographic variables. The display and summarization of results from these models will also move from the SHGs to general, natural-history categories (for example, neotropical migrant, interior forest species, and early, forest successional-stage species).

The present predictor variables used within ECOSEARCH, although arbitrarily defined from natural history information, will provide a reasonably accurate predictor of species occurrence. Giorgi (1999) compared predictions of species occurrence from ECOSEARCH to field observations for different species of birds (30), mammals (7), and amphibians (4) at 73 individual points in wetlands, farmland, and upland forest in western Massachusetts and found that ECOSEARCH correctly classified 60 percent of occurrences at these individual points.

As we move toward statistical models, natural-history models will still provide reasonable predictors of occurrence for species that are rare or hard to detect. Other aspects of ECOSEARCH that we expect to continue will be the prediction of occurrence based on samples of point-intercept data (instead of species-habitat crosswalks) and the prediction of occurrence across landscapes using continuous grids of data (instead of arbitrary polygons). We share our view of the future to facilitate further development of ever-more accurate species-habitat models.

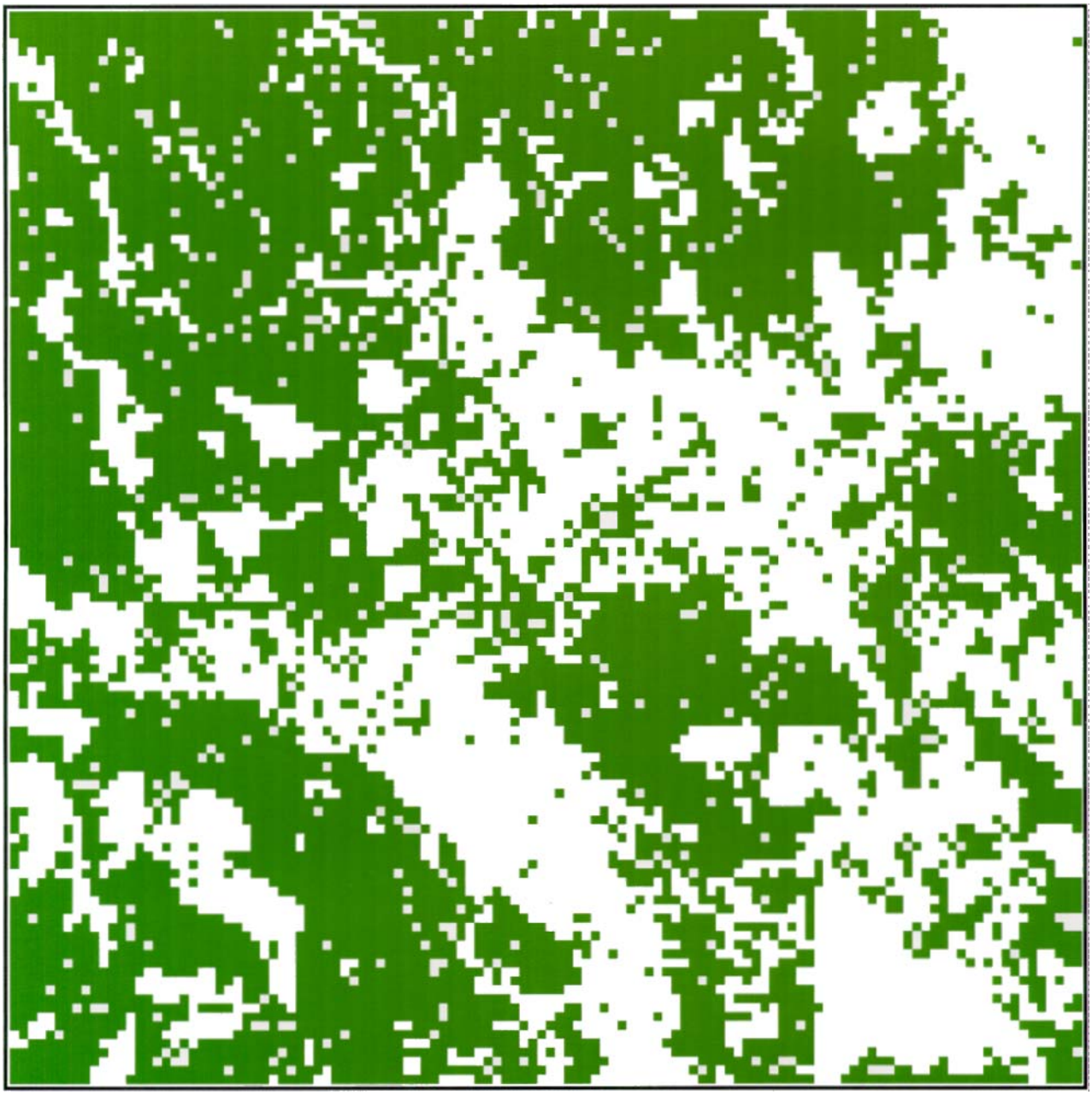


Figure 5-4.—The present distribution of broadleaf deciduous upland trees on the KWMA study area.

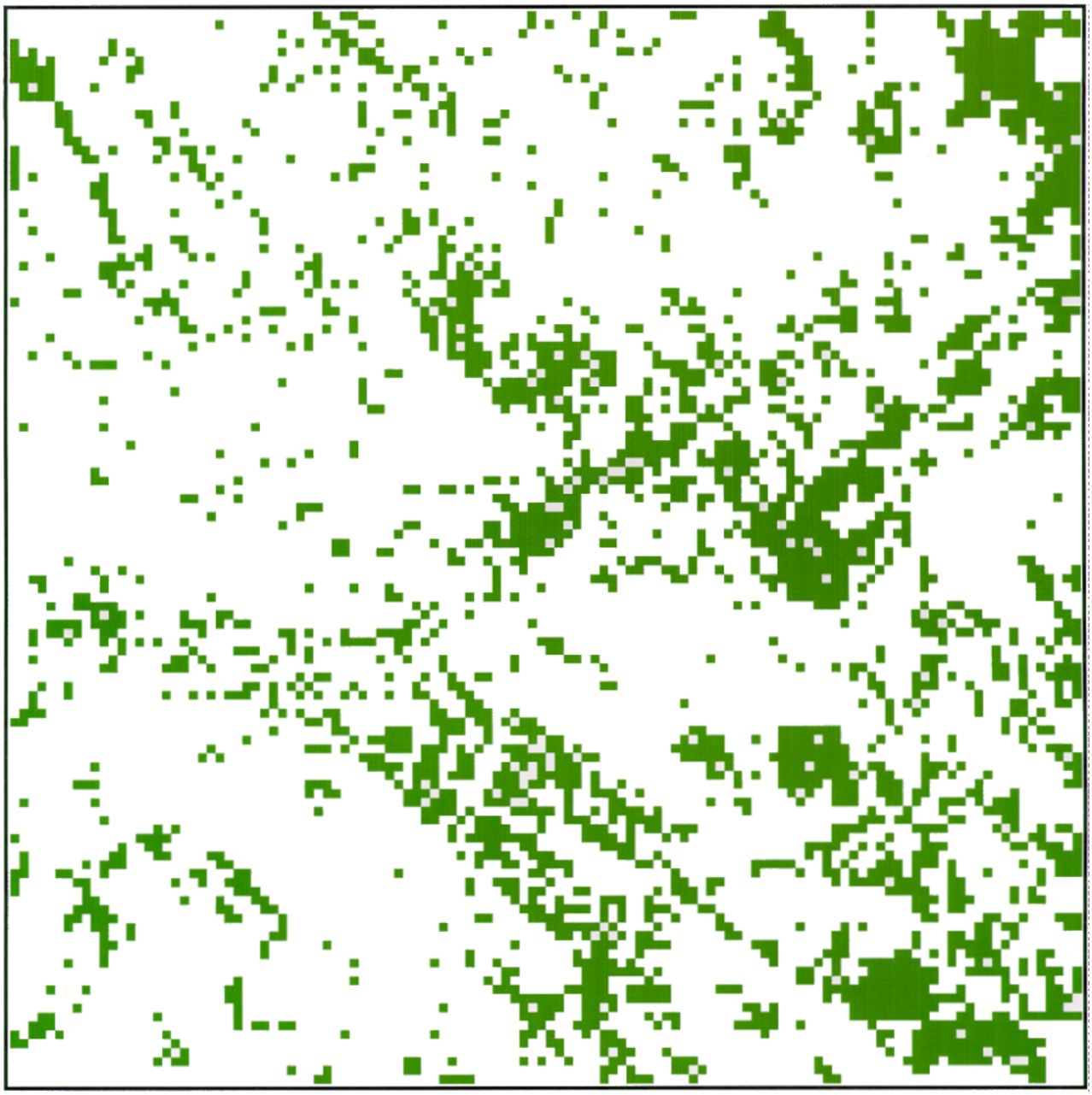


Figure 5-5.—The present distribution of needleleaf evergreen upland trees on the KWMA study area.

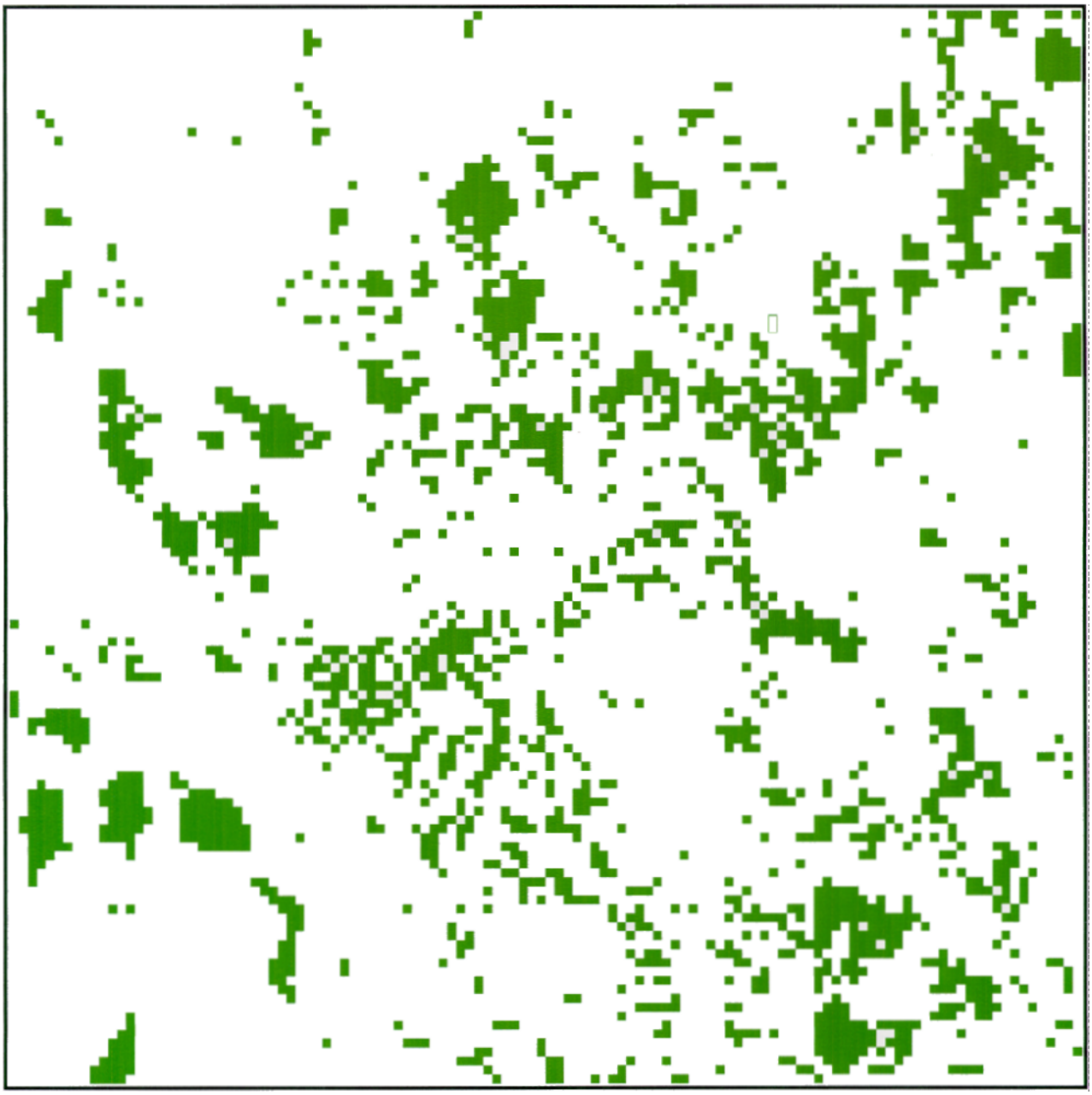


Figure 5-6.—The present distribution of upland midstory woody vegetation on the KWMA study area.

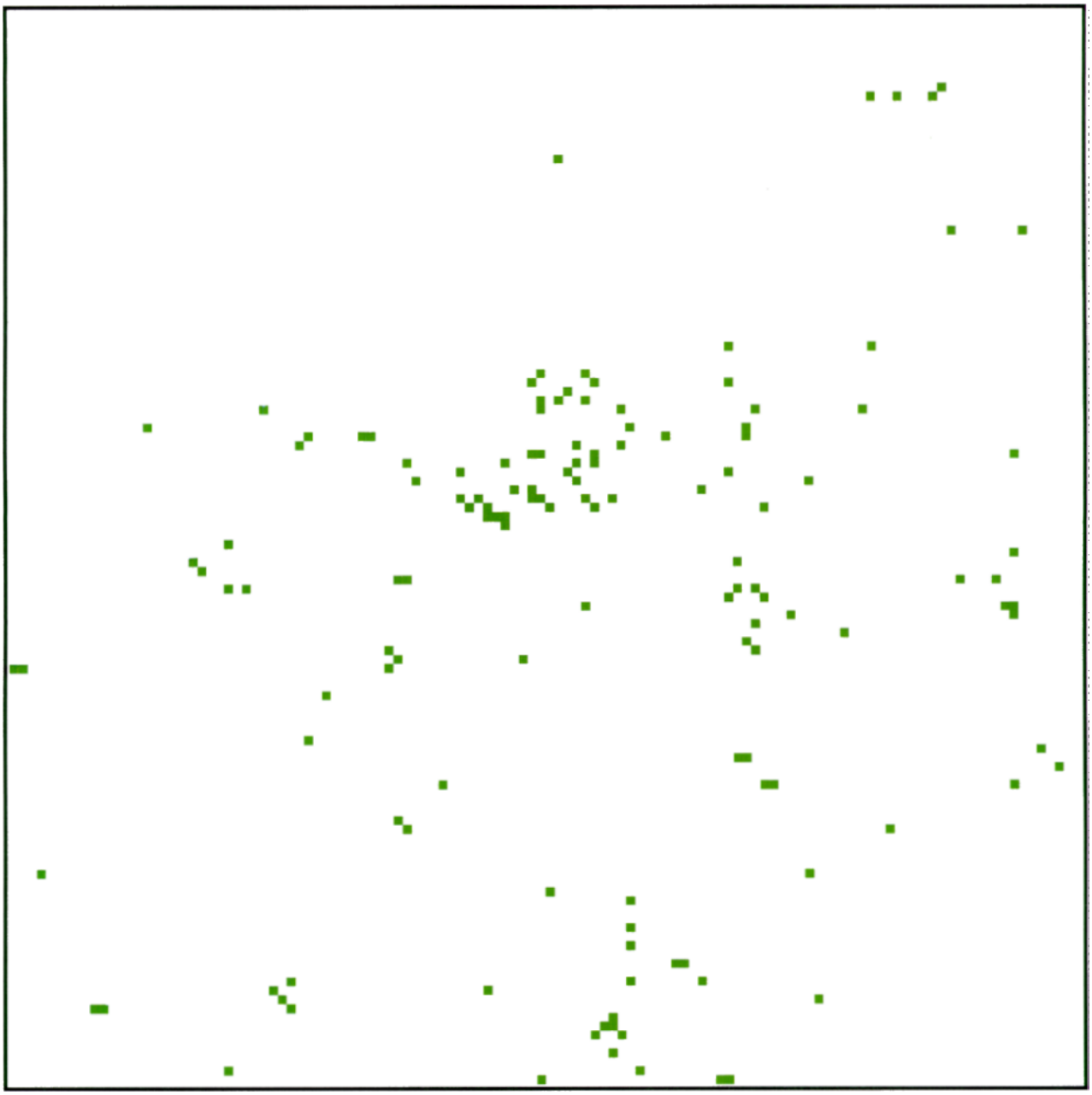


Figure 5-7.—The present distribution of short woody upland vegetation in the understory layer on the KWMA study area.

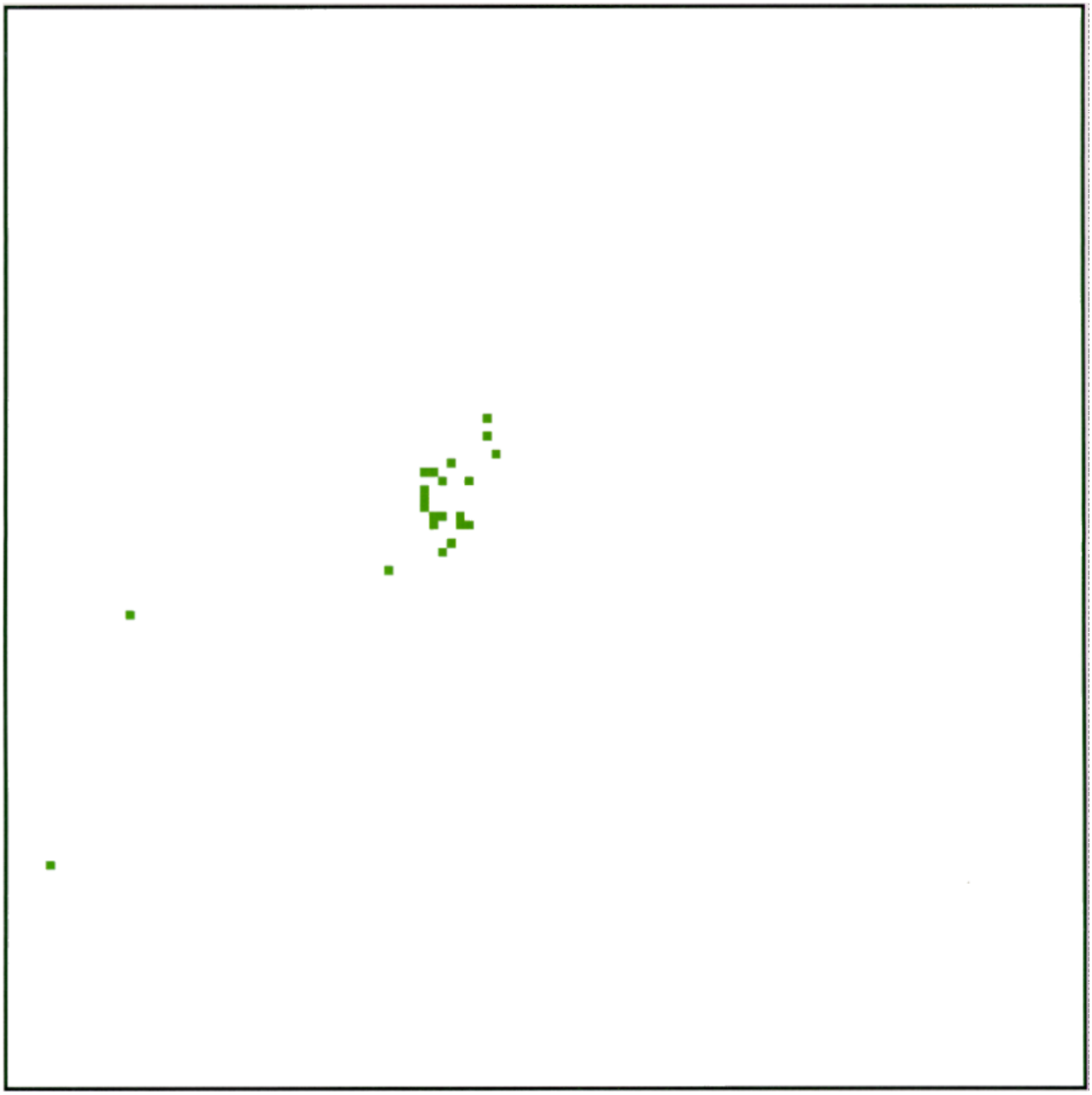


Figure 5-8.—The present distribution of upland herbaceous vegetation in the understory on the KWMA study area.

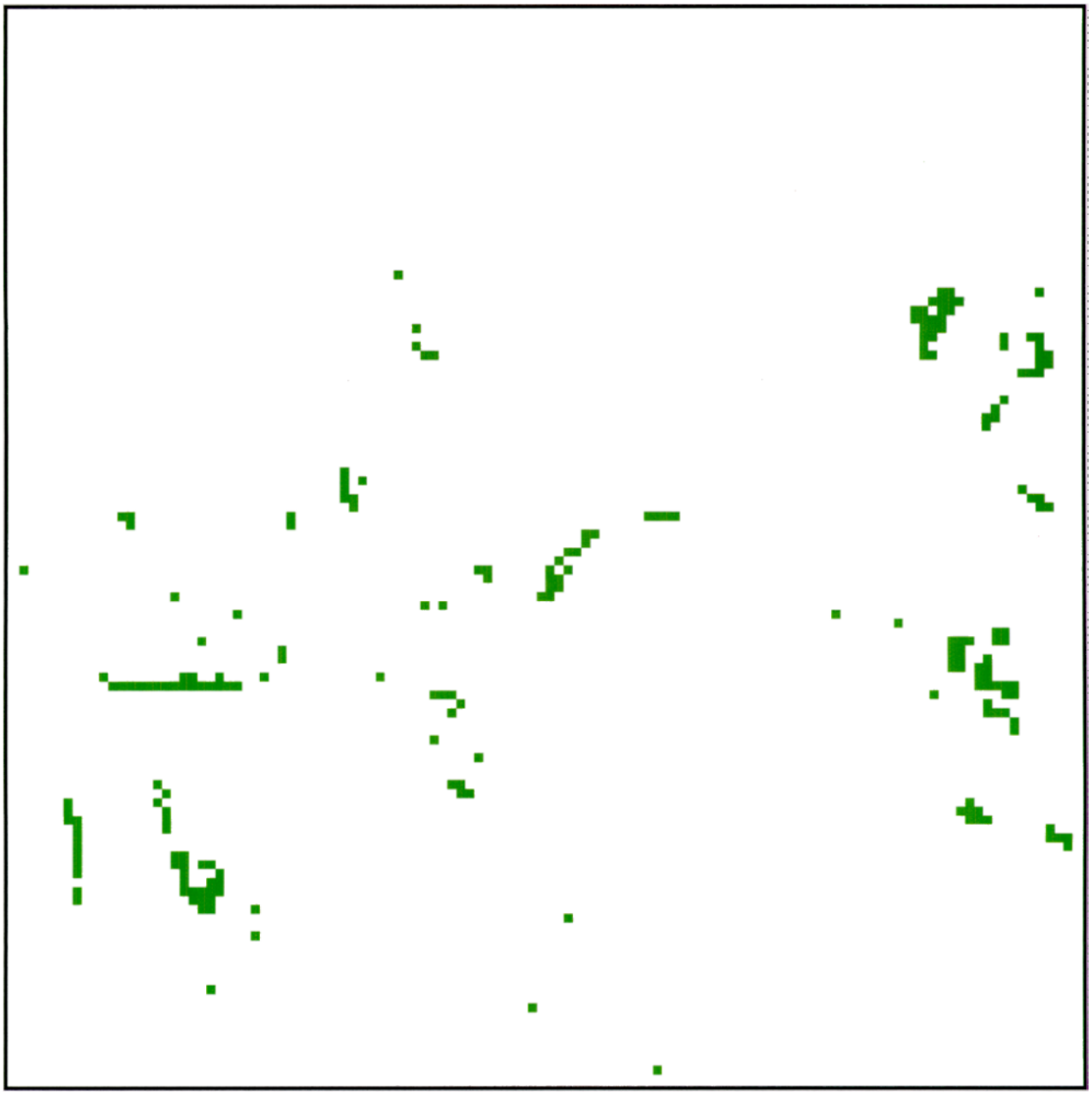


Figure 5-9.—The present distribution of wetland deciduous and coniferous trees on the KWMA study area.

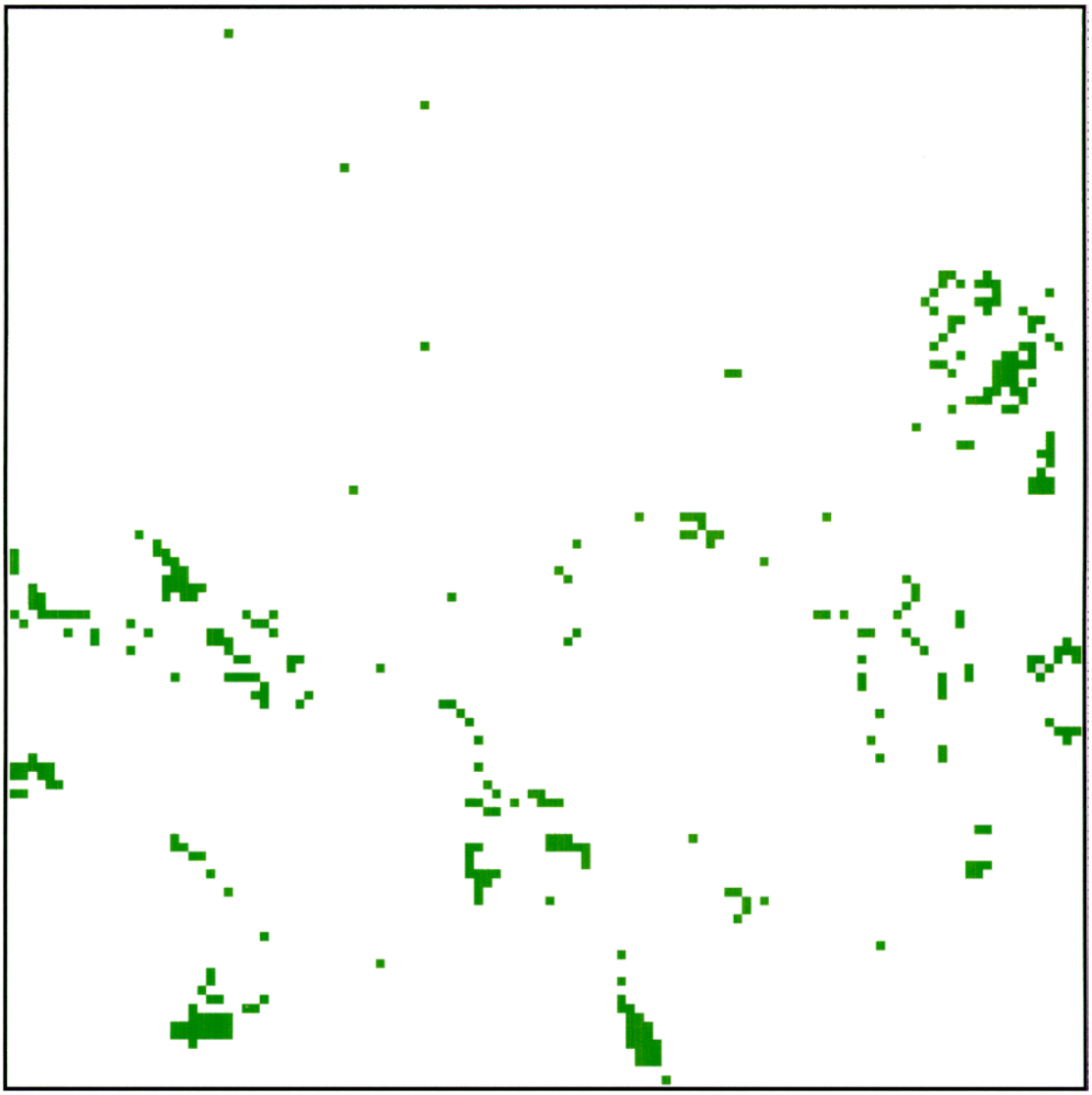


Figure 5-10.—The present distribution of wetland coniferous and deciduous midstory woody vegetation on the KWMA study area.

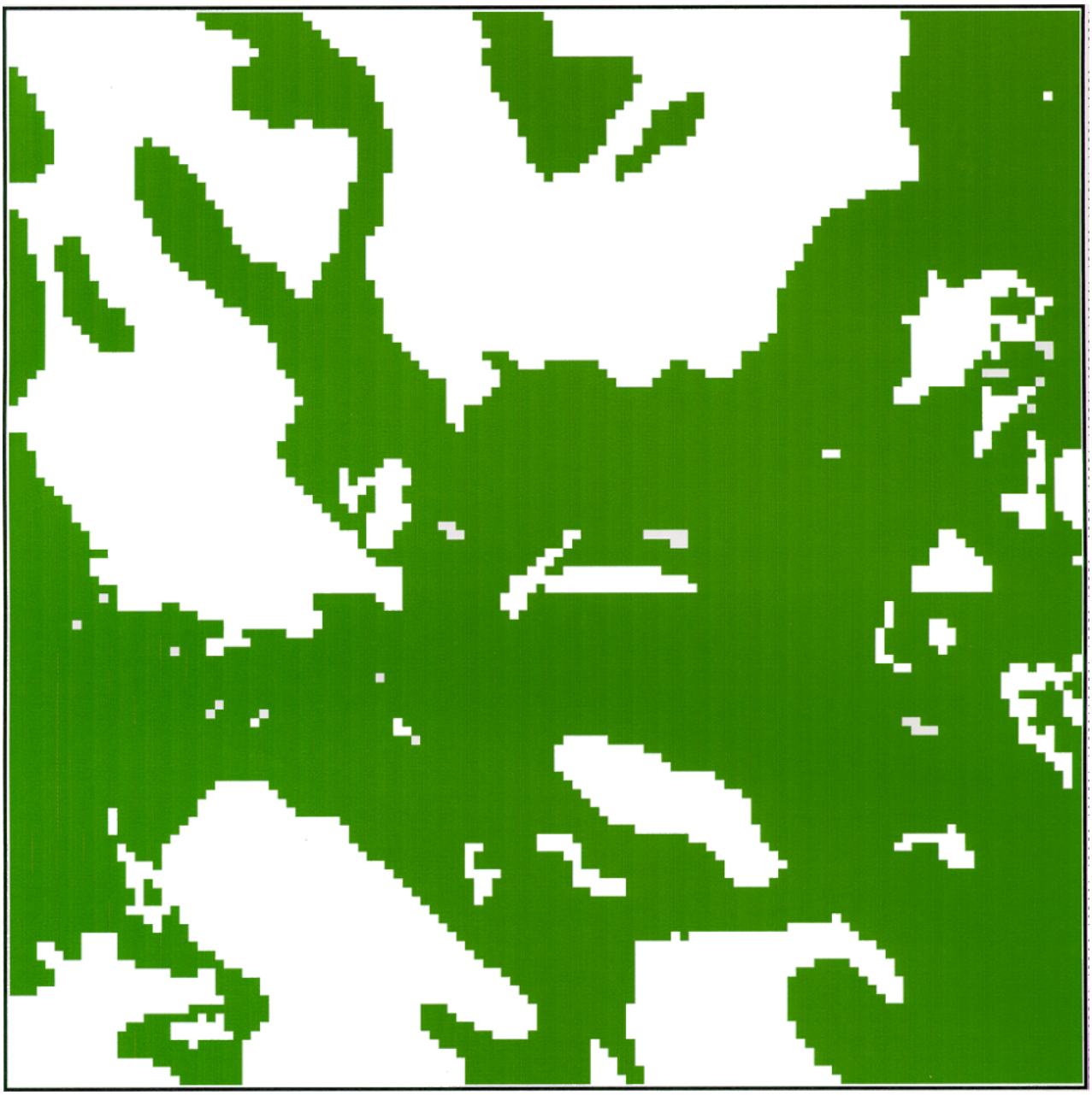


Figure 5-11.—The predicted distribution (management option B) of upland needleleaf evergreen tree climax vegetation on the KWMA study area as estimated from ELT classification data.

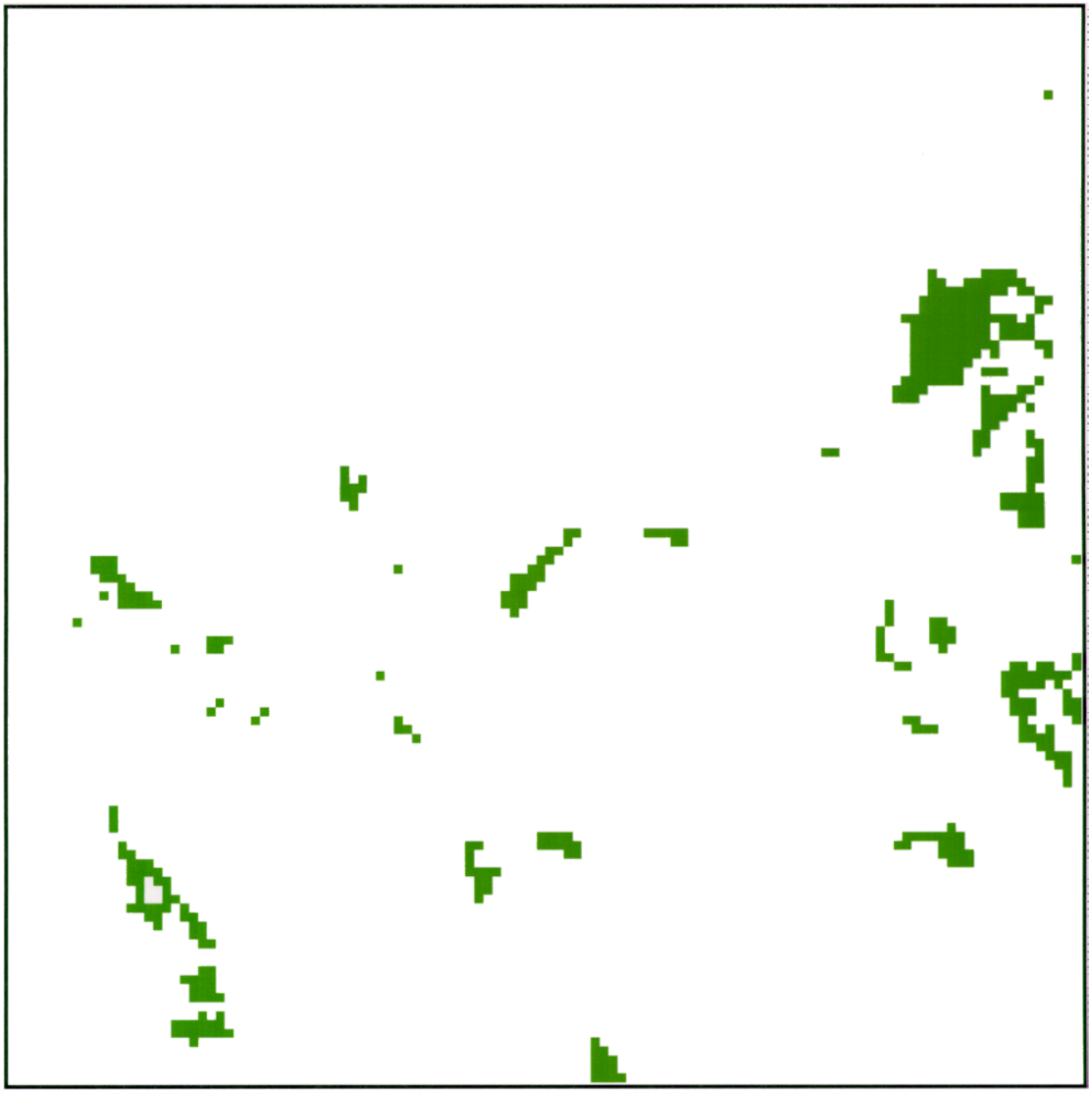


Figure 5-12.—The predicted distribution (management option B) of wetland needleleaf evergreen tree climax vegetation on the KWMA study area as estimated from ELT classification data.

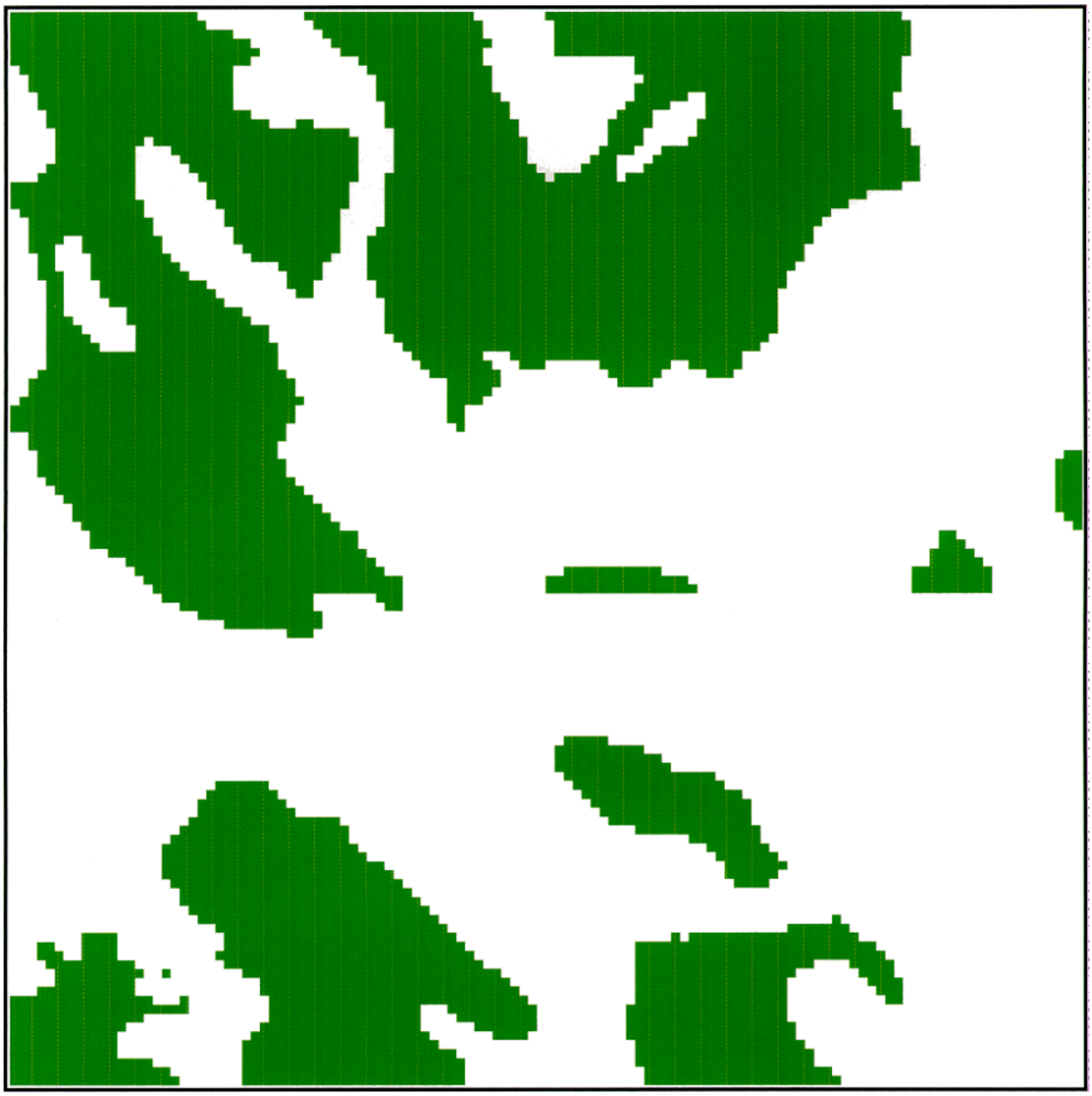


Figure 5-13.—The predicted distribution (management option B) of upland broadleaf deciduous tree climax vegetation on the KWMA study area as estimated from ELT classification data.

Figure 5-14.—The predicted distribution (management option B) of wetland broadleaf deciduous tree climax vegetation on the KWMA study area as estimated from ELT classification data.

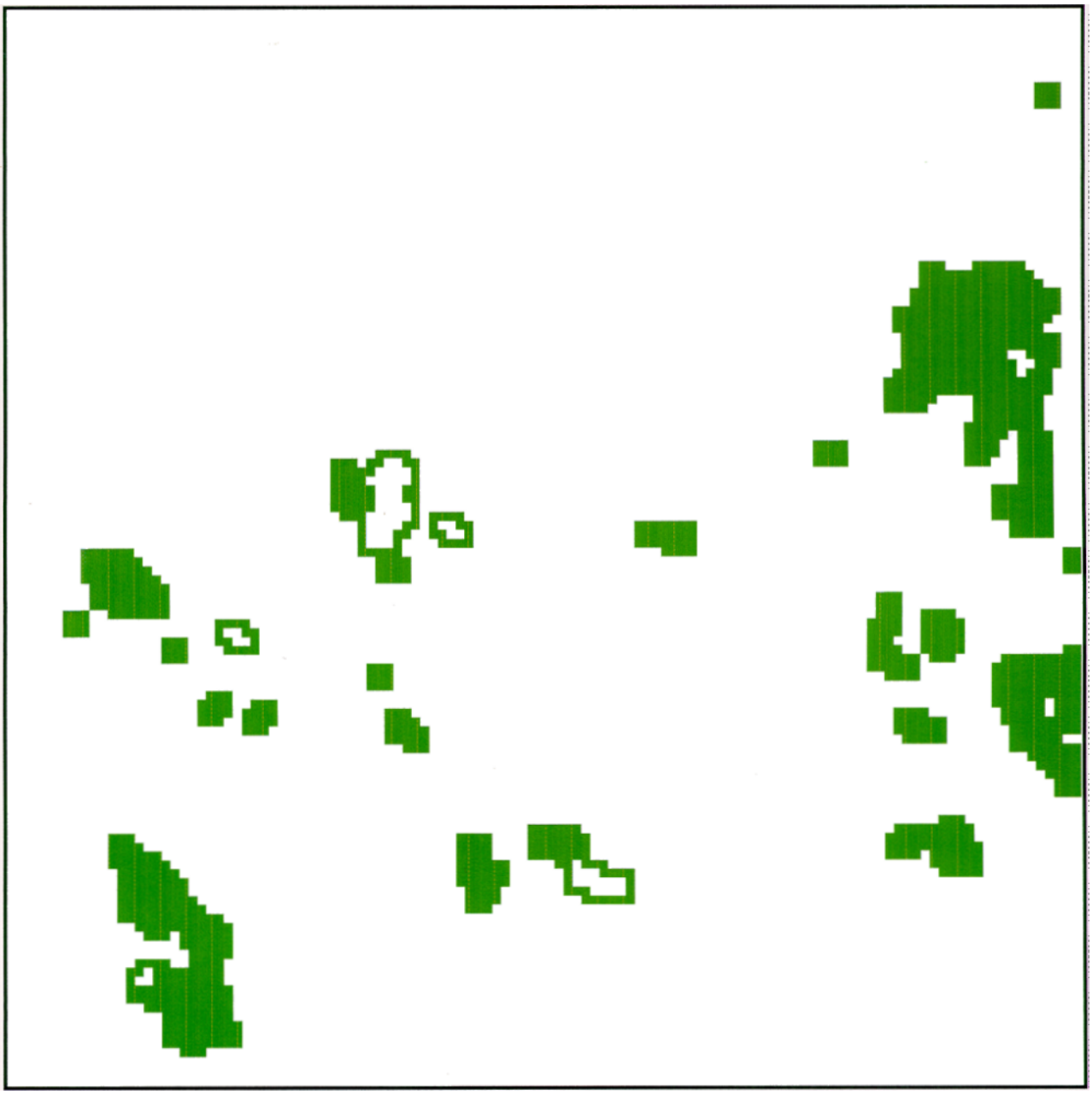


Figure 5-15.—The predicted distribution of habitat structures likely to occur on the KWMA study area under management option D. An extensive clearcut extends to within 50 m of seasonal, semi-permanent, and permanent wetland boundaries. Climax vegetation is retained within the wetland boundaries and within the 50-m border around the wetlands.

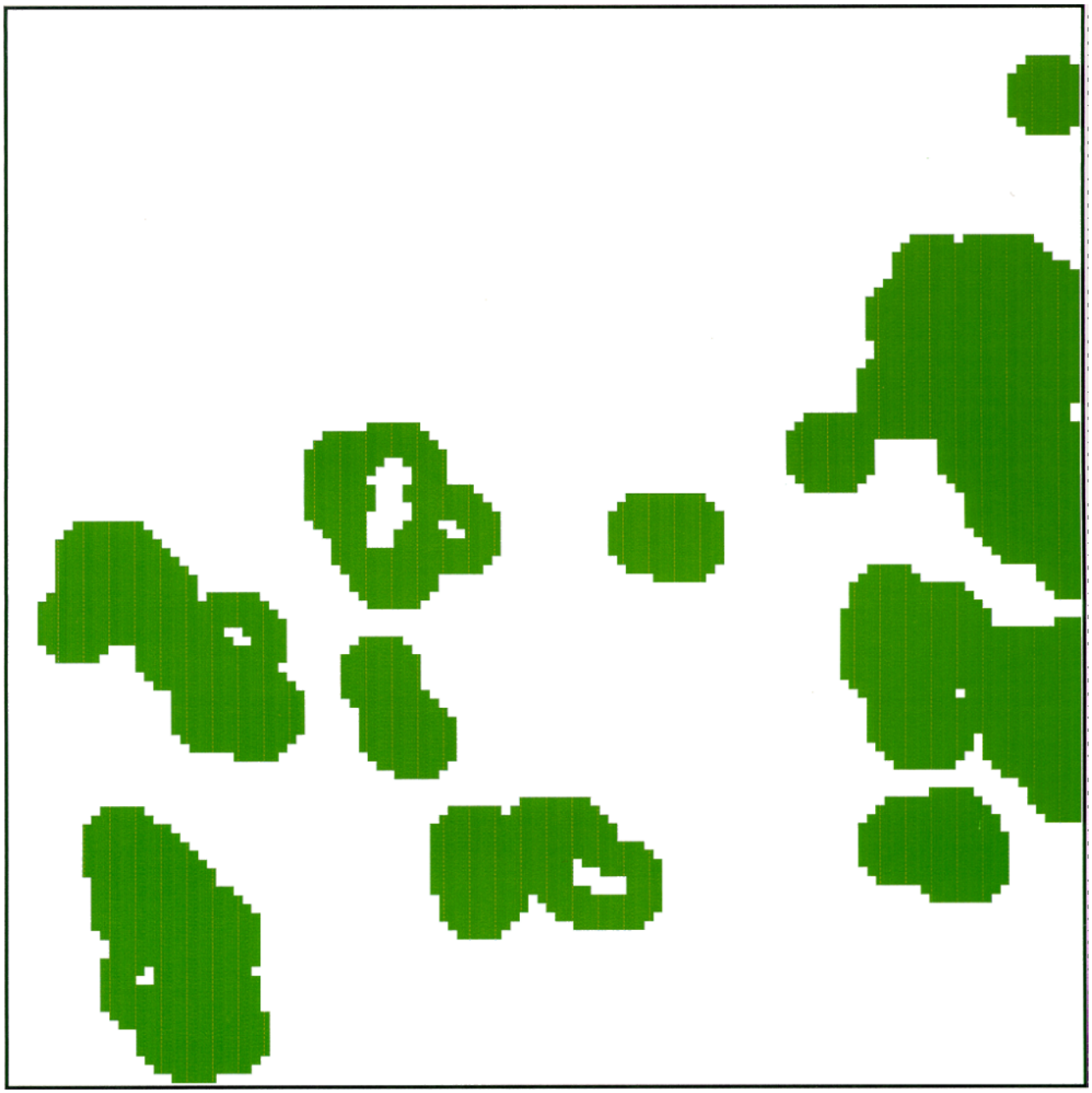


Figure 5-16.—The predicted distribution of habitat structures likely to occur on the KWMA study area under management option E. Conditions are similar to those in Figure 5-15 except that a 200-m upland border is retained around the wetlands.

Table 5.2—Areas of predicted habitat for wildlife species and species-habitat groups on the KWMA study area. Habitat areas are noted for present conditions (A) and four management options (B-E) defined in text. The group habitat area value will equal the species value if only a single species is present for a group. The species-habitat groups are those listed in Appendix C.

Species habitat group number	Group value and species within species - habitat group	Habitat (ha) under management option				
		A	B	C	D	E
1.	Group value	4,470.25	2,763.5	3,580.25	3,798.5	3,802.25
	Eastern chipmunk	3,094.25	1,483.0	0	37.25	149.25
	Hairy tailed mole	1,280.75	1,280.5	0	280.0	607.5
	Woodchuck	95.25	0	3,580.25	3,481.25	3,045.5
2.	Group value	7,169.5	7,169.5	7,169.5	7,169.5	7,169.5
	Coyote	3,584.75	3,584.75	3,584.75	3,584.75	3,584.75
	Red fox	3,584.75	3,584.75	3,584.75	3,584	3,584.75
4.	Bank swallow	0	0	3,270.5	3,270.5	3,270.5
5.	Group value	4,038.0	3,417.5	3,556.5	3,379.25	3,434.25
	Ovenbird	3,323.0	3,417.5	0	0.75	548.0
	Rufous-sided towhee	715.0	0	3,556.5	3,378.5	2,886.25
7.	Group value	16,993.25	15,672.75	0	107.0	1,449.0
	Black bear	3,584.75	3,584.75	0	0	51.0
	Bobcat	3,584.75	3,584.7	0	20.75	522.75
	Gray fox	3,584.75	3,584.75	0	86.25	766.25
	Lynx	3,584.75	3,584.75	0	0	51.0
	Ruffed grouse	2,654.25	1,333.75	0	0	58.0
10.	Whip-poor-will	197.75	0	0	0	0
11.	Peregrine falcon	3,584.75	3,584.75	3,584.70	3,584.75	3,584.75
13.	Group value	5,788.5	5,788.0	3,584.75	3,880.75	4,353.5
	Rock vole	2,203.75	2,203.25	0	296.0	768.75
	Striped skunk	3,584.75	3,584.75	3,584.75	3,584.75	3,584.75
14.	Porcupine	3,582.0	3,584.75	0	367.0	1,084.25
16.	Group value	1,113.25	1,920.0	0	11.25	460.5
	Black-billed cuckoo	850.0	0	0	0	0
	Solitary vireo	263.25	1,920.0	0	11.25	460.5
18.	Gray-cheeked thrush	535.25	2,158.5	0	50.75	656.25
21.	Group value	6,546.5	7,048.5	3,458.5	3,711.0	4,409.25
	European starling	20.0	0	0	0	0
	Mourning dove	3,555.5	3,561.5	0	272.25	937.0
	Northern flicker	2,971.0	3,487.0	3,458.5	3,438.7	3,472.25
22.	Group value	2,281.25	5,807.0	0	785.5	2,286.0
	Pine warbler	502.5	1,313.25	0	219.25	630.25
	Purple finch	1,243.5	2,335.25	0	515.5	999.5
	White-winged crossbill	535.25	2,158.5	0	50.75	656.25
29.	Bullfrog	186.0	186.0	186.0	186.0	186.0
30.	Group value	794.25	810.0	118.5	722.0	805.0
	Green frog	155.75	169.25	39.0	171.0	169.25
	Northern leopard frog	173.0	175.0	39.75	172.25	170.0
	Pickerel frog	465.5	465.75	39.75	378.75	465.75

Continued

Table 5.2—Continued

Species habitat group number	Group value and species within species - habitat group	Habitat (ha) under management option				
		A	B	C	D	E
31.	Group value	6,173.25	5,563.5	78.0	1,487.75	3,074.0
	Eastern American toad	2,649.5	2,653.5	39.0	366.25	905.5
	Jefferson salamander	431.0	431.5	0	338.0	418.25
	Red spotted newt	1,077.5	1,079.0	0	384.0	871.25
	Spotted salamander	718.25	100.0	0	36.75	91.5
	Wood frog	1,297.0	1,299.5	39.0	362.75	841.5
32.	Northern spring peeper	196.5	175.0	40.0	173.0	170.0
35.	Northern water thrush	81.5	98.75	0	91.25	91.75
36.	Group value	74.25	0	111.0	0	0
	Common snipe	54.75	0	80.25	0	0
	Swamp sparrow	19.5	0	30.75	0	0
37.	Water shrew	14.75	3.5	0	3.5	3.5
40.	Wilson's warbler	46.25	0	67.75	1.0	0
41.	Yellow-bellied flycatcher	24.25	148.0	0	135.75	137.0
42.	Muskrat	93.0	11.0	186.0	166.25	11.0
43.	Beaver	69.5	17.5	0	4.5	17.5
45.	Group value	29,209.75	24,339.25	14,272.25	16,427.5	18,379.75
	American woodcock	12.75	0	0	0	0
	Dark-eyed junco	2,335.75	0	3,556.5	3,521.0	3,062.75
	Eastern smooth green snake	3,199.75	1,489.5	25.0	33.25	118.5
	Hermit thrush	376.0	143.5	0	133.25	133.25
	Lincoln's sparrow	878.0	0	3,582.0	3,382.0	2,868.75
	Long tailed shrew	1,251.0	2,383.25	0	372.75	866.0
	Masked shrew	200.25	179.5	0	163.25	165.75
	Northern short-tailed shrew	399.0	9.0	25.0	15.5	11.75
	Pygmy shrew	59.0	31.25	0	33.25	31.25
	Red-back salamander	3,530.25	3,541.5	0	354.25	908.75
	Smoky shrew	3,535.25	3,541.5	0	356.25	911.5
	Snowshoe hare	3,583.75	3,584.75	0	382.75	961.0
	Southern red-backed vole	3,579.0	3,584.75	0	395.5	949.5
	White-footed mouse	3,584.5	3,584.75	3,551.25	3,574.25	3,580.25
	White-throated sparrow	2,056.5	25.25	3,532.5	3,473.5	3,074.0
	Winter wren	629.0	2,240.75	0	236.75	736.75
46.	Group value	3,592.25	3,584.75	98.75	531.75	1,059.0
	Eastern garter snake	3,584.75	3,584.75	98.75	531.75	1,059.0
	Spotted salamander	7.5	0	0	0	0
48.	American black duck	57.5	0	57.0	6.0	0
49.	Group value	4,082.5	3,591.0	382.0	688.0	1,798.0
	Common yellowthroat	90.5	0	382.0	244.75	158.75
	Mourning warbler	332.25	0	0	0	0
	Veery	75.0	6.25	0	6.25	6.25
	White-tailed deer	3,584.75	3,584.75	0	437.0	1,633.0
50.	Moose	3,600.0	3,600.0	0	91.25	1,387.75

Continued

Table 5.2—Continued

Species habitat group number	Group value and species within species - habitat group	Habitat (ha) under management option				
		A	B	C	D	E
51.	Group value	3,928.0	1,343.0	0	30.0	153.5
	Black-and-white warbler	2,132.5	1,341.75	0	8.5	66.0
	Black-throated blue warbler	9.75	1.25	0	1.25	1.25
	Chestnut-sided warbler	724.75	0	0	0	0
	Nashville warbler	869.0	0	0	0	0
	Tennessee warbler	192.0	0	0	20.25	86.25
52.	Spruce grouse	181.75	2,007.75	0	118.75	567.25
53.	Canada warbler	3,584.75	3,584.75	0	398.75	966.0
54.	Group value	7,615.0	7,349.0	7,714.75	8,497.75	8,456.5
	Deer mouse	3,580.0	3,584.75	0	588.25	1,149.0
	Meadow jumping mouse	131.75	0	3,556.25	3,351.5	2,856.25
	Meadow vole	72.25	0	3,584.75	3,386.75	2,875.5
	Southern bog lemming	246.75	179.5	246.75	309.0	223.0
	Woodland jumping mouse	3,584.25	3,584.75	327.0	862.25	1,352.75
55.	Group value	7,169.5	7,169.5	0	894.75	2,031.0
	Ermine	3,584.75	3,584.75	0	224.5	773.75
	Long tailed weasel	3,584.75	3,584.75	0	670	1,257.25
56.	Mink	17.75	2.0	0	4.0	2.25
58.	Fisher	3,487.5	3,584.75	0	0	51.0
64.	Chipping sparrow	1,297.25	15.0	3,582.0	3,512.5	3,080.25
65.	Gray catbird	2,064.0	0	0	489.25	615.5
66.	Group value	4,441.75	8,594.5	0	899.75	2,573.5
	Black-backed woodpecker	994.25	2,544.75	0	368.25	972.25
	Boreal chickadee	948.0	2,469.75	0	359.75	900.75
	Brown creeper	2,499.5	3,580.0	0	171.75	700.5
67.	Group value	3,080.0	2,187.25	0	641.75	1,359.25
	Rose-breasted grosbeak	2,497.75	23.75	0	570.75	693.75
	Swainson's thrush	582.25	2,163.5	0	71.0	665.5
68.	Group value	1,674.25	0	3,584.5	3,426.5	2,971.0
	Least flycatcher	952.25	0	0	27.25	96.0
	Willow flycatcher	722.0	0	3,584.5	3,399.25	2,875.0
69.	Tree swallow	0	0	252.5	252.5	252.5
70.	Eastern bluebird	1,116.5	0	0	1.75	0
71.	Eastern phoebe	450.5	0	0	20.25	86.25
72.	Rusty blackbird	102.0	167.0	4.5	155.0	156.0
74.	Alder flycatcher	29.25	0	0	0	0
76.	Red-winged blackbird	139.0	0	25.0	5.5	2.75
78.	Group value	1,814.25	5.0	7,138.5	6,887.25	5,955.25
	Indigo bunting	603.5	0	3,556.5	3,492.0	3,052.5

Continued

Table 5.2—Continued

Species habitat group number	Group value and species within species - habitat group	Habitat (ha) under management option				
		A	B	C	D	E
	Song sparrow	1,210.75	5.0	3,582.0	3,395.25	2,902.75
79.	Magnolia warbler	142.5	0	0	480.25	536.75
81.	Group value	6,169.25	7,169.5	0	52.25	807.0
	Barred owl	2,584.5	3,584.75	0	8.5	257.0
	Great-horned owl	3,584.75	3,584.75	0	43.75	550.0
83.	Wood duck	123.75	193.0	0	184.75	188.0
85.	Evening grosbeak	1,147.75	2,412.75	0	359.0	876.75
89.	Northern goshawk	3,584.75	3,584.75	0	0	149.25
90.	Common raven	3,584.75	3,584.75	0	213.5	1,288.0
94.	Group value	12,104.5	12,121.25	0	413.75	1,721.0
	American crow	3,584.25	3,584.75	0	355.75	1,115.75
	Broad-winged hawk	2,584.5	3,584.75	0	8.5	257.0
	Common grackle	167.5	23.75	0	31.5	23.75
	Northern saw-whet owl	3,584.75	3,584.75	0	8.5	257.0
	Wood thrush	2,183.5	1,343.25	0	9.5	67.5
97.	American robin	3,579.75	3,584.75	0	395.5	949.5
98.	Blackburnian warbler	533.0	2,238.5	0	258.25	750.0
99.	Group value	36,702.5	38,228.5	0	4,295.25	11,027.5
	Bay-breasted warbler	603.0	2,240.75	0	235.5	732.5
	Black-capped chickadee	3,584.5	3,584.75	0	385.25	983.75
	Black-throated green warbler	533.0	2,238.5	0	258.25	750.0
	Cape May warbler	1,147.75	2,412.75	0	359.0	876.75
	Cedar waxwing	1,848.25	23.0	0	335.25	408.25
	Downy woodpecker	3,584.0	3,584.75	0	603.75	1,163.75
	Golden-crowned kinglet	205.5	2,089.0	0	167.75	615.5
	Hairy woodpecker	3,434.25	3,584.75	0	382.75	961.0
	Northern oriole	954.0	0	0	20.75	86.5
	Northern parula	432.75	2,240.75	0	235.5	732.5
	Philadelphia vireo	2,155.25	0	0	0.25	3.75
	Pileated woodpecker	3,539.0	3,584.75	0	124.75	700.25
	Scarlet tanager	3,434.25	3,584.75	0	382.75	961.0
	Red-breasted nuthatch	986.5	2,412.75	0	359.0	876.75
	Red-eyed vireo	3,179.0	1,489.5	0	28.0	115.75
	White-breasted nuthatch	2,720.25	1,569.75	0	18.0	106.75
	Yellow-bellied sapsucker	3,353.25	3,584.75	0	395.5	949.5
	Yellow warbler	1,008.0	3.25	0	3.25	3.25
100.	Group value	15,743.25	17,924.75	0	3,099.75	6,555.25
	American goldfinch	640.5	6.75	0	11.25	6.75
	Blue jay	3,584.75	3,584.75	0	655.5	1,255.25
	Gray jay	1,163.25	2,544.75	0	368.25	972.25
	Northern flying squirrel	3,317.75	3,541.5	0	354.25	908.75
	Pine siskin	1,670.75	2,383.25	0	560.5	1,044.0
	Ruby-crowned kinglet	1,318.0	2,238.5	0	258.25	750.0
	Ruby-throated hummingbird	695.0	40.5	0	496.25	668.75

Continued

Table 5.2—Continued

Species habitat group number	Group value and species within species - habitat group	Habitat (ha) under management option				
		A	B	C	D	E
	Southern flying squirrel	3,353.25	3,584.75	0	395.5	949.5
101.	Group value	14,102.0	10,800.0	0	7,750.0	12,003.25
	Big brown bat	3,600.0	3,600.0	0	540.5	1,735.25
	Eastern kingbird	1,263.5	0	0	8.75	46.25
	Eastern pipistrelle	683.75	0	0	2,761.0	2,898.0
	Hoary bat	3,600.0	3,600.0	0	515.0	1,719.0
	Little brown myotis	683.75	0	0	2,761.0	2,898.0
	Northern long-eared bat	671.0	0	0	648.75	987.75
	Red bat	3,600.0	3,600.0	0	515.0	1,719.0
102.	American kestrel	13.25	0	3,584.75	3,558.0	3,137.75
103.	Group value	8,925.5	7,518.75	0	1,037.5	2,293.0
	American redstart	1,128.0	3.25	0	24.75	93.0
	Eastern wood-pewee	3,457.75	3,584.75	0	603.75	1,163.75
	Great crested flycatcher	3,264.25	1,517.0	0	43.5	154.25
	Olive-sided flycatcher	1,075.5	2,413.75	0	365.5	882.0
104.	Yellow-rumped warbler	1,147.75	2,412.75	0	359.0	876.75
105.	Red squirrel	3,353.25	3,584.75	0	395.5	949.5
108.	Great blue heron	532.0	535.5	0	306.75	511.75
111.	Brown-headed cowbird	3,584.5	3,584.75	25.0	401.5	952.75
113.	Raccoon	87.0	0	0	284.5	47.25
		261,949.75	256,531.5	69,713.5	100,912.25	137,981.0

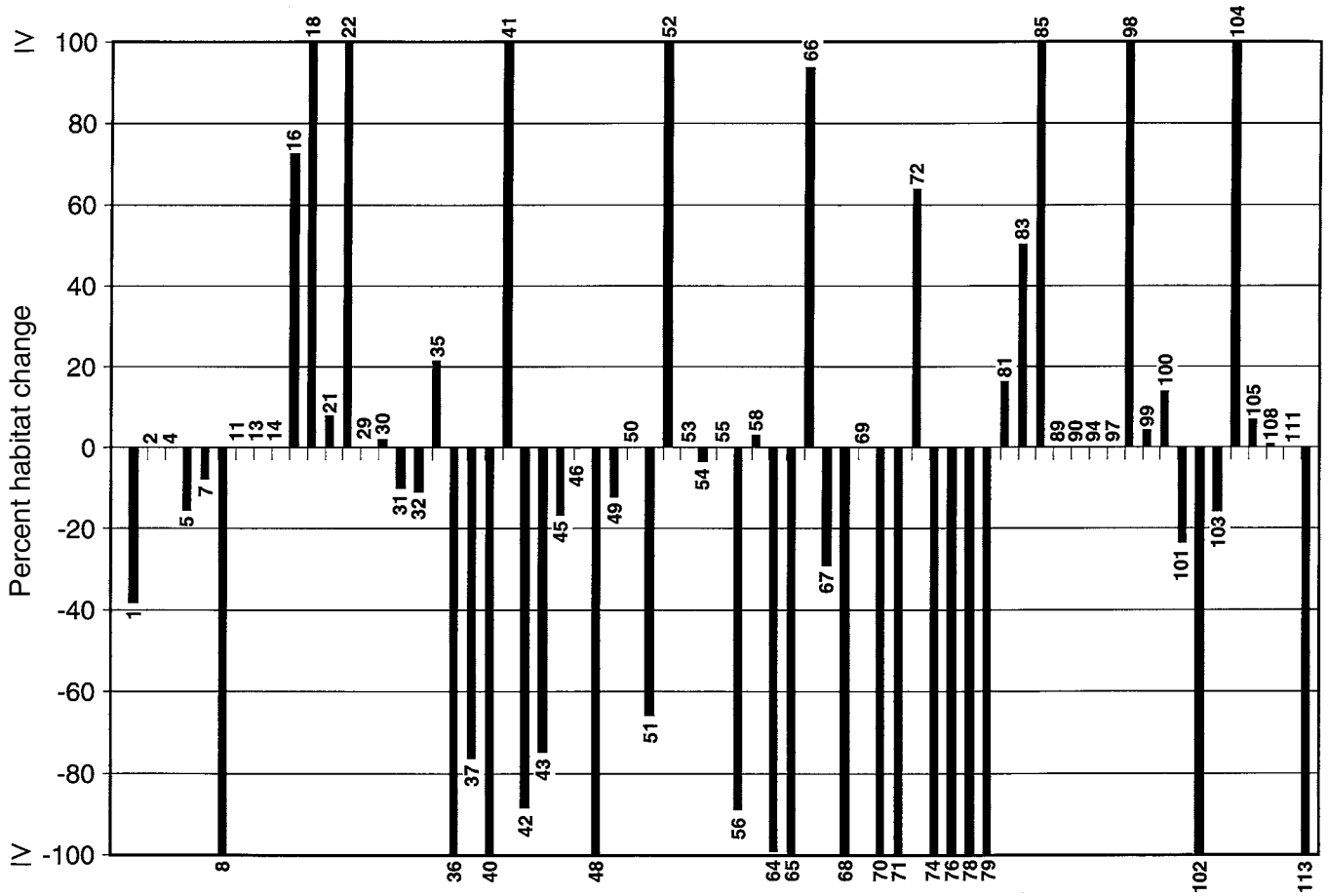


Figure 5-17.—A species-habitat group profile for the KWMA study area that compares predicted areas of habitat if a climax forest condition exists (option B), with those under the present managed forest condition (option A). Bars indicate the direction and magnitude with which predicted habitat areas under option B differ from habitat areas predicted under option A. Numbers at the end of each bar identify the individual species-habitat group. Data from Table 5-2.

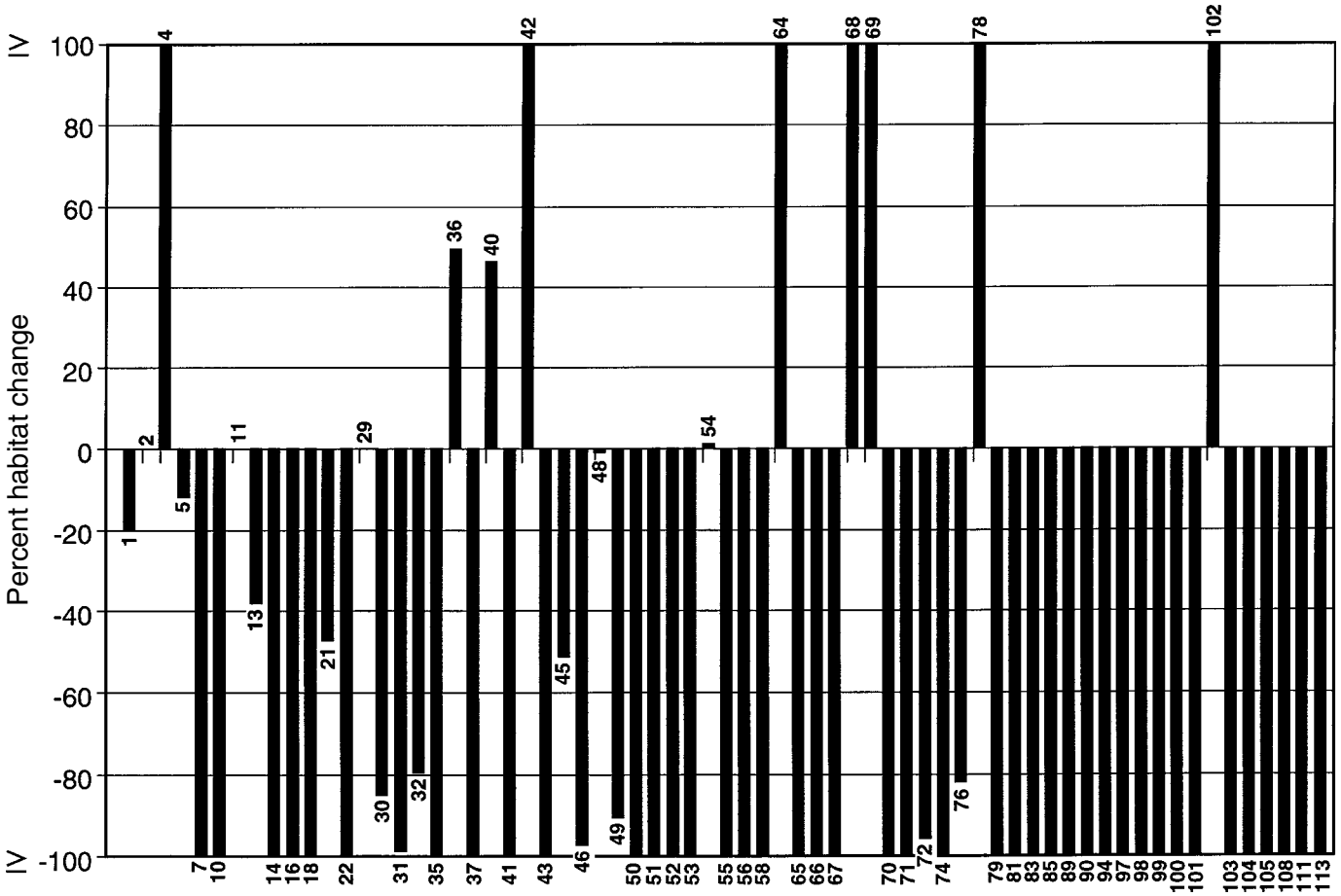


Figure 5-18.—A species-habitat group profile for the KWMA study area that compares predicted areas of habitat if the area is completely clearcut (option C), with those under the present managed forest condition (option A). Bars indicate the direction and magnitude with which predicted habitat areas under option C differ from habitat areas predicted under option A. Numbers at the end of each bar identify the individual species-habitat group. Data from Table 5-2.

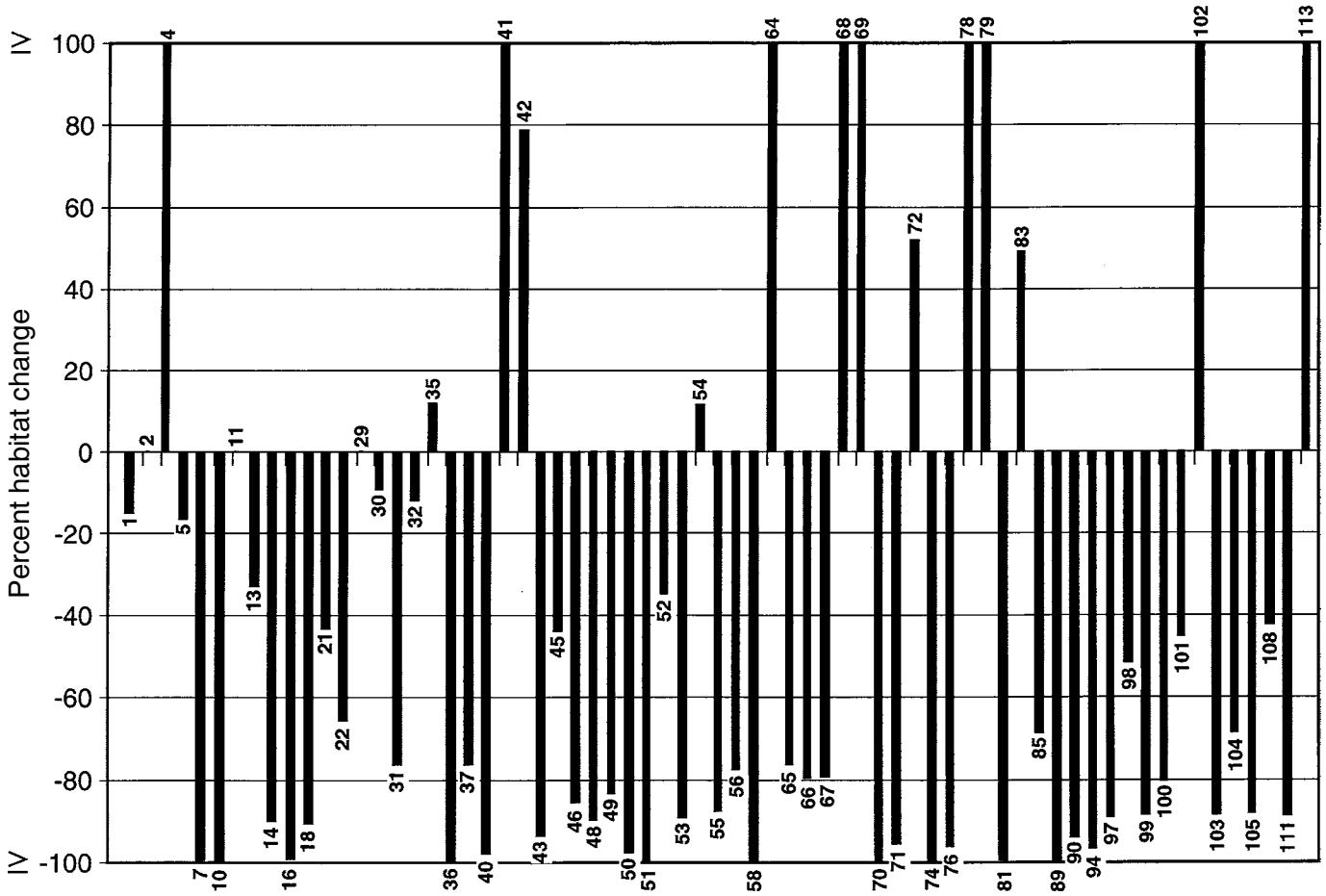


Figure 5-19.—A species-habitat group profile for the KWMA study area that compares predicted areas of habitat, if the area is clearcut to within 50 m of all seasonal, semi-permanent and permanent wetlands on the study area (option D), with those under the present managed forest condition (option A). Bars indicate the direction and magnitude with which predicted habitat areas under option D differ from habitat areas predicted under option A. Numbers at the end of each bar identify the individual species-habitat group. Data from Table 5-2.

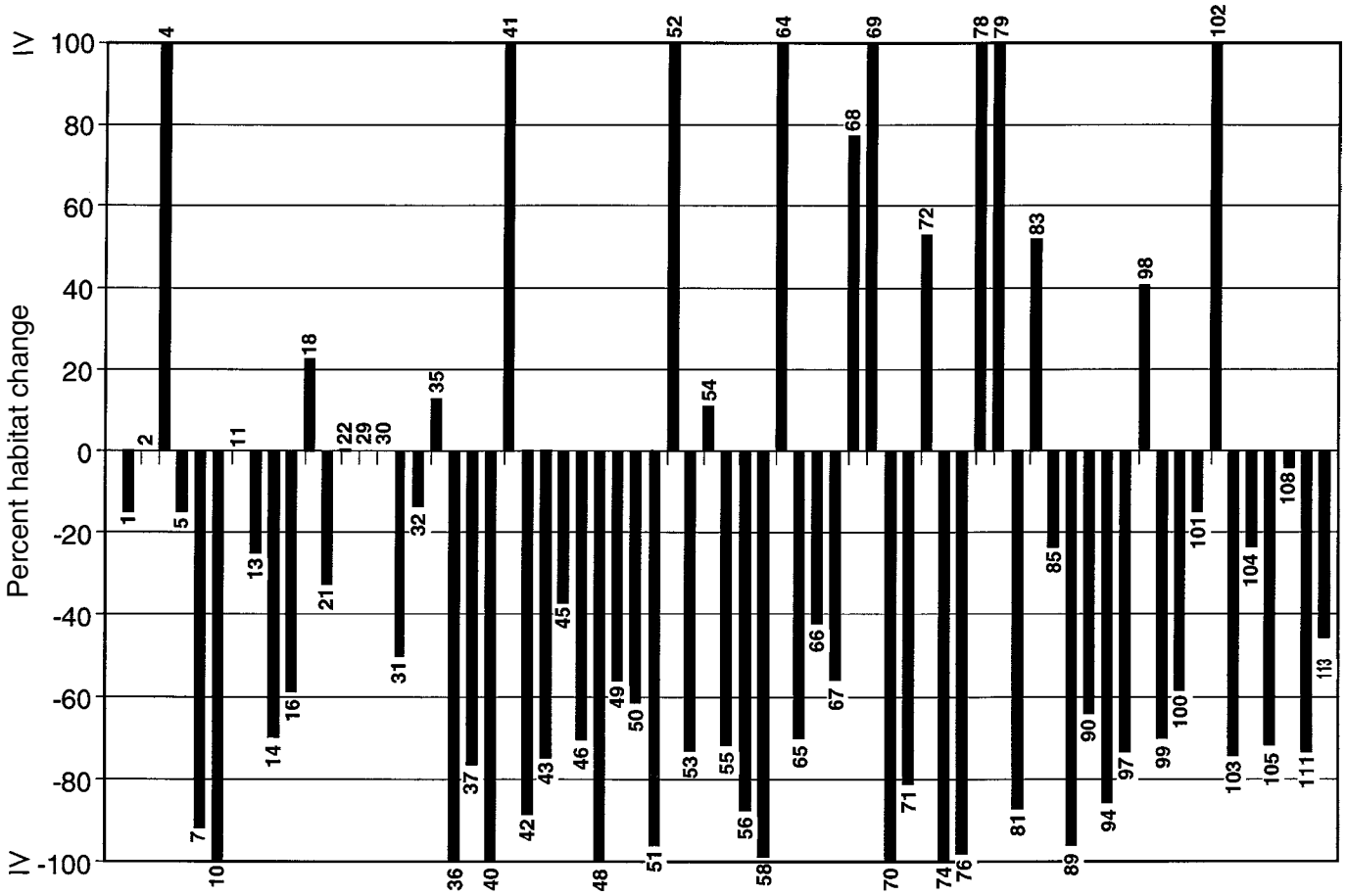


Figure 5-20.—A species-habitat group profile for the KWMA study area that compares predicted areas of habitat is the area is clearcut to within 200 m of all seasonal, semi-permanent, and permanent wetlands on the study area (option E), with those under the present managed forest condition (option A). Bars indicate the direction and magnitude with which predicted habitat areas under option E differ from habitat areas predicted under option A. Numbers at the end of each bar identify the individual species-habitat group. Data from Table 5-2.

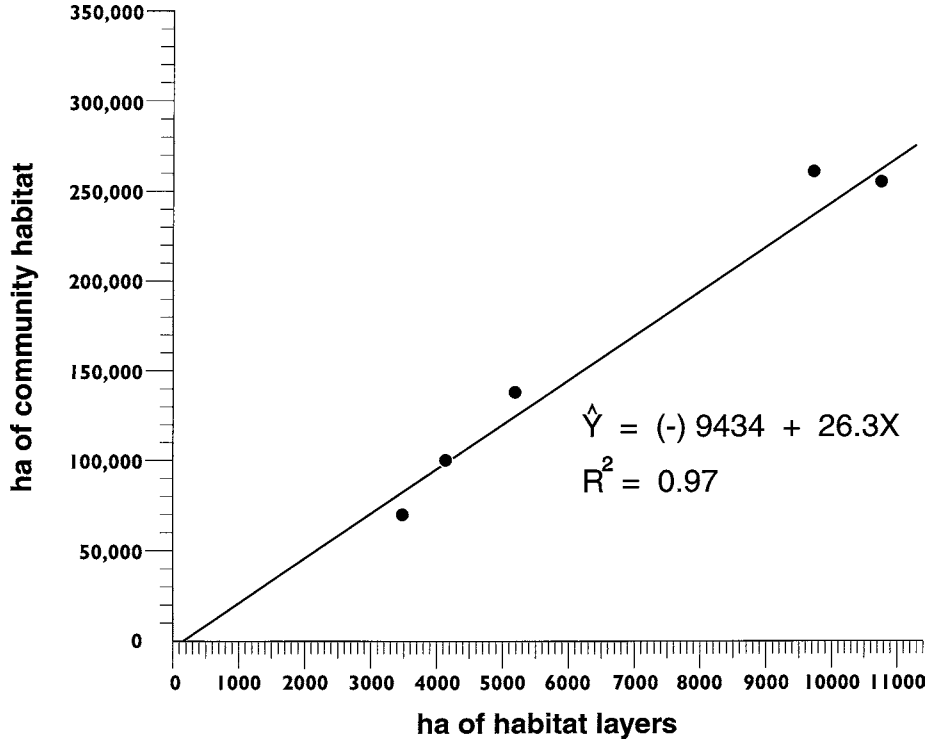


Figure 5-21.—The predicted relationship between habitat volume, represented by area of habitat layers, and area of community habitat on the KWMA. About 26 ha of community habitat is gained or lost for every ha of habitat layer that is gained or lost.

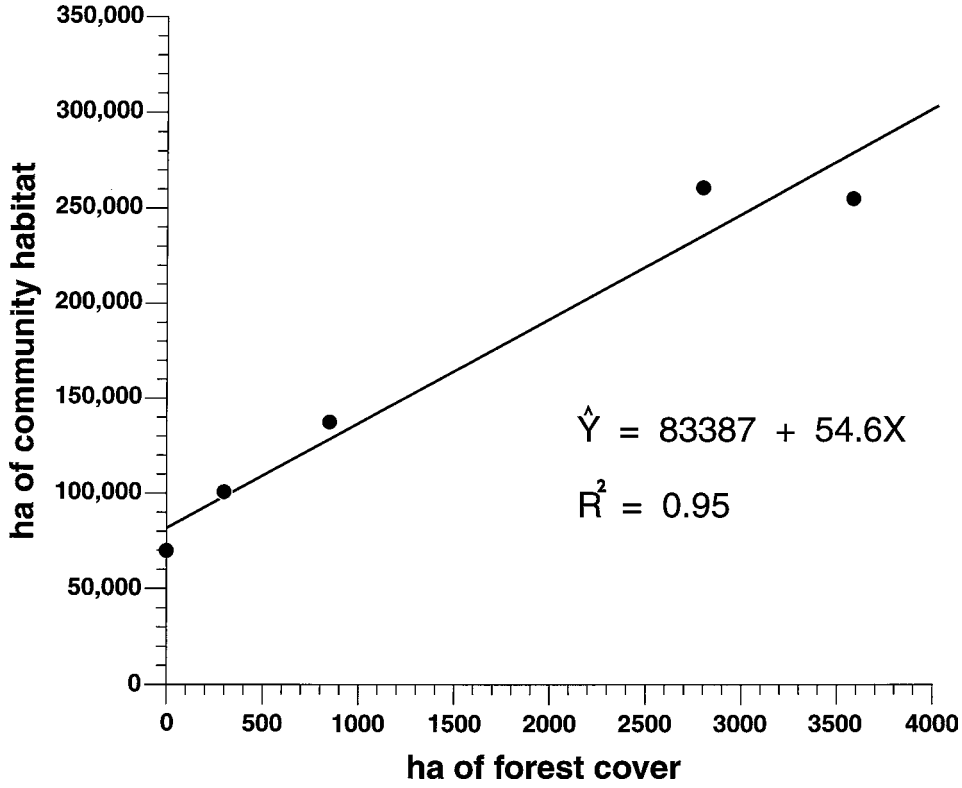


Figure 5-22.—The predicted relationship between areas of forest cover and area of community habitat on the KWMA. About 54 ha of community habitat is gained or lost for every ha of forest cover that is gained or lost.

Literature Cited

Allen, T.F.H.; Hoekstra, T.W. 1992. **Toward a unified ecology.** New York, NY: Columbia University Press. 384 p.

Brown, E.R., tech. ed. 1985. **Management of wildlife and fish habitats in forests of western Oregon and Washington.** R6-F&WL-192, Part 2. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 302 p.

Christensen, N.L. (Chair); Bartuska, A.M.; Brown, J.H.; Carpenter, S.; D'Antonio, C.; Francis, R.; Franklin, J.F.; MacMahon, J.A.; Noss, R.F.; Parsons, D.J.; Peterson, C.H.; Turner, M.G.; Woodmansee, R.G. 1996. **The report of the Ecological Society of America committee on the scientific basis for ecosystem management.** Ecological Applications. 6: 665-691.

Cody, M.L. 1974. **Competition and the structure of bird communities.** Monograph of Population Ecology 7. Princeton, NJ:Princeton University Press. 318 p.

Cody, M.L. 1975. **Towards a theory of continental species diversity: bird distributions over Mediterranean habitat gradients.** In: Cody, M.L.; Diamond, J.M., eds.. Ecology and evolution of communities. Cambridge, MA.:Havard University Press: 214-215.

Cody, M.L. 1985. **An introduction to habitat selection in birds.** In: Cody, M.L., ed. Habitat selection in birds. Orlando, FL: Academic Press: 3-56.

Cowardin, L.M.; Carter, V.; Golet, F.C.; LaRoe, E.T. 1979. **Classification of wetlands and deepwater habitats of the United States.** FWS/OBS-79/31. Washington, D.C.:U.S. Fish and Wildlife Service, Biological Services Program. 131 p.

DeGraaf, R.M.; Angelstam, P. 1993. **Effects of timber size-class on predation of artificial nests in extensive forest.** Forest Ecology and Management. 61: 127-136.

DeGraaf, R.M.; Hestbeck, J.B.; Yamasaki, M. 1998. **Associations between breeding bird abundance and stand structure in the White Mountains, New Hampshire and Maine, USA.** Forest Ecology and Management. 103: 217-233.

DeGraaf, R.M.; Rudis, D.D.. 1986. **New England wildlife: habitat, natural history, and distribution.** Gen. Tech. Rep. NE-108. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 491 p.

DeGraaf, R.M.; Yamasaki, M.; Leak, W.B.; Lanier, J.W. 1992. **New England wildlife: management of forested habitat.** Gen. Tech. Rep. NE-144. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 271 p.

Dwyer, T.J.; Sepik, G.F.; Derleth, E.L.; McAuley, D.G. 1988. **Demographic characteristics of a Maine woodcock population and effects of habitat management.** Fish and Wildl. Res. 4. Washington D.C.: U.S. Fish and Wildlife Service. 29 p.

Environmental Systems Research Institute. 1992. **Cell-based modeling with GRID™, Version 6. 2nd ed.** Redlands, CA: Environmental Systems Research Institute.

Geibert, E.H. 1979. **Songbird diversity along a powerline right-of-way in an urbanizing Rhode Island environment.** Transactions Northeast Section Wildlife Society. 36: 32-44.

Giorgi, K.S.H. 1999. **Evaluation of ECOSEARCH: A wildlife-habitat model for predicting species occurrence.** Amherst, MA: University of Massachusetts. 71 p. M.S. thesis.

Heatwole, H. 1982. **A review of structuring in herptofaunal assemblages.** In: Scott, N.J., ed. Herpetological communities. Wildl. Res. Rept. 13. Washington, D.C.: U.S. Fish and Wildlife Service: 1-19.

Helle, P. 1985. **Habitat selections of breeding birds in relation to forest succession in northeastern Finland.** Ornis Fennica. 62: 113-123.

Hilden, O. 1965. **Habitat selection in birds.** Annales Zoologici Fennica. 2: 53-75.

International Business Machines. 1984. **IBM Personal computer: Professional FORTRAN.** Boca Raton, FL: Ryan-McFarland Corporation.

Lack, D. 1933. **Habitat selection in birds.** Journal of Animal Ecology. 2: 239-262.

Lack, D. 1971. **Ecological isolation in birds.** Blackwell, Oxford, UK: Blackwell Scientific Publisher: 404 p.

Longcore, J.R.; Sepik, G.F. 1993. **Proceedings of the eighth American woodcock symposium.** Biol. Rep. 16. Washington, D.C.: U.S. Fish and Wildlife Service. 139 p.

MacArthur, R.H.; MacArthur, J. 1961. **On bird species diversity.** Ecology. 42: 594-598.

MacArthur, R.H.; MacArthur, J.W.; Preer, J. 1962. **On bird species diversity: II. Prediction of bird census from habitat measurements.** American Naturalist. 96(888): 167-174.

Maser, C.; Mate, B.R.; Franklin, J.F.; Dryness, C.T. 1981. **Natural history of Oregon coast mammals.** Gen. Tech. Rep. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 496 p.

McAuley, D.G.; Longcore, J.R.; Sepik, G.F.; Pendleton. G.W. 1996. **Habitat characteristics of American woodcock**

nest sites on a managed area in Maine. Journal of Wildlife Management. 60(1): 138-148.

Mengel, R. 1964. **Species formation in wood warblers.** Living Bird. 3: 9-43.

National Wetlands Inventory. 1990. **Photointerpretation conventions for the National Wetlands Inventory.** St. Petersburg, FL: U.S. Fish and Wildlife Service. 45 p. +appendices.

National Wetlands Inventory. 1992. **Digitizing conventions for the National Wetlands Inventory.** St. Petersburg, FL: U.S. Fish and Wildlife Service. 22 p. +attachments.

Rabenold, K.N. 1978. **Foraging strategies, diversity, and seasonality in bird communities of Appalachian spruce-fir forests.** Ecological Monographs. 48: 397-424.

Roth, R.R. 1976. **Spatial heterogeneity and bird species diversity.** Ecology. 57: 773-782.

Short, H.L. 1983. **Wildlife guilds in Arizona desert habitats.** Tech. Note 362. Washington, DC: U.S. Department of the Interior, Bureau of Land Management. 258 p.

Short, H.L. 1985. **Management goals and habitat structure.** In: Johnson, R.R.; Zieball, C.D.; Patton, D.R., tech. coords. Riparian ecosystems and their management: reconciling conflicting uses. Gen. Tech. Rep. RM-120. First North American Riparian Conference. U.S.Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 257-262.

Short, H.L. 1992. **Use of the habitat linear appraisal system to inventory and monitor the structure of habitats.** In: McKenzie, D.H.; Hyatt, D. E.; McDonald, V. J., eds. Ecological indicators, Vol. 2. New York, NY: Elsevier Applied Science: 961-974.

Short, H.L.; Hestbeck, J.B.; Tiner, R.W. 1996. **ECOSEARCH: a new paradigm for evaluating the utility of wildlife habitat.** In: DeGraaf, R.M.; Miller, R.I., (eds). Conservation of faunal diversity in Forested Landscapes. New York, NY: Chapman & Hall: 569-594.

Smith, G.S. 1991. **NWI maps made easy.** A user's guide to National Wetlands Inventory maps of the Northeast Region. Newton Corner, MA: U.S. Fish and Wildlife Service.

Straw, J.A. Jr.; Krementz, D.G.; Olinde, M.W.; Sepik, G.F. 1994. **American woodcock.** In: Tacha, T.C.; Braun, C.E., eds. Migratory shore and upland game bird management in North America. Washington, D.C.: International Association of Fish and Wildlife Agencies: 97-114.

Swenson, E.I. 1981. **Soil survey of Hampshire County, Massachusetts, Central Part.** Washington, D.C.: U.S.Department of Agriculture, Soil Conservation Service. 172. p. +maps.

Swenson, E.I. 1989. **Soil survey of Hampden and Hampshire counties, Massachusetts, Eastern Part.** Washington, D.C.: U.S.Department of Agriculture, Soil Conservation Service. 174 p. +maps.

Thomas, J.W., tech. ed. 1979. **Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington.** Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture. 512 p.

U.S.Geological Survey. 1990. **Digital elevation models. Data users guide, 5.** Reston, VA: National Mapping Program.

Verner, J.; Boss, A.S. tech. eds. 1980. **California wildlife and their habitats: western Sierra Nevada.** Gen. Tech. Rep. PSW-37. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 439 p.

Willson, M.F. 1974. **Avian community organization and habitat structure.** Ecology. 55: 1017-1029.

Short, Henry L.; Hestbeck, Jay B.; DeGraaf, Richard M. 2001. **New England wildlife: a model for ecosystem management – ECOSEARCH (Version 1).** Gen. Tech. Rep. NE-283. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. [CD-ROM].

This volume describes how ECOSEARCH species-habitat models are developed using information about the natural history of species, habitat descriptions, and specific descriptors for soils, topography, water regimes, and vertical habitat structure. Also, examples are provided that demonstrate the impacts of: 1) converting a wooded swamp into a recreational lake with adjoining golf course and housing lots in western Massachusetts; 2) converting a mature forest to earlier successional stages for woodcock management on a National Wildlife Refuge; and 3) varying logging practices on a national forest. ECOSEARCH was developed as a first step to a testable, scientific basis for ecosystem management. ECOSEARCH uses a FORTRAN program to predict occurrence for >300 species of New England wildlife using natural history models and information contained in geographic-information matrices. ECOSEARCH is based on the assumptions that many wildlife species are associated with certain habitat attributes that can be estimated from vegetative structure, water regimes, soil types, and topographic conditions. The challenge of predicting species occurrences is to discover the constraints that structure particular ecosystems.

Keywords: ecosystem management, New England wildlife

Headquarters of the Northeastern Research Station is in Newtown Square, Pennsylvania. Field laboratories are maintained at:

Amherst, Massachusetts, in cooperation with the University of Massachusetts

Burlington, Vermont, in cooperation with the University of Vermont

Delaware, Ohio

Durham, New Hampshire, in cooperation with the University of New Hampshire

Hamden, Connecticut, in cooperation with Yale University

Morgantown, West Virginia, in cooperation with West Virginia University

Parsons, West Virginia

Princeton, West Virginia

Syracuse, New York, in cooperation with the State University of New York, College of Environmental Sciences and Forestry at Syracuse University

Warren, Pennsylvania

The U. S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact the USDA's TARGET Center at (202)720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue SW, Washington, DC 20250-9410, or call (202)720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.

"Caring for the Land and Serving People Through Research"