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MODELING THE EFFECTS OF CONSERVATION RESERVE PROGRAM LANDS ON THE DIVERSITY AND ABUNDANCE OF WILDLIFE AND PLANT SPECIES IN A TEMPERATE AGRO-ECOSYSTEM

By

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ABSTRACT

MODELING THE EFFECTS OF CONSERVATION RESERVE PROGRAM LANDS ON THE DIVERSITY AND ABUNDANCE OF WILDLIFE AND PLANT SPECIES IN A TEMPERATE AGRO-ECOSYSTEM

By

Richard B. Minnis

The Conservation Reserve Program (CRP) provides the opportunity to model changes in wildlife and plant species composition in agricultural landscapes when land use practices are altered. Avian, mammalian, invertebrate, and vegetation characteristics were examined in 5 age classes (1-5 growing seasons) of CRP fields in Gratiot County, Michigan in 1992. Models developed from the data indicate that both field specific and landscape variables are important in predicting wildlife abundance and diversity. Field specific variables that describe the successional changes in vegetation composition and structure of CRP fields were important in predicting the relative abundance and diversity of invertebrate and avian species. Landscape variables such as the proportion and juxtaposition of different cover types within the landscape also significantly ($P < 0.10$) affected wildlife diversity and abundance. Maintaining a diversity of CRP age classes within a landscape, through enrollment or periodic manipulation of fields, produces the highest and most stable overall wildlife diversity.

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INTRODUCTION

One challenge facing natural resource managers is how to maintain biological diversity across heterogeneous landscapes under multiple ownership. Biological diversity, or biodiversity, refers to the variety and variability that has evolved within and among living organisms and the environments in which organisms occur. This includes ecosystem, species, and genetic diversity, and the diversity of ecological complexes. The recent accelerated losses in species richness and genetic diversity due to fragmentation, isolation and overall world wide reduction of biotic communities and habitats have focused attention on the world's biodiversity (Spellerberg 1989). Estimates suggest that the rate of species loss is 1,000 to 10,000 times greater now than before extensive human alteration of landscapes, such as large scale clearcutting of rain forests (Wilson 1988). The majority of research on biodiversity has focused on the tropical rain forests of South America (Wilson 1988). However, loss of biodiversity is quickly becoming an important issue in North America.

The composition and availability of wildlife habitat in the United States have changed dramatically over the past 2 centuries due to increased urbanization and changing land-use practices in agricultural and forested ecosystems (Karr 1981). Klopatek et al. (1979) estimated that 23 of the 106 endemic vegetation types of the United States have been reduced by over 50% because of human-induced changes in land-use. More specifically, habitat changes caused by the specialization and intensification of agricultural practices have contributed to significant declines in wildlife populations (U.S. Dept. of Agriculture 1987a, Berner 1988). The past mosaic of wetlands, small woodlots, and open grasslands has given way to vast expanses of farmland interspersed with highways and cities (Berner 1988). As a result of these changes in agricultural areas, traditional wildlife habitat has largely been reduced to small islands within expanses of agricultural crops.

Recent efforts have been made at the federal level to conserve the diversity of plant and animal species in the United States. For instance, the National Forest Management Act of 1976 mandates the management of biodiversity on federal lands. However, with 60% of the continental United States in private ownership, efforts to maintain biodiversity on private lands are needed (Walton 1981, Morrill 1987). Nearly 337 million hectares of privately owned lands in the United States are farmland; therefore, management for biodiversity in agricultural areas has potential to significantly impact wildlife habitat and populations.

The rate of landscape change due to farming practices was much slower in the past decades than it is currently, which provided greater opportunity for organisms to adapt to the changing landscape (Fry 1989). Currently, agricultural landscapes contain many wildlife species, such as the grasshopper sparrow (*Ammodramus savannarum*), whose long-term survival relies on the less intensive farming practices used in past years (Fry 1989). The landscape in which these agricultural wildlife species evolved consisted of a rich mosaic of vegetation types, including woodlots, hedgerows, hay fields, ponds, marshes, and fallow fields in rotations (Lowe et al. 1986). More recently, agricultural landscapes have become more intensively managed leaving farmland species to survive in landscapes of primarily agricultural crops.

Intensification of agriculture has decreased landscape and habitat diversity and contact between neighboring habitats (Fry 1989). It is particularly important, therefore, to understand how such changes in the spatial characteristics of habitats affect species and how this relates to population and community processes (Hassel 1980). Historically, several federal government-initiated land retirement programs have regulated land-use practices and assisted in the conservation of wildlife habitat in agricultural landscapes (Isaacs and Howell 1988). Under past land retirement programs, cropland was taken out of production and either left idle or planted to a cover crop. These programs exhibited various degrees of success in providing and diversifying wildlife habitat (Berner 1988).

The most recent set-aside program is the Conservation Reserve Program (CRP), established under provisions of the 1985 Food Security Act (Farm Bill). The CRP provides economic incentive to farmers to remove highly erodible and environmentally sensitive cropland from production for 10 years. Benefits of the program may include curtailing soil erosion and excess commodity production and the creation of large acreages of wildlife habitat.

The CRP has the potential to be the most beneficial land retirement program for wildlife to date (Berner 1988). Past studies have demonstrated that multi-year set-aside programs are generally better for wildlife than annual set-aside programs because of the quality of habitat produced, promoting unmowed, residual cover for wildlife use (Higgins et al. 1987). Similarly, the CRP, a multi-year set-aside, requires a permanent cover crop to be planted and maintained on fields.

The CRP also provides the unique opportunity to examine the impact of shifting land-use patterns on avian, mammalian, invertebrate, and plant communities associated with grasslands established in agricultural landscapes (Bartlett and Mitchell 1991). The proximity of CRP fields to features that physically diversify the landscape should also receive attention because neighboring vegetation types and their management may impact the plant and animal communities on CRP fields (Best et al. 1990). It has been suggested that not all lands enrolled in CRP hold equal potential as wildlife habitat (Allen 1992). Consideration of CRP fields in conjunction with their surrounding vegetation types may provide insights into ways to identify CRP lands that will have the greatest impact on biodiversity within agricultural landscapes.

Maintaining and managing biodiversity require land managers to consider broader geographic scales than have historically been used in managing natural resources. Specifically, habitat management plans must focus on landscape-level rather than field-level goals because a single unit of land may not provide all habitat components to support a diversity of wildlife species.

OBJECTIVES

The objectives of this study were to: 1) investigate the influence of different age classes of CRP fields on invertebrate biomass, 2) investigate the influence of plant communities adjacent to CRP fields on the avian and plant communities associated with CRP fields, 3) determine the impact CRP fields have on local and regional wildlife diversity within the landscape, 4) identify the scale at which land retirement programs, such as CRP, may have the greatest impact on regional wildlife and plant diversity, and 5) develop predictor models that describe changes in wildlife species diversity and abundance in agricultural landscapes in relation to changing land-use practices.

STUDY AREA

Gratiot County, Michigan (T9,10,11,12N; R1,2,3,4,W) was selected as the study area because the land-use patterns were typical of a temperate agricultural landscape in Michigan and CRP lands were readily available (Fig. 1). The climate of Gratiot County is variable with cold winters and warm to hot summers (Feenstra 1979). The average winter and summer temperatures are -4.2 C and 20.9 C, respectively (Feenstra 1979). Total annual precipitation averages 75.4 cm, of which 62 % (46.5 cm) generally falls between 1 April and 30 September (Feenstra 1979). Average seasonal snowfall is 104.9 cm, with an average of 68 days exhibiting at least 2.5 cm of snow on the ground (Feenstra 1979).

Present topography and soils have been formed mainly from glacial deposits and lake formations of the Wisconsin Glacier, resulting in 2 general physiographic areas in the county (Feenstra 1979). The western half consists of a series of glacial moraines, till and outwash plains, and channels. The eastern half is a level lake plain that was formed by a glacial lake (Feenstra 1979).

Soils on the west half of the county are associated with 2 moraine deposits, the Owosso and West Branch, and consist of Perrington, Ithaca, Marlette, and Capac soils. The soils on the lake plain in the eastern half of Gratiot County are Parkhill, Lenawee, Selfridge, Dixboro, and Corunna soils (Feenstra 1979).

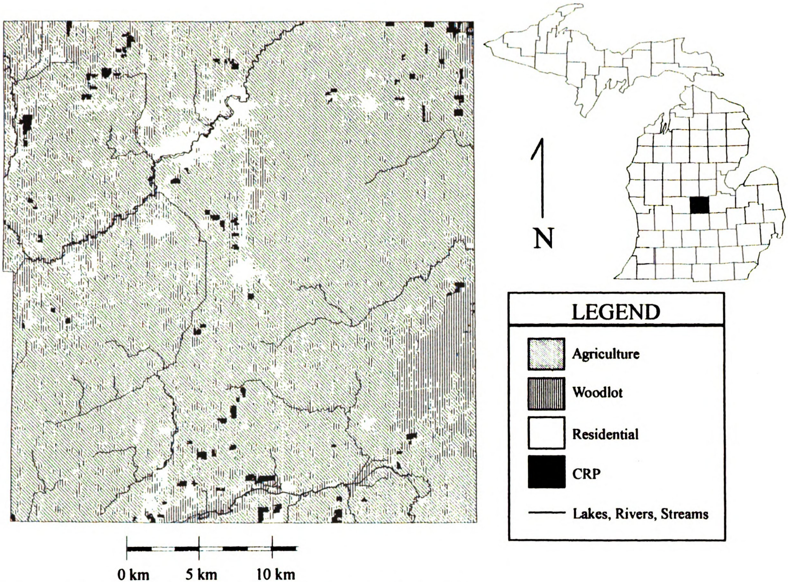


Figure 1. Location and land-use composition of Gratiot County, Michigan, 1992.

The dominant vegetation type in the county is agricultural crops (Feenstra 1979). Eighty-three percent of the county is farmland. Principal crops are corn, field beans, soybeans, and wheat. About 8% of the county is wooded primarily with bottomland aspen (*Populus* spp.), elm (*Ulmus* spp.), cottonwood (*Populus deltoides*), swamp oak (*Quercus bicolor*), soft maple (*Acer* spp.), ash (*Fraxinus* spp.), upland oak (*Quercus* spp.), basswood (*Tilia americana*), and pine (*Pinus* spp.) plantations.

The land-use practices immediately surrounding each study site ranged from almost entirely agricultural to a diverse array of nearly all cover types (Table 1). The landscape (259-ha area) around each study site contained a diversity of cover types. Four study sites were located in landscapes where > 50% of the surrounding landscape was in agricultural production. Five study sites were located in landscapes where > 50% of the surrounding area had been enrolled into CRP. Two study sites were in regions with large amounts (> 55%) of woodland. The remaining study sites had no single cover type that dominated the surrounding landscape.

Table 1. Characteristics of Conservation Reserve Program (CRP) study sites in Gratiot County, Michigan, 1992, and composition of vegetation types within a 259-ha area surrounding each site.

CRP Field Characteristics			Adjacent Cover Types (%)					Proportion of Cover Types (%)				
field	age	size(ha)	woodlot	residential	CRP	row crops	open fields	woodlot	residential	CRP	row crops	open fields
1	5	14.3	42	12	46	0	0	50	8	26	17	0
5	4	8.1	20	20	60	0	0	11	11	57	0	21
6	4	19.8	0	32	28	50	0	4	12	6	58	20
7	4	12.2	0	0	0	65	35	0	16	9	60	16
8	5	14.4	0	20	46	0	34	6	22	56	16	0
9	5	11.7	18	34	21	31	0	13	23	28	38	0
10	5	7.7	34	0	0	0	66	32	0	50	18	0
11	5	8.1	33	0	0	0	67	28	0	0	25	48
12	5	11.1	18	1	81	0	0	16	7	77	0	0
89A	3	12.2	0	0	0	100	0	30	0	0	70	0
89B	3	8.6	32	0	0	0	68	0	5	0	70	25
89C	3	10.1	0	36	0	64	0	0	20	20	20	40
90A	2	7.7	47	16	37	0	0	57	23	20	0	0
90B	2	12.1	0	0	32	0	68	5	0	30	45	20
90C	2	12.8	0	12	0	88	0	0	13	0	8	75
91A	1	15.1	0	0	0	80	20	75	0	5	5	15
91B	1	10.4	0	0	0	0	100	10	10	0	0	80
91C	1	12.1	0	0	50	50	0	20	0	50	30	0

METHODS

Nineteen 6.5- to 20-ha CRP fields were selected for study in Gratiot County, Michigan. Fields ranged in age of enrollment from 1 to 6 years (enrollment years 1986 to 1991), with at least 3 fields in each age class except 6-year-old fields (n = 1). Due to limited enrollment in 1986, only 1 field was available for sampling in the 6-year-old age class and, lacking replication, was not included in any analyses (Table 1). Fields were planted to a mixture of introduced grasses and legumes, specifically alfalfa, red clover, and sweet clover (Table 2).

Vegetation

Vegetation characteristics were sampled in July and August, 1992. To quantify the structure and composition of field vegetation, data were collected every 20 m along 6 permanent 100 m transects (6 sampling points per transect). Horizontal cover of vegetation was assessed using a Robel pole (Robel et al. 1970). Maximum height of living and standing dead vegetation was measured at each sampling point. Canopy cover of live and dead vegetation, grasses, forbs, woody vegetation, and litter cover was measured at each point using a 50 x 50 cm sampling frame as described by Daubenmire (1959). Percent bare ground within the frame was also recorded. Frequency of occurrence of plant species was measured by identifying all species occurring within the frame.

Table 2. Planting mixtures (kg/ha) of Conservation Reserve Program (CRP) study sites in Gratiot County, Michigan.

Field	Year Enrolled	Planting Mixture
1	1987	2.2 kg timothy, 4.5 kg orchard grass, 2.2 kg alfalfa, 1.1 kg sweet clover
2	1986	2.2 kg timothy, 4.5 kg orchard grass, 2.2 kg sweet clover
5	1988	2.2 kg timothy, 3.4 kg orchard grass, 2.2 kg alfalfa, 2.2 kg white sweet clover
6	1988	Same as field 5
7	1988	Same as field 1
8	1987	Same as field 1
9	1987	Same as field 1
10	1987	Same as field 1
11	1987	3.4 kg timothy, 2.2 kg alsike, 2.2 kg sweet clover
12	1987	2.2 kg timothy, 3.4 kg orchard grass, 2.2 kg alfalfa, 2.2 kg white sweet clover
89A	1989	3.4 kg alfalfa, 3.4 kg orchard grass
89B	1989	Same as field 89
89C	1989	Same as field 1
90A	1990	Same as field 89
90B	1990	Same as field 89
90C	1990	Same as field 89
91A	1991	Same as field 89
91B	1991	Same as field 89
91C	1991	Same as field 89

A profile board (Nudds 1977) was used to estimate horizontal cover in 4 height strata (0-0.5 m, 0.5-1.0 m, 1.0-1.5 m, and 1.5-2.0 m) on CRP fields and in adjacent vegetation types. The board was observed from a distance of 15 m, and the percentage of the board covered by vegetation in each stratum was recorded as being 0, 20, 40, 60, 80, or 100%.

Vertical cover of herbaceous and woody vegetation was measured using the line intercept method (Canfield 1941). Vegetation was stratified into herbaceous cover, woody cover < 1 m, woody cover 1-3 m, woody cover 3-5 m, and woody cover >5 m. Cover was determined as the proportion of each line intercept covered by vegetation (MacArthur and MacArthur 1961, MacArthur and Horn 1969, Gysel and Lyon 1980). Line intercepts were randomly placed on CRP fields and in adjacent vegetation types within 60 m of the CRP field edge.

To aid in determining the effects of surrounding vegetation types on the plant and animal communities within CRP fields, adjacent cover types were classified as woodlot, residential, or open field (Table 3). Cover types classified as open field were further subdivided into CRP fields, row crop fields, and other fields consisting of pastures, hayfields, and fallow fields.

Vegetation on the edges (first 60 m) of CRP study sites was stratified by the cover types adjacent to each site to determine the impacts different vegetation types adjacent to CRP fields have on CRP plant communities (Fig. 2). Sample points for vegetation sampling were randomly placed within each stratum and sampled as described above.

Table 3. Classification of cover types adjacent to Conservation Reserve Program fields in Gratiot County, Michigan, 1992.

Cover Type	Description
Woodlot	Areas of wooded vegetation > 60 m in width with wooded vegetation > 3 m in height
Residential Area	Areas such as yards, barns, or any other structure typically associated with human habitation
Row Crop/Agriculture	Areas of active agricultural production, such as corn or soy bean production
Open Field Areas	Areas dominated by herbaceous vegetation with little or no wooded vegetation > 3 m in height

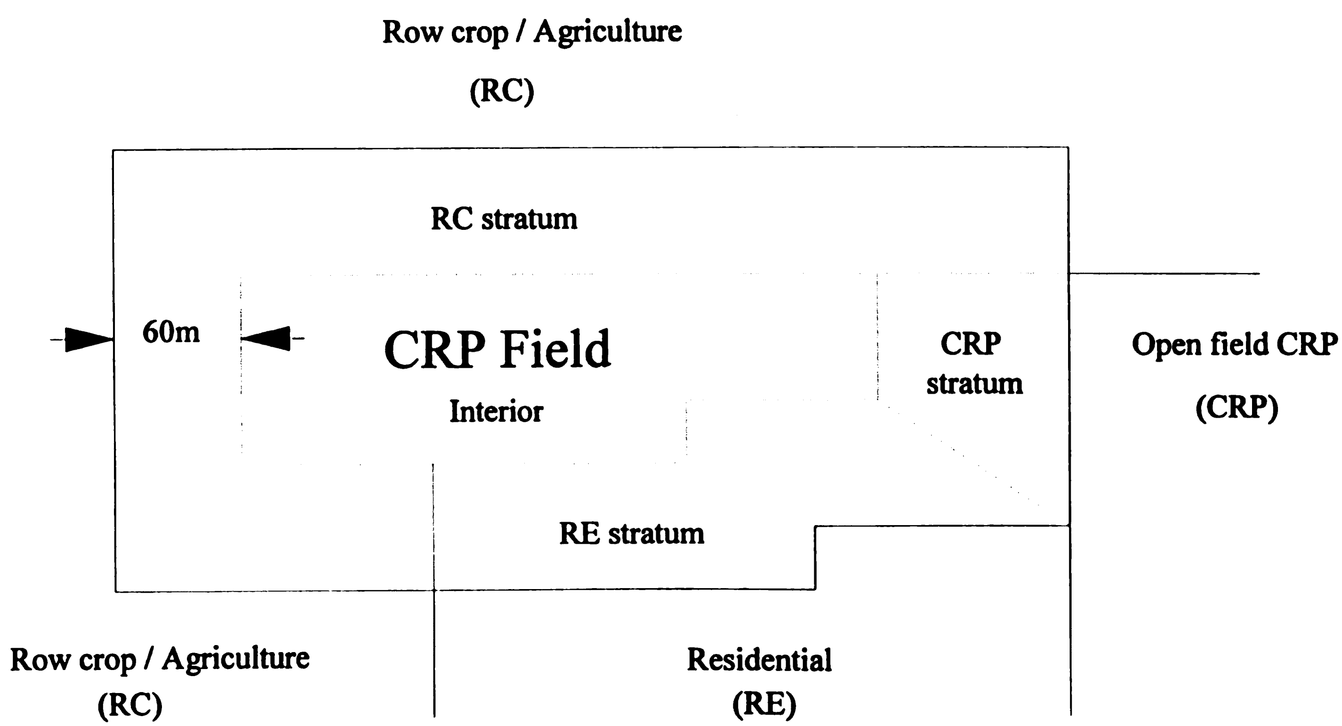


Figure 2. Stratification of Conservation Reserve Program (CRP) study sites in Gratiot County, Michigan, 1992, by adjacent cover types for vegetation sampling.

Kruskal-Wallis one-way analysis of variance (ANOVA) (Siegel 1956) was used to determine differences among age classes for all vegetation characteristics. The Kruskal-Wallis multiple comparison (Miller 1980) was used to determine which age classes significantly differed from one another.

Birds

In collaboration with a concurrent study on the influence of CRP vegetation on bird diversity, bimonthly bird censuses were conducted from permanent lines delineated on each site to determine relative species abundance and densities (Millenbah 1993). The first permanent line used for bird censuses on each field was established 25 m from a random corner with additional lines every 50 m along the long axis of study sites. Censuses were conducted from sunrise to 3 hours after sunrise. Observers walked slowly along the lines making frequent stops to scan for birds. All birds seen or heard were recorded and bird locations were plotted on maps of the study sites. Perpendicular distance from the line to all passerines (song birds) was recorded in 5 m increments up to 50 m. Prior to each census, sites were scanned for non-passerines and other avian species, such as ring-necked pheasants (*Phasianus colchicus*), barn swallows (*Hirundo rustica*), and American crows (*Corvus brachyrhynchos*). The locations and gender of species were plotted on maps when possible.

Birds in vegetation types bordering CRP fields were censused using the point count transect method (O'Brien 1990). The ends of birding transects on CRP fields were used as the sampling points. At each sampling point, observers recorded bird species seen or heard in the vegetation type adjacent to each field for a period of 5 minutes. The gender (when possible to identify), distance from the edge of the CRP field in 5-m increments (up to 50 m) and cover type in which the bird was located were recorded.

Bird species diversity was calculated using the Shannon-Weaver diversity index (Shannon and Weaver 1949). Friedman's two-way ANOVA (Siegel 1956) was used to determine differences in bird species diversity among age classes and birding periods. Friedman's multiple comparison (Miller 1980) was used to determine which age classes and birding periods significantly differed from one another.

Invertebrates

Invertebrates were sampled monthly from June to August to determine relative differences in diversity and biomass among age classes and sample months. Twenty one - 39 samples were collected at randomly selected locations on CRP study sites. The sweep net technique (Ruesink and Haynes 1973) was used to collect invertebrates, with 10 sweeps of a 50-cm net per sampling location. Invertebrates were identified to order or class, dried in an oven at 60 C for 48 hours, and weighed to determine biomass of each taxonomic group. Invertebrate diversity was calculated using the Shannon-Weaver diversity index (Shannon and Weaver 1949).

Comparisons of invertebrate biomass by order among age classes within months and within age classes among months were conducted using ANOVA (Sokal and Rohlf 1981). Total invertebrate biomass was compared among age classes using ANOVA. Tukey's multiple comparison (Sokal and Rohlf 1981) was used to determine which age classes and months were significantly different from one another. The F_{max} test was used to test for homogeneity of variance (Sokal and Rohlf 1981).

Mammals

Data collected by Furrow (1994), on 3 replicates of 3 age classes (1-, 3-, and 5-years-old) of CRP fields, to examine vegetation influences on small mammal species diversity, abundance, and composition were used in this study. Large Sherman live-traps (H.B. Sherman, Co., Tallahassee, Fla.) were used to monitor small mammal populations on fields. Small mammals were live-trapped on CRP fields for 5 consecutive nights each month from May to August. A 6 x 6 grid with traps spaced 25 m (Smith et al. 1975) apart was centered on each field. Assessment lines, with trap stations 25 m apart, were established in each of the 4 cardinal directions from the edge of the grid to field edges and 60 m onto adjacent cover types. Two traps were placed at each station and covered with vegetation to maximize captures and minimize heat stress to animals. Traps were baited with a mixture of whole oats, lard, and anise extract. Traps were checked each morning, and newly captured animals were identified, ear tagged, and released. Ear tag number, species identification, gender, and trap location were recorded.

Mammalian diversity was calculated using the Shannon-Weaver diversity index (Shannon and Weaver 1949). Kruskal-Wallis one-way ANOVA (Siegel 1956) was used to determine differences in mammalian diversity and abundance among age classes within months. The Kruskal-Wallis multiple comparison (Miller 1980) was used to determine which age classes significantly differed from one another.

Impacts of Surrounding Vegetation Types on CRP Fields

Base map and land-use information for Gratiot County were obtained from the Michigan Department of Natural Resources (MDNR). Land-use composition was classified with the Michigan Resource Information System (MIRIS) (Michigan Landuse

Classification and Referencing Committee 1979) (Appendix A). Base map information included roadways, waterways, and legal boundaries. Soil maps were digitized from the United States Department of Agriculture (U.S.D.A.) Soil Conservation Service's survey for the county (Feenstra 1979). The Geographical Information System (GIS) ARC/INFO was used to calculate the proportion of different cover types adjacent to CRP study sites and the area of each cover type within the landscape surrounding CRP sites.

To determine the minimum management unit area that has potential to provide the maximum landscape diversity, 313 randomly selected sample areas ranging in size from 1 ha to 1,480,577 ha were selected from the land-use map. Landscape diversity was calculated for each sample using the Shannon-Weaver diversity index (Shannon and Weaver 1949). Landscape diversity was calculated by using the proportion of each cover type within the landscape as P_i and is, therefore, a measure of the amount and number of different cover types within the landscape.

Linear and non-linear regressions were used to determine the equation that best explained the relationship between landscape diversity and sample area (Sokal and Rohlf 1981). The area in the landscape capable of maximizing the landscape diversity was determined as the point at which a line tangent to the regression line has a slope approaching zero. This area represented the size of the landscape at which overall landscape diversity can be maximized.

One-hundred and thirteen randomly selected 259-ha units of Gratiot County were examined using ARC/INFO to determine variation in land-use practices and landscape composition within the county, (Fig. 3). The diversity of cover types within each 259-ha sample (landscape diversity) was calculated using the Shannon-Weaver diversity index

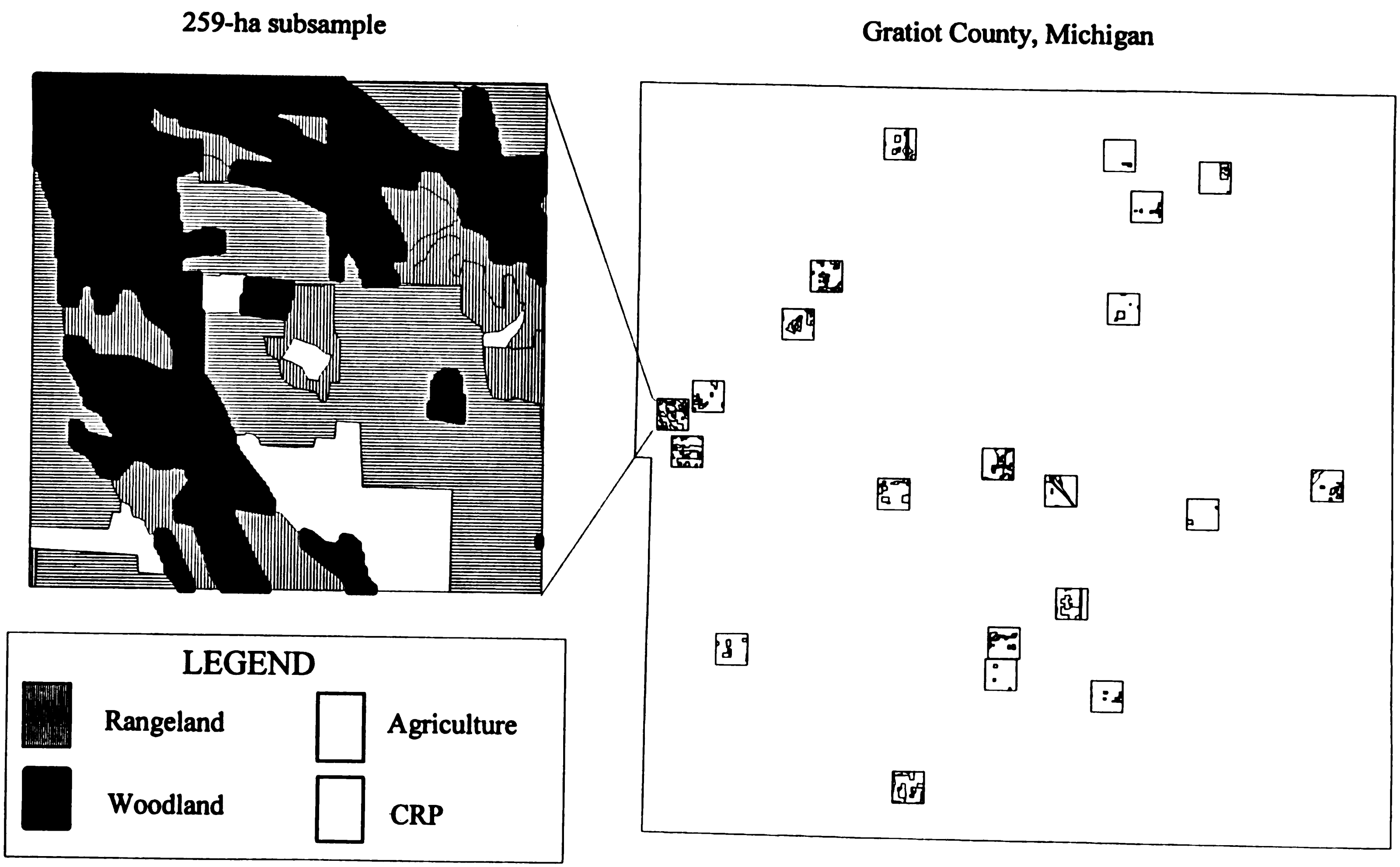


Figure 3. An example of the distribution and composition of 259-ha units randomly sampled throughout Gratiot County, Michigan.

(Shannon and Weaver 1949). The resulting value represented the diversity of each 259-ha unit by MIRIS cover type, of which an average of 13% was CRP lands. To determine the effect of reverting CRP lands to agricultural production, landscape diversity was recalculated with the existing 13% CRP lands recoded as agriculture. The recalculated landscape diversity value (no CRP) was compared to the initial diversity value (13% CRP) using a paired-t test (Sokal and Rohlf 1981).

Spearman rank correlation analysis was used to examine the association between landscape diversity and bird species diversity (Siegel 1956). Bird species diversity is often linked to the diversity of habitats within a landscape (Robbins et al. 1989). An area of 259-ha was used as the unit area to calculate landscape diversity because other studies have indicated that breeding birds within grassland ecosystems often maintain home ranges < 259-ha (Cody 1985).

Soils

Soil maps were overlaid onto maps of CRP study sites and surrounding landscapes to determine the impact that different soils have on floral and faunal communities. The relative potential of each soil to produce and maintain wildlife and agricultural production was taken from U.S.D.A. Soil Conservation Service soil surveys (Table 4). Specifically, each soil was classified for its ability to support openland and forest wildlife, forest production, and grain and grass production. Soils were given a numeric rating from 0 (very poor) to 3 (good) for each of the above properties. A value

Table 4. Suitability[a] of soils on Conservation Reserve Program study sites in Gratiot County, Michigan, 1992 to produce agricultural and wildlife commodities.

Soil	Soil Name	Openland Wildlife	Forest Wildlife	Forest Production	Grain Production	Grass Production
Ad	Adrian	poor	poor	poor	poor	poor
Be	Belleville	fair	fair	fair	poor	fair
BoB	Boyer	fair	good	good	poor	fair
CaA	Capac	good	good	good	good	good
CcA	Capac Variant	fair	good	good	fair	fair
Cr	Corunna	fair	fair	fair	good	fair
Ed	Edwards	very poor	poor	poor	very poor	poor
Gd	Gilford	poor	poor	poor	fair	poor
ItA	Ithaca	good	good	good	fair	good
Ke	Kingsville	fair	fair	fair	poor	fair
Le	Lenawee	fair	fair	fair	fair	fair
MaB	Marlette B	good	good	good	good	good
MaC	Marlette C	good	good	good	fair	good
MeA	Metamora	good	good	good	good	good
MtB	Metea	fair	good	good	poor	fair
Ph	Parkhill	fair	fair	fair	good	fair
PkB	Perrington B	good	good	good	good	good
PkC	Perrington C	good	good	good	fair	good
PtB	Plainfield	poor	poor	poor	poor	poor
RdA	Riverdale	fair	fair	fair	poor	fair
SeA	Selfridge	fair	good	good	poor	fair
SpC	Spinks	fair	fair	fair	poor	fair
TdA	Tedrow	fair	poor	poor	poor	fair
Ve	Vestaburg	poor	poor	poor	poor	fair

[a] From Soil Survey of Gratiot County, Michigan (Feenstra 1979).

for each study site was calculated by weighting the numeric quality of each soil (0-3) by the proportion of the field containing that soil and summing across all soils (Fig. 4).

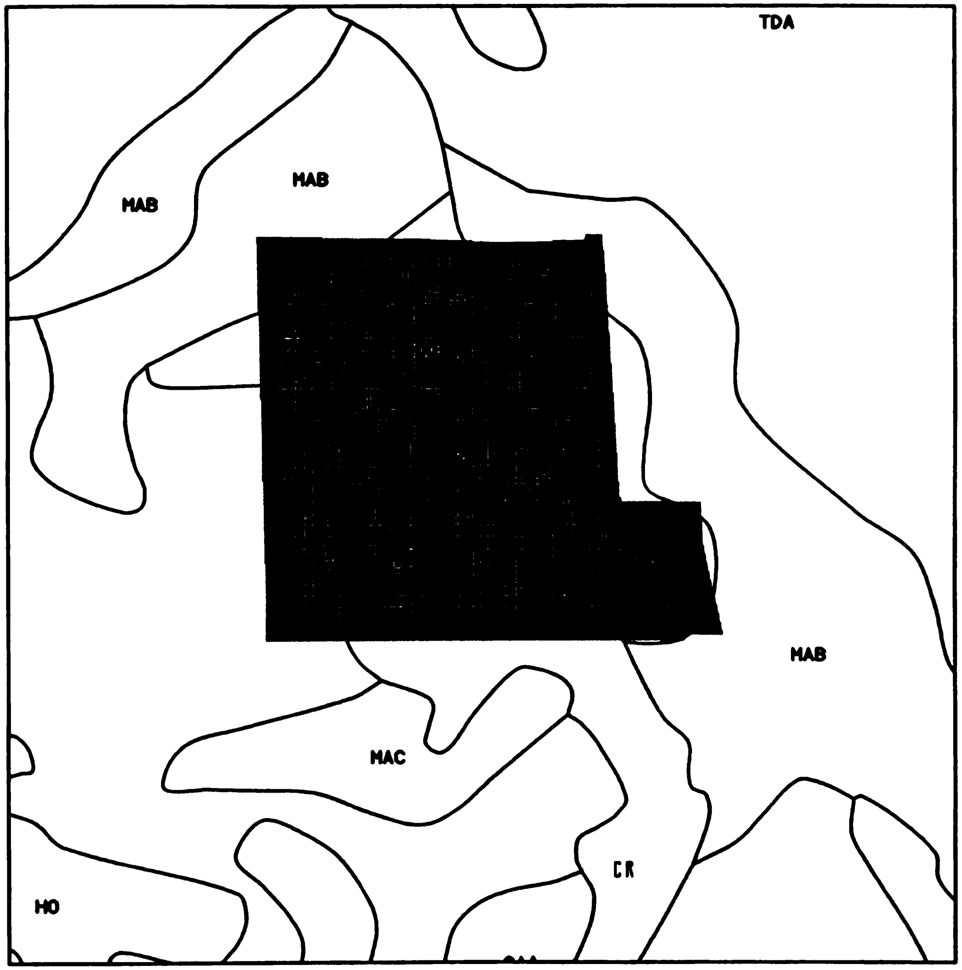
The diversity of soils on each study site was calculated using the Shannon-Weaver diversity index (Shannon and Weaver 1949). Soil diversity values were correlated with bird species diversity, bird species richness, and plant species richness using Spearman rank correlation to determine the association soils have with the CRP plant and animal communities. Study site potential values were correlated against bird species diversity and plant species richness using Spearman rank correlation (Siegel 1956) to determine the association between soil quality on the CRP plant and animal communities. Bird species diversity and plant species richness were also correlated against the study site soil potentials weighted by the size of the study site.

Within Age Class Comparisons - Vegetation

Vegetation on CRP fields within the adjacent cover type strata was compared with similar strata on fields of the same age using multiple analysis of variance (MANOVA) (Sokal and Rohlf 1981). For example, vegetation data from the woodlot cover stratum on field 91A (1-year-old field) were compared to data from the woodlot cover stratum on field 91B (1-year-old field). MANOVA's were used to determine if similar strata (i.e. woodlot) differed in plant structure within age classes.

Models

Bird and mammal species diversity and relative abundance, invertebrate diversity and biomass, and plant species richness were regressed against 17 landscape and field features to develop models that predict the effects of CRP lands on the abundance and



Soil	Proportion of soil on site		Openland value		
MaB	0.45	x	3	=	1.35
MaC	0.34	x	3	=	1.02
Cr	0.13	x	2	=	0.26
RdA	0.06	x	2	=	0.12
Gd	0.02	x	1	=	0.02
Study site openland value				=	2.77

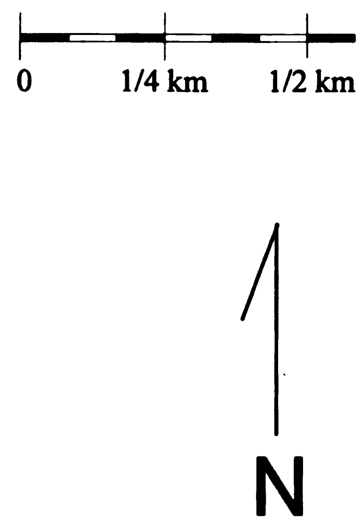


Figure 4. Map of Conservation Reserve Program study site 1 in Gratiot County, Michigan. Study site potential for openland wildlife is calculated as the proportion of each soil on the field multiplied by the quality of that soil (Feenstra 1979).

diversity of wildlife and plant species in Michigan's temperate agro-ecosystems. Variables included in the regressions were size of CRP field (SIZE), age of CRP field (AGE), proportion of surrounding landscape that was wooded (PWO), proportion of residential area in landscape (PRE), proportion of landscape in agricultural production (PRC), proportion of landscape enrolled into CRP (PCRP), proportion of open fields other than CRP or agriculture in the landscape (POF), the diversity of the landscape (LANDDIV), the diversity of soils on the CRP field (SOILDIV), the diversity of MIRIS cover types adjacent to CRP fields (CTYPEDIV), the openland wildlife potential value for each field (OPENWILD), the proportion of the CRP field surrounded by woodlots (AWO), the proportion of the CRP field surrounded by residential area (ARE), the proportion of the CRP field surrounded by agricultural production (ARC), the amount of the CRP field surrounded by other CRP fields (ACRP), the amount of the CRP field surrounded by open fields other than CRP fields and agricultural production (AOF), and the number of times a pair of lines placed in the cardinal directions intersects a different cover type within the landscape (INTRSCTS). An increase in the number of intersects of the lines within a landscape indicates an increase in the interspersion of cover types within that landscape (Pielou 1977).

Regressions were conducted using the software package Statistical Analysis Systems (SAS Institute Inc. 1988). With SAS, least-squares forward selection was used to fit the best model to the data. Selection for the best model was based on the following 5 criteria: 1) model was significant at $P = 0.10$; 2) r-squared no longer substantially increased with addition of variables; 3) each variable in the model was significant; 4) the error degrees of freedom were nearly twice the regression degrees of freedom; and 5) the model made sense biologically. For all analyses, each independent variable was graphed against the dependent variables for examination of nonlinear relationships. Regression r-squared values were graphed against the number of variables in the model to examine the decline in efficiency of adding an additional variable.

To examine the impact of landscape features on grassland-specific bird species, the density of 4 bird species was regressed against the 17 landscape and field features described earlier. Species examined included the bobolink (*Dolichonyx oryzivorus*), grasshopper sparrow, savanna sparrow (*Passerculus sandwichensis*), and sedge wren (*Cistothorus platensis*). Bobolinks, grasshopper sparrows, and sedge wrens were chosen as ecological indicator species because of continuing declines in numbers over the past 2 decades (Herkert 1994). Savanna sparrows have been steadily increasing in numbers (Herkert 1994) and may further increase the understanding of factors influencing populations within agricultural landscapes.

RESULTS

Vegetation

Ninety-four species of plants were identified on CRP study sites and adjacent cover types (Table 5, Appendix B). Eighty-two plant species occurred on CRP study sites (Millenbah 1993) and 25 species were located exclusively in adjacent cover types. Plant species richness declined through the first 4 growing seasons, but increased on 5-year-old fields (Table 6).

Many significant differences in vegetation variables were detected among CRP age classes (Table 6). Four-year-old fields had significantly ($P < 0.10$) more horizontal cover, as measured by the Robel pole (Robel et al. 1970), than 1-year-old fields (Table 6). Three-year-old fields had significantly ($P < 0.10$) more litter depth than 1-year-old fields (Table 6). The percent of total canopy cover, as measured by the Daubenmire (Daubenmire 1959) frame, indicated that 2- and 4-year-old fields had the greatest canopy cover (Table 6) of all age classes. Live and dead canopy cover were also greatest on 2- and 4-year-old fields (Table 6). Two-year-old fields had the greatest forb cover, where as, 3-year-old fields had the least (Table 6). Three- and 4-year-old fields had significantly ($P < 0.10$) more litter cover than 1-year-old fields (Table 6). Significant ($P < 0.10$) differences existed among age classes in the percentage of bare ground and horizontal cover in the 0-0.5m height stratum, Friedman's multiple comparison (Miller 1980) was unable to detect which age classes differed from one another (Table 6).

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Table 5. Plant species richness and diversity (Shannon-Weaver index) (Shannon and Weaver 1949) of Conservation Reserve Program (CRP) fields in Gratiot County, Michigan, 1992, and cover types adjacent to fields.

Field	Age (yrs)	No. of Species	Diversity	Adjacent Cover Types[a]
1	5	13	2.59	WO, RE, CRP
5	4	5	1.40	WO, RE, CRP
6	4	17	2.28	RE, CRP, RC
7	4	12	1.82	RC, OF
8	5	11	1.81	RE, CRP, OF
9	5	11	2.61	WO, RE, CRP, RC
10	5	21	2.78	WO, OF
11	5	21	2.43	WO, OF
12	5	8	1.94	WO, RE, CRP
89A	3	15	1.87	RC
89B	3	26	1.71	WO, OF
89C	3	24	1.47	RE, RC
90A	2	21	2.23	WO, RE, CRP
90B	2	18	2.39	CRP, OF
90C	2	5	1.11	RE, RC
91A	1	16	2.05	RC, OF
91B	1	16	2.39	OF
91C	1	27	2.24	CRP, RC

[a] WO = woodlot, RE = residential area, RC = row crop production, OF = open field.

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Table 6. Mean (standard error) vegetation characteristics on 5 age classes of Conservation Reserve Program fields in Gratiot County, Michigan, 1992.

	Age Class				
Characteristic	1	2	3	4	5
Robel Pole					
Horizontal Cover (dm)*	2.5A	3.6AB	3.3AB	4.14B	3.3AB
	(0.4)	(0.6)	(0.3)	(<0.0)	(0.2)
Live Height (dm)	2.9	4.5	4.4	5.2	3.8
	(0.5)	(0.9)	(0.5)	(0.2)	(0.4)
Dead Height (dm)	7.4	9.2	9.2	9.4	9.3
	(0.7)	(0.4)	(1.1)	(1.4)	(1.3)
Litter Depth (cm)*	2.3A	3.1AB	11.3B	6.7AB	4.7AB
	(0.9)	(1.8)	(3.2)	(1.1)	(0.8)
Daubenmire Frame					
% Total Canopy*	55.1BC	84.3A	57.2ABC	82.8AC	63.2ABC
	(4.6)	(1.5)	(5.3)	(6.9)	(2.0)
% Live Canopy*	51.4BC	74.6A	53.1AB	73.3AC	57.3AB
	(3.3)	(1.6)	(5.6)	(5.6)	(2.3)
% Dead Canopy*	3.9A	8.8AB	4.6AB	9.4B	5.9AB
	(0.9)	(0.5)	(1.1)	(1.6)	(0.9)
% Grass Canopy	26.9	26.9	45.4	53.8	41.8
	(4.2)	(11.1)	(7.8)	(2.6)	(3.5)
% Forb Canopy*	29.1AB	54.8A	12.5B	28.4AB	21.3AB
	(0.4)	(10.6)	(2.2)	(8.2)	(3.7)
% Woody Canopy	0.0	0.8	<0.1	0.0	0.2
	(0.0)	(0.7)	(<0.0)	(0.0)	(0.1)
% Litter Cover*	25.6A	40.2AC	57.5BC	45.8B	54.6ABC
	(12.2)	(3.4)	(3.8)	(1.4)	(2.3)
% Bare Ground*	33.2A	7.1A	2.5A	2.2A	2.7A
	(11.8)	(2.7)	(1.6)	(1.2)	(0.8)
Profile Board					
% Horizontal Cover 0-0.5m*	95.6A	96.4A	90.0A	99.5A	96.4A
	(0.9)	(1.0)	(4.1)	(0.3)	(1.1)
% Horizontal Cover 0.5-1.0m*	48.3A	52.4A	19.2B	66.0C	48.6A
	(6.1)	(10.1)	(6.7)	(10.1)	(6.6)
% Horizontal Cover 1.0-1.5m	0.0	0.0	0.0	14.9	8.2
	(0.0)	(0.0)	(0.0)	(11.3)	(2.7)
% Horizontal Cover 1.5-2.0m	0.0	0.0	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)

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Table 6 Cont.

Characteristic	Age Class 1	2	3	4	5
Line Intercepts					
% Herbaceous Cover < 1m*	79.0A	93.3B	93.8B	95.3B	88.8AB
	(7.9)	(0.2)	(0.4)	(0.2)	(0.2)
% Woody Cover < 1m	0.0	1.1	0.8	0.0	0.1
	(0.0)	(1.1)	(0.8)	(0.0)	(<0.1)
% Woody Cover 1-3m	0.0	0.0	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
% Woody Cover 3-5m	0.0	0.0	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
% Woody Cover >5m	1.1	0.1	0.0	0.0	0.1
	(0.1)	(0.1)	(0.0)	(0.0)	(<0.1)

* Significantly different among age classes (Kruskal-Wallis, $P < 0.10$). Within the same row, means having the same letter are not significantly different (multiple comparison test modified from Miller 1980).

Four-year-old fields had significantly ($P < 0.10$) more horizontal cover in the 0.5-1.0 m height stratum than other age classes, while 3-year-old fields had significantly ($P < 0.10$) less cover than the other age classes (Table 6). One-year-old fields had significantly ($P < 0.10$) less herbaceous cover, as determined by line intercepts, than 2-, 3-, and 4-year-old fields (Table 6). No significant differences ($P > 0.10$) were detected among age classes in the remaining vegetation characteristics measured (Table 6).

Birds and Mammals

Fifty-four bird species were identified on CRP study sites and in adjacent vegetation types (Appendix C). Thirty-two of the bird species occurred on CRP study sites (Millenbah 1993), and 22 species were located only in vegetation types adjacent to CRP fields. Bird species diversities were not significantly different ($P > 0.10$) within a birding period among age classes (Table 7), however, mean avian diversities were significantly different ($P < 0.10$) among age classes over the entire summer (Table 7).

Ten small mammal species (n = 461) were trapped on CRP study sites and adjacent vegetation types (Appendix D). All 10 species occurred on CRP fields with adjacent vegetation types not supporting any different small mammal species (Furrow 1994). One-year-old fields tended to have higher numbers of small mammals, however, no significant differences ($P > 0.10$) in small mammal relative abundance were detected among age classes of CRP for all months sampled (Table 8). Three-year-old fields had a significantly ($P < 0.10$) higher diversity of small mammals than 1-year-old fields in June (Table 8). Small mammal diversity differed ($P < 0.10$) among age classes in August, Tabl

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Table 7. Mean bird species diversity (Shannon and Weaver 1949) (standard error) on 1- to 5-year-old Conservation Reserve Program fields in Gratiot County, Michigan, summer 1992.

Age Class	Birding period							entire summer[c]
	1[a]	2	3	4	5	6	7	
1	1.23	1.46	1.15	1.46	1.65	1.32	1.34	1.37
	(0.2)	(0.2)	(0.3)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)
2	1.11[b]	1.49	1.40	1.23	1.39	1.61	1.11	1.36
		(0.1)	(0.2)	(0.5)	(0.1)	(0.3)	(0.3)	(0.1)
3	1.73	1.07	1.38	1.31	1.39	1.09	1.01	1.28
	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.1)
4	1.05	1.04	1.13	1.24	1.36	1.21	1.21	1.18
	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
5	1.18	1.18	0.77	1.15	1.35	1.15	1.07	1.15
	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)	(0.2)	(0.2)	(0.1)

[a] period 1 = 1 May - 15 May, period 2 = 16 May - 31 May, period 3 = 1 June - 15 June, period 4 = 16 June - 30 June, period 5 = 1 July - 15 July, period 6 = 16 July - 31 July, and period 7 = 1 August - 15 August.

[b] Only 1 field sampled in this period and age class.

[c] Significantly different among age classes (Friedman, $P<0.10$). Use of Friedman's multiple comparison test (Miller 1980) failed to detect differences among age classes.

Table 8. Mean (standard error) relative abundance and diversity (Shannon and Weaver 1949) of small mammals captured on 1-, 3-, and 5-year-old Conservation Reserve Program fields in Gratiot County, Michigan, 1992 (from Furrow 1994).

	Relative Abundance			Diversity		
	Age Class			Age Class		
Trapping Period	1	3	5	1	3	5
May	17.33	3.33	5.00	0.00	0.23	0.42
	(8.37)	(0.89)	(1.00)	(0.00)	(0.23)	(0.21)
June[a]	15.67	15.00	11.00	0.13A	0.28B	0.26AB
	(7.23)	(7.23)	(9.02)	(0.13)	(0.10)	(0.20)
July	12.67	12.00	11.00	0.06	0.53	0.39
	(4.63)	(8.19)	(5.30)	(0.06)	(0.32)	(0.20)
August[a,b]	12.67	21.67	18.33	0.24A	0.82A	0.98A
	(3.71)	(12.25)	(8.84)	(0.17)	(0.35)	(0.28)

[a] Significantly different diversity of small mammals among age classes within months (Kruskal-Wallis one-way analysis-of-variance, $P < 0.10$). Means having the same letter within rows are not significantly different (Kruskal-Wallis multiple comparison (Miller 1980)).

[b] Significant differences among age classes could not be detected using the Kruskal-Wallis multiple comparison (Miller 1980).

however, the differences between specific age classes could not be detected with use of the Kruskal-Wallis rank Statistic (Miller 1980).

Invertebrates

Nine orders and 2 classes of invertebrates were identified on CRP fields during 1992. Orders identified included Lepidoptera (moths and butterflies), Orthoptera (grasshoppers and crickets), Coleoptera (beetles), Hemiptera (true bugs), Homoptera (leaf hoppers), Diptera (flies), Hymenoptera (bees and wasps), Neuroptera (lacewings), and Odonata (dragonflies and damselflies). The classes Arachnida (spiders) and Gastropoda (snails and slugs) were also identified on CRP fields. The low frequency of occurrence of Hymenoptera, Neuroptera, Odonata, and Gastropoda prevented statistical analysis on those taxonomic groups.

Arachnid biomass did not differ among months on 1-, 3-, 4-, and 5-year-old fields (ANOVA, P = 0.755, 0.585, 0.150, and 0.262, respectively) (Table 9). Two-year-old fields had significantly (ANOVA, P = 0.071) more Arachnid biomass in June than in July (Table 9). Three-year-old fields had significantly more (P = 0.030) Arachnid biomass in August than did 1-, 2-, 4-, and 5-year-old fields (Table 9).

Lepidopteran biomass was significantly greater in June than in July and August on 3-, 4-, and 5-year-old fields (ANOVA, P = 0.024, 0.003, and 0.002, respectively) (Table 9). No differences in Lepidopteran biomass were found across age classes in June, July, or August (ANOVA, P = 0.494, 0.282, 0.506, respectively) (Table 9).

Orthopteran biomass was significantly greater (ANOVA, P = 0.042) in August than in June on 2-year-old fields (Table 9). Orthopteran biomass was greater (ANOVA,

Table 9. Mean[a] invertebrate biomass in g/10 sweeps by order (class) in June, July, and August on 1- through 5-year-old Conservation Reserve Program fields in Gratiot County, Michigan, 1992.

Age (yrs)	Month	Arachnid	Lepidoptera	Orthoptera	Coleoptera	Hemiptera	Homoptera	Diptera	Total Biomass
1[b]	June[c]	0.0003AX	0.01434AX	0.0028AX	0.0050AX	0.0206AX	0.0130AX	0.0028ABX	0.0594AXY
	July	0.0004AX	0.00053AX	0.0155AX	0.0057AX	0.0058AY	0.0036AY	0.0012AX	0.0405ABY
	August	0.0006AX	0.00880AX	0.3178AX	0.0102AX	0.0124AXY	0.0063AXY	0.0018AX	0.0921AX
2	June	0.0008AX	0.00641AX	0.0079AX	0.0054AX	0.0153AX	0.0170AX	0.0030ABX	0.0515AX
	July	0.0001AY	0.0040AX	0.0165AXY	0.0046AX	0.0090BX	0.0101AX	0.0012AX	0.0518BX
	August	0.0002AXY	0.0006AX	0.0436AY	0.0024BX	0.0080AX	0.0168BX	0.0010AX	0.0810ACX
3	June	0.0005AX	0.0094AX	0.0101BXY	0.0037AX	0.0341AX	0.0360BX	0.0037ABX	0.0979BX
	July	0.0013AX	0.0008AY	0.0045AY	0.0022AX	0.0050AX	0.0020AY	0.0011AY	0.0185ABY
	August	0.0016BX	0.0003AY	0.0203AX	0.0017BX	0.0037BY	0.0077ABY	0.00133AY	0.0464BCZ
4	June	0.0009AX	0.0072AX	0.0021AX	0.0026AX	0.0326AX	0.0023AX	0.0021BX	0.0347AX
	July	tr[d]AX	0.0015AY	0.0096AY	0.0039AX	0.0050AY	0.0081AX	0.0017AX	0.0329ABX
	August	0.0008AX	trAY	0.0120AY	0.0005BX	0.0012BY	0.0044AX	0.0005AX	0.0254BCX
5	June	0.0012AX	0.0063AX	0.0024AX	0.0023AX	0.0230AX	0.0057AX	0.0010AX	0.0476AX
	July	0.0009AX	0.0005AY	0.0097AX	0.0016AX	0.0017AY	0.0071AX	0.0007AX	0.0198AY
	August	0.0002AX	0.0003AY	0.0029AX	0.0010BX	0.0004BY	0.0067AX	0.0010AX	0.0148BY

[a] All standard errors were < 0.0001 g/10 sweeps.

[b] Within the same column and month, age classes having the same upper case letter (ABC) are not significantly different (Tukey's multiple comparison test, $\alpha = 0.10$) (Sokal and Rohlf 1981).

[c] Within the same column and age class, months having the same upper case letter (XYZ) are not significantly different (Tukey's multiple comparison test, $\alpha = 0.10$).

[d] tr = trace < 0.0001 g/10 sweeps.

P = 0.053) in August than in July on 3-year-old fields (Table 9). Three-year-old fields had significantly more (ANOVA, P = 0.003) Orthopteran biomass than did 1-, 2-, 4-, and 5-year-old fields in June (Table 9). No significant differences in Orthopteran biomass were detected among age classes in July or August (ANOVA, P = 0.824 and 0.107, respectively).

No significant differences (P > 0.10) were detected in Coleopteran biomass among months within age classes (Table 9). Two-, 3-, 4-, and 5-year-old fields had significantly more (ANOVA, P < 0.001) Coleopteran biomass than did 1-year-old fields in August (Table 9).

Hemipteran biomass on 1-year-old fields was significantly greater (ANOVA, P = 0.056) in June than in July (Table 9). Hemipteran biomass was significantly greater in June than in July and August on 3-, 4-, and 5-year-old fields (ANOVA, P < 0.001). Two-year-old fields had more (ANOVA, P = 0.061) Hemipteran biomass than did 1-, 3-, 4-, and 5-year-old fields in July (Table 9). One- and 2-year-old fields had more (ANOVA, P < 0.001) Hemipteran biomass than did 3-, 4-, and 5-year-old fields in August.

Homopteran biomass was significantly greater (ANOVA, P = 0.021) in June than in July on 1-year-old fields (Table 9). Homopteran biomass was significantly greater (ANOVA, P < 0.01) in June than in July and August on 3-year-old fields. Three-year-old fields had significantly more (ANOVA, P < 0.001) Homopteran biomass in June than did 1-, 2-, 4-, and 5-year-old fields (Table 9). Homopteran biomass was significantly greater (ANOVA, P = 0.054) on 2- and 3-year-old fields than on 1-, 4-, and 5-year-old fields in August.

Dipteran biomass was significantly greater (ANOVA, P = 0.017) on 3-year-old fields in June than in July and August (Table 9). In June, the Diptera biomass was significantly lower (P = 0.032) on 5-year-old fields than on 1-, 2-, 3-, and 4-year-old fields (Table 9). No differences (P > 0.10) were detected among age classes in July and August for Dipteran biomass.

Total invertebrate biomass was significantly greater (ANOVA, P = 0.076) in August than in July on 1-year-old fields (Table 9). Three-year-old fields had significantly more invertebrate biomass in June than in July and August and significantly lower biomass in July than in June and August (ANOVA, P < 0.001) (Table 9). Total invertebrate biomass was greater (ANOVA, P < 0.001) in June than in July and August on 5-year-old fields. In June, more invertebrate biomass (ANOVA, P = 0.001) was found on 3-year-old fields than on 1-, 2-, 4-, and 5-year-old fields (Table 9). In July, invertebrate biomass was significantly greater (ANOVA, P = 0.051) on 2-year-old fields than on 5-year-old fields. One-year-old fields had significantly more invertebrate biomass than did 3-, 4-, and 5-year-old fields in August, and 5-year-old fields had significantly less invertebrate biomass than did 2-, 3-, and 4-year-old fields (ANOVA, P < 0.001).

Invertebrate data pooled for the entire sampling period (June, July, and August) showed significant differences (P < 0.10) among age classes in Orthopteran, Coleopteran, Homopteran, and Dipteran biomass (Table 10). Orthopteran biomass was significantly greater (ANOVA, P = 0.068) on 2-year-old fields than 5-year-old fields. One-year-old fields had significantly more Coleopteran biomass than 3-, 4-, and 5-year-old fields, and

Table 10. Mean invertebrate biomass in g/10 sweeps (standard errors) on 1- through 5-year-old Conservation Reserve Program Fields in Gratiot County, Michigan, 1992.

Age	Arachnida[a]	Lepidoptera	Orthoptera	Coleoptera	Hemiptera	Homoptera	Diptera
1	0.0004A	0.0079A	0.0167AB	0.0070A	0.0129A	0.0077AC	0.0019AB
	(tr[b])	(tr)	(tr)	(tr)	(0.0001)	(tr)	(tr)
2	0.0004A	0.0037A	0.0227B	0.0041AC	0.0108A	0.0146AB	0.0017AB
	(tr)	(tr)	(tr)	(tr)	(0.0001)	(0.0001)	(tr)
3	0.0012A	0.0035A	0.0116AB	0.0025BC	0.0143A	0.0153B	0.0020A
	(tr)	(tr)	(0.0001)	(tr)	(0.0001)	(0.0001)	(tr)
4	0.0006A	0.0029A	0.0079AB	0.0023BC	0.0129A	0.0050C	0.0014AB
	(tr)	(tr)	(0.0001)	(tr)	(0.0001)	(tr)	(tr)
5	0.0007A	0.0024A	0.0050A	0.0016B	0.0083A	0.0065C	0.0009B
	(tr)	(tr)	(tr)	(tr)	(tr)	(tr)	(tr)

[a] Within the same column, age classes having the same upper case letter are not significantly different (Tukey's multiple comparison test, $\alpha = 0.10$) (Sokal and Rohlf 1981).

[b] tr = trace < 0.0001 g/10 sweeps.

5-year-old fields had significantly less Coleopteran biomass than did 1-, 2-, 3-, and 4-year-old fields (ANOVA, $P < 0.001$). Homopteran biomass was significantly greater on 3-year-old fields than on 1-, 4-, and 5-year-old fields, where as 2-year-old fields had significantly more Homopteran biomass than did 4- and 5-year-old fields (ANOVA, $P = 0.002$). Dipteran biomass was significantly greater (ANOVA, $P = 0.058$) on 3-year-old fields than on 5-year-old fields.

Within Age Class Comparisons - Vegetation

Across all age classes, the vertical and horizontal cover of vegetation in adjacent cover type strata on each CRP field differed (MANOVA, $P < 0.10$) from the structure of vegetation in the same adjacent cover type stratum on fields of the same age (Table 11). For example, the vegetation within the woodlot stratum on fields 1, 9, 10, 11, and 12 (5-year-old-fields) was significantly different (MANOVA, $P = 0.0005$) structurally. Differences (MANOVA, $P < 0.10$) were detected across all age classes and within all adjacent cover type strata (Table 11).

Soils

Twenty-four soils types were found on the 18 CRP study sites with up to 7 soil types occurring on a single field (Table 12) (Appendix Ea-r). Mean soil diversity values for each field ranged from 0.13 to 1.38 (Table 12). The most common soils on the study sites were Perrington B and C, Capac and Capac Variant, and Marlette B and C. The potential of each study site to support openland and forest wildlife or grain and grass production ranged from 1.00 (poor) to 3.00 (good) (Table 13). The correlation between plant species diversity and soil diversity was not significant ($r=-0.0114$) (Fig. 5).

Table 11. Comparisons (MANOVA) (Sokal and Rohlf 1981) of horizontal and vertical cover of vegetation on edges of Conservation Reserve Program (CRP) fields in Gratiot County, Michigan, 1992, stratified by adjacent cover types and age classes.

Age	Cover Type Stratum	CRP Fields Compared	Probability
1	row crop	91A, 91C	0.0031
1	open field	91A, 91B	0.0655
2	CRP	90A, 90B	0.0702
3	row crop	89A, 89C	0.0001
4	row crop	6,7	0.0103
4	residential	5,6	0.0977
5	residential	1,8,9	0.0001
5	woodlot	1,9,10,11,12	0.0005
5	CRP	1,8,12	0.0023
5	open field	10,11	0.0356

Table 12. Diversity of soils (Shannon-Weaver index) (Shannon and Weaver 1949) on Conservation Reserve Program study sites in Gratiot County, Michigan, 1992.

Field	Soil[a] (%)	Soil Diversity
1	MaB (45), MaC (34), Cr (13), RdA (6), Gd (2)	1.24
5	PkC (63), PkB (24), CaA (3)	0.74
6	PkC (59), ItA (35), Le (4), Ke (2)	0.89
7	MaB (50), MaC (47), CaA (1.5), Ad (1.5)	0.83
8	PkC (64), PkB (27), MeA (9)	0.85
9	PkC (92), ItA (8)	0.28
10	MtB (57), PkB (16), PtC (14), Ph (13)	1.15
11	CcA (69), Ph (31)	0.62
12	CcA (97), Ph (3)	0.13
89A	PkC (77), ItA (23)	0.54
89B	MaB (56), SpC (23), MaC (15), CaA (6)	1.11
89C	PkC (51), MeA (31), PkB (19)	1.02
90A	PkC (94), ItA (6)	0.23
90B	ItA (47), PkC (44), PkB (9)	0.93
90C	Ed (52), Ph (19), CaA (16), Be (5), Cr (4), Bob (3), SeA (1)	1.38
91A	MaB (47), CaA (40), Ad (13)	0.99
91B	TdA (41), Ve (26), PtB (25), Ke (8)	1.26
91C	MaB (36), CaA (26), MaC (24), Ad (14)	1.34

[a] See appendix F for a description of soils.

Table 13. Relative suitability of Conservation Reserve Program study sites in Gratiot County, Michigan, to provide wildlife habitat and agriculture production. Calculated as the sum of the percentage of each soil on study sites multiplied by the ability of soils to produce wildlife and agricultural commodities (Feenstra 1979).

Field	Openland Wildlife	Forested Wildlife	Forest Production	Grain Production	Grass Production
1	2.77	2.77	2.77	2.52	2.77
2	3.00	3.00	3.00	2.41	3.00
5	3.00	3.00	3.00	2.37	3.00
6	2.94	2.94	2.94	1.98	2.94
7	2.97	2.97	2.97	2.50	2.97
8	3.00	3.00	3.00	2.36	3.00
9	3.00	3.00	3.00	2.00	3.00
10	2.01	2.59	2.59	1.57	2.01
11	2.00	2.69	2.69	2.31	2.00
12	2.00	2.97	2.97	2.05	2.00
89A	3.00	3.00	3.00	2.00	3.00
89B	2.77	2.77	2.77	2.38	2.77
89C	3.00	3.00	3.00	1.98	3.00
90A	3.00	3.00	3.00	2.00	3.00
90B	3.00	3.00	3.00	2.91	3.00
90C	1.12	1.68	1.68	1.26	1.64
91A	2.74	2.74	2.74	2.74	2.74
91B	1.49	1.08	1.00	1.00	1.75
91C	2.72	2.72	2.72	2.48	2.72

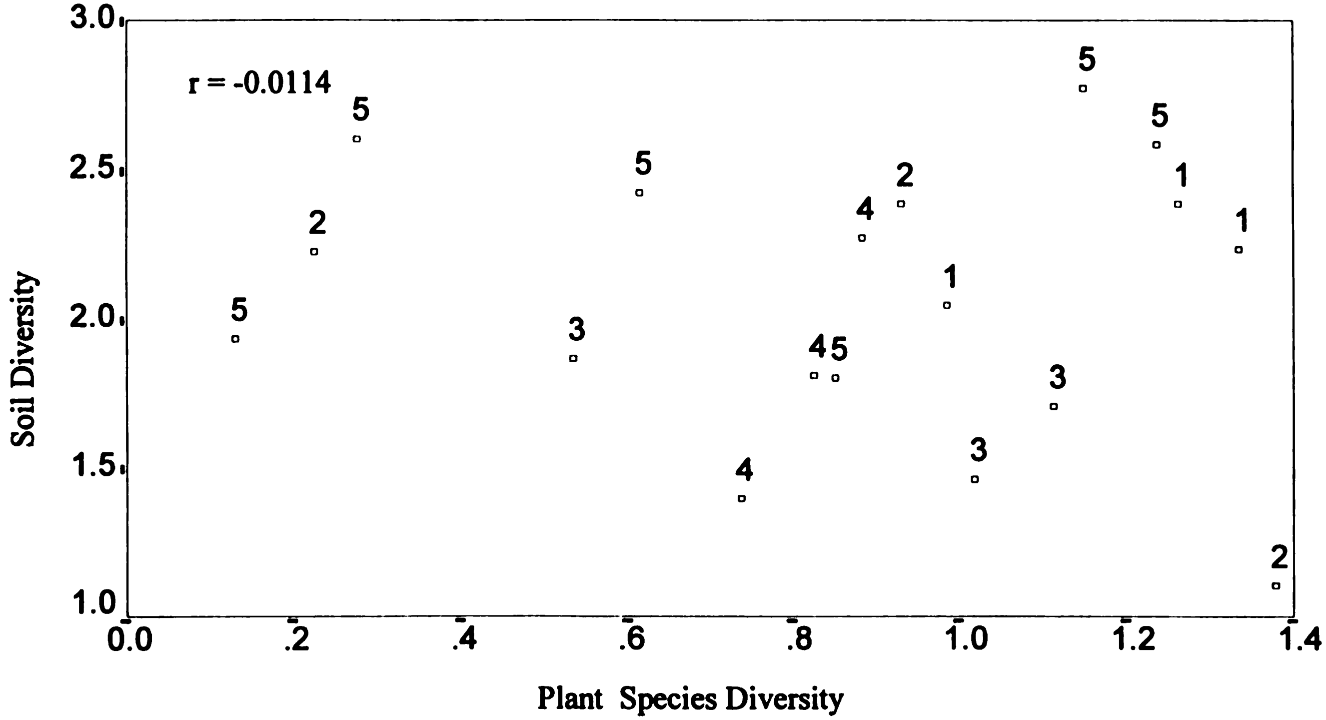

Figure 5. Correlation between soil diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the diversity of plant species (Shannon-Weaver Diversity Index) found on Conservation Reserve Program (CRP) study sites in Gratiot County, Michigan, 1992. Numbers denote number of years study sites have been enrolled into CRP.

Bird Species Diversity

Bird species diversity showed a significant ($P = 0.029$) negative correlation with study site age ($r = -0.48$) (Fig. 6) (Millenbah 1993). Correlation of bird species diversity on each CRP field with the diversity of cover types within a 259-ha landscape around the fields (landscape diversity) showed little association ($r = 0.08$, $P = 0.448$) (Fig. 7). A weak nonsignificant correlation was found between bird species diversity and the potential of soils on each study site to support openland and forest wildlife ($r = 0.0939$, $P = 0.434$ and $r = -0.2306$, $P = 0.294$, respectively) and to support forest, grain, and grass production ($r = -0.2410$, -0.1254, and 0.1436, $P = 0.294$, 0.496, and 0.434, respectively) (Figs. 8-12). Weighting the study site potentials by the area of the field had little effect on the associations; non significant ($P > 0.10$) correlations ranged from $r = -0.2839$ to 0.1428. The correlations between bird species diversity and soil diversity on the study sites showed no significant association ($r = 0.0860$, $P = 0.964$) (Fig. 13).

Landscape Area Defined

The regression of landscape diversity values from the samples of the county that ranged in size from 1 ha to the entire county (n=313) against the area of each sample yielded the regression equation: $\text{Diversity} = -0.196 * \log(\text{Area})^{0.671}$. The first line with slope of 0 tangent to the regression line indicated that 268-ha (intersection point) is the management unit area for resource managers to address for maintaining a diversity of wildlife habitats in agricultural landscapes. Two-hundred and fifty nine ha was used as the base management unit for ease of application of the models to preexisting land and road layout.

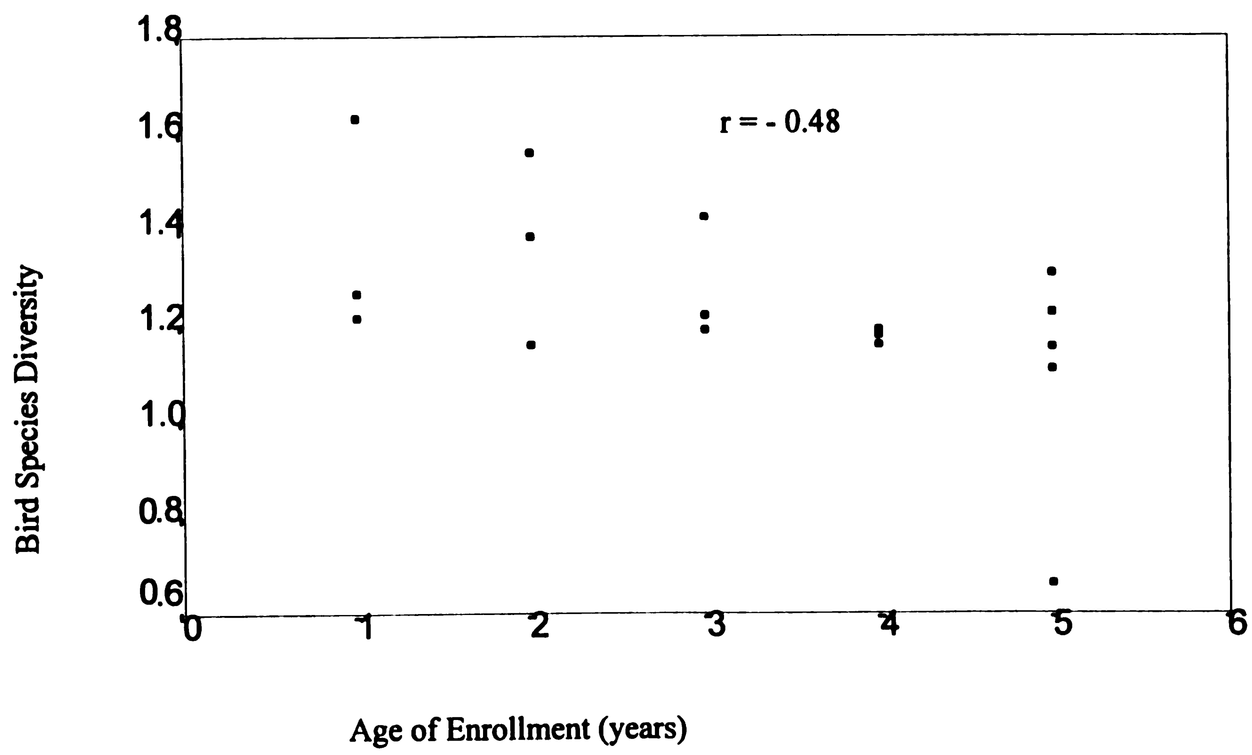

Figure 6. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the number of years study sites have been enrolled in the Conservation Reserve Program in Gratiot County, Michigan, 1992.

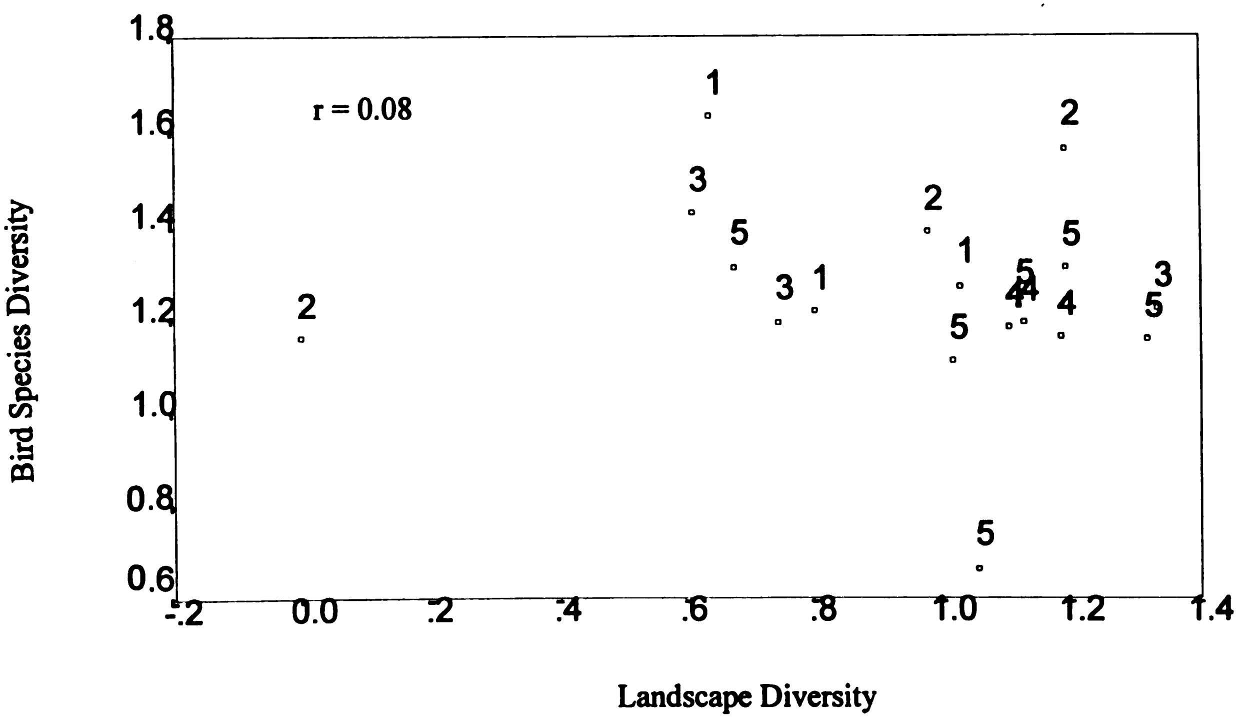

Figure 7. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the landscape diversity (Shannon-Weaver Diversity Index) of 259-ha areas centered around Conservation Reserve Program (CRP) study sites in Gratiot County, Michigan, 1992. Numbers denote number of years study sites have been enrolled into CRP.

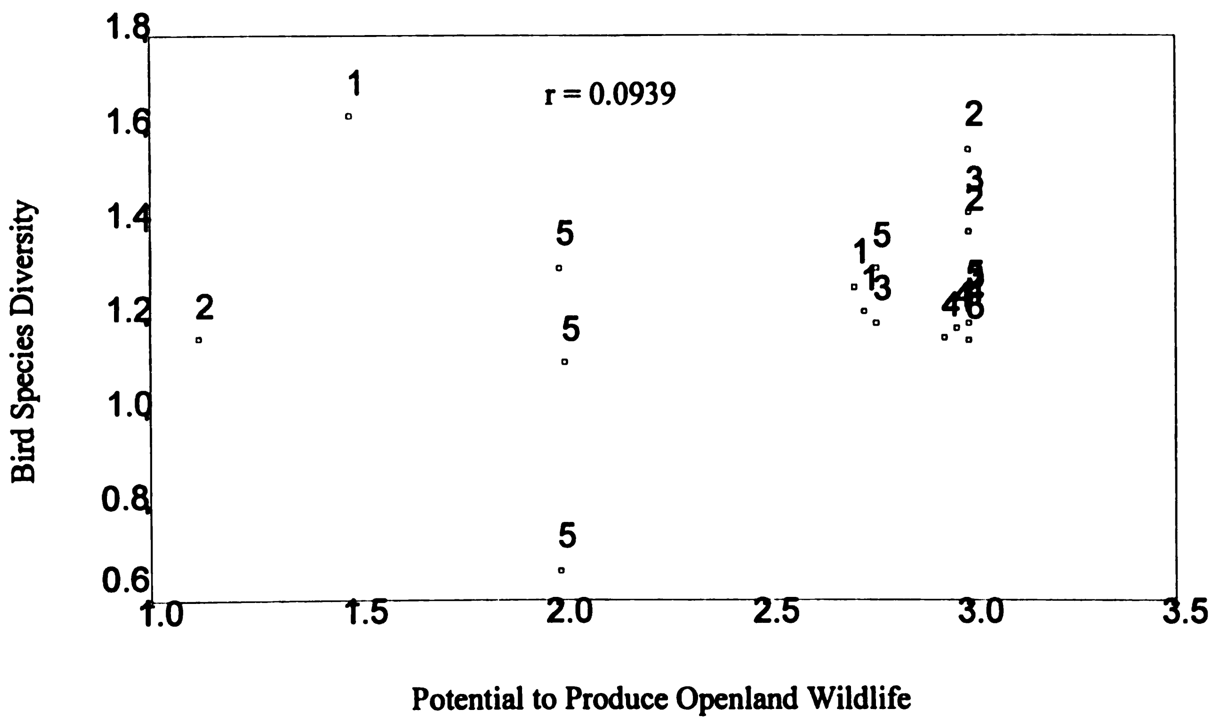

Figure 8. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the potential of soil types on each study site to produce openland wildlife (Fig. 4, Table 13). Number denotes the number of years study sites have been enrolled into the Conservation Reserve Program in Gratiot County, Michigan, 1992.

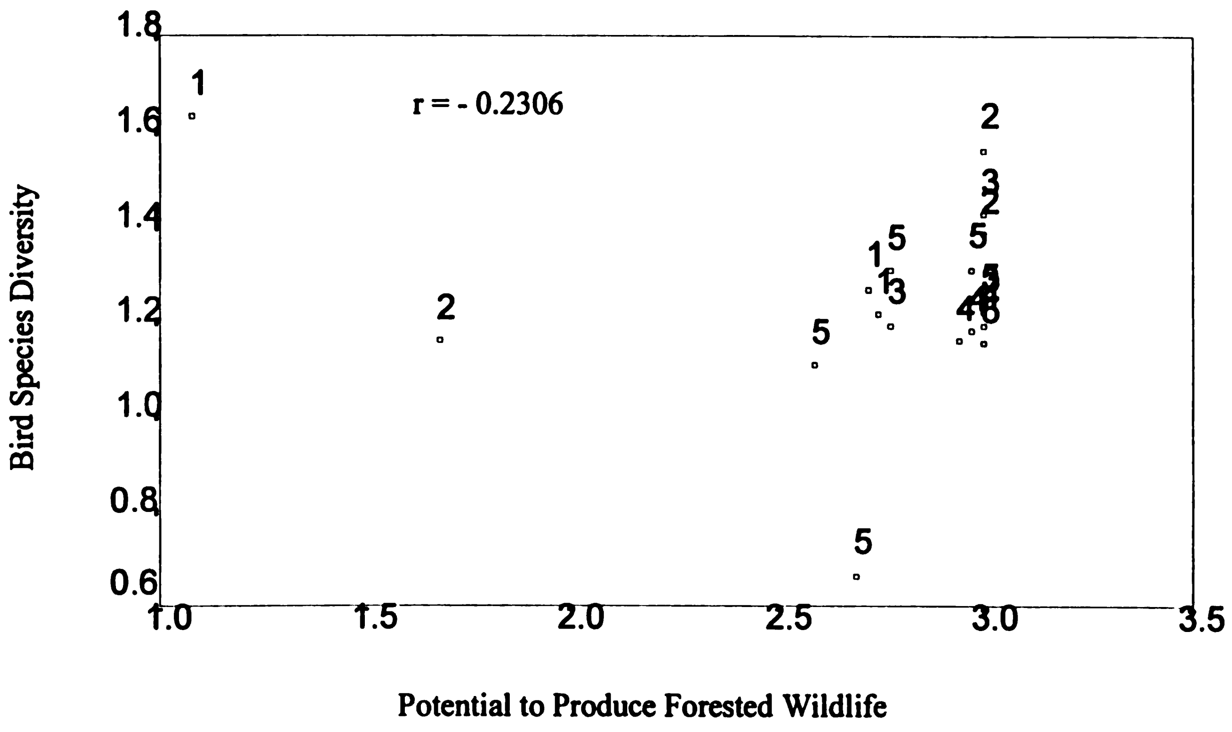

Figure 9. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the potential of soil types on study sites to produce forested wildlife (Fig. 4, Table 13). Number denotes the number of years study sites have been enrolled into the Conservation Reserve Program in, Gratiot County, Michigan, 1992.

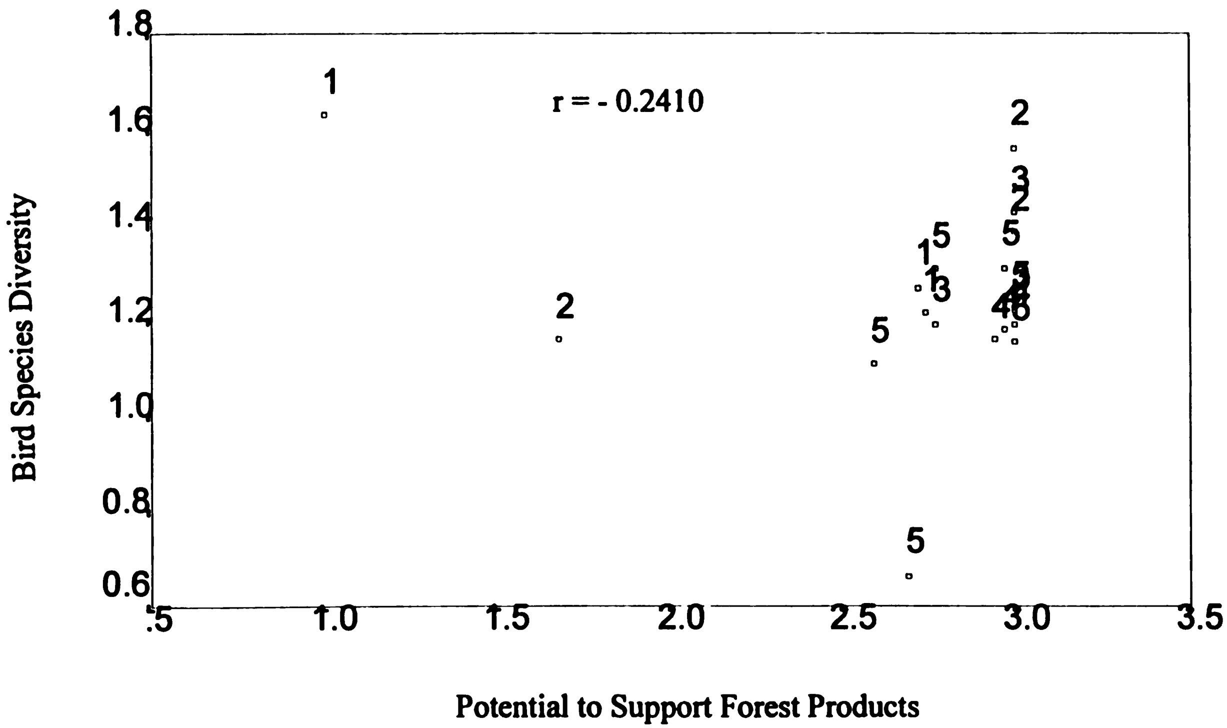

Figure 10. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the potential of soils on Conservation Reserve Program (CRP) study sites to support forest production (Fig. 4, Table 13). Number denotes the number of years study sites have been enrolled into CRP in Gratiot County, Michigan, 1992.

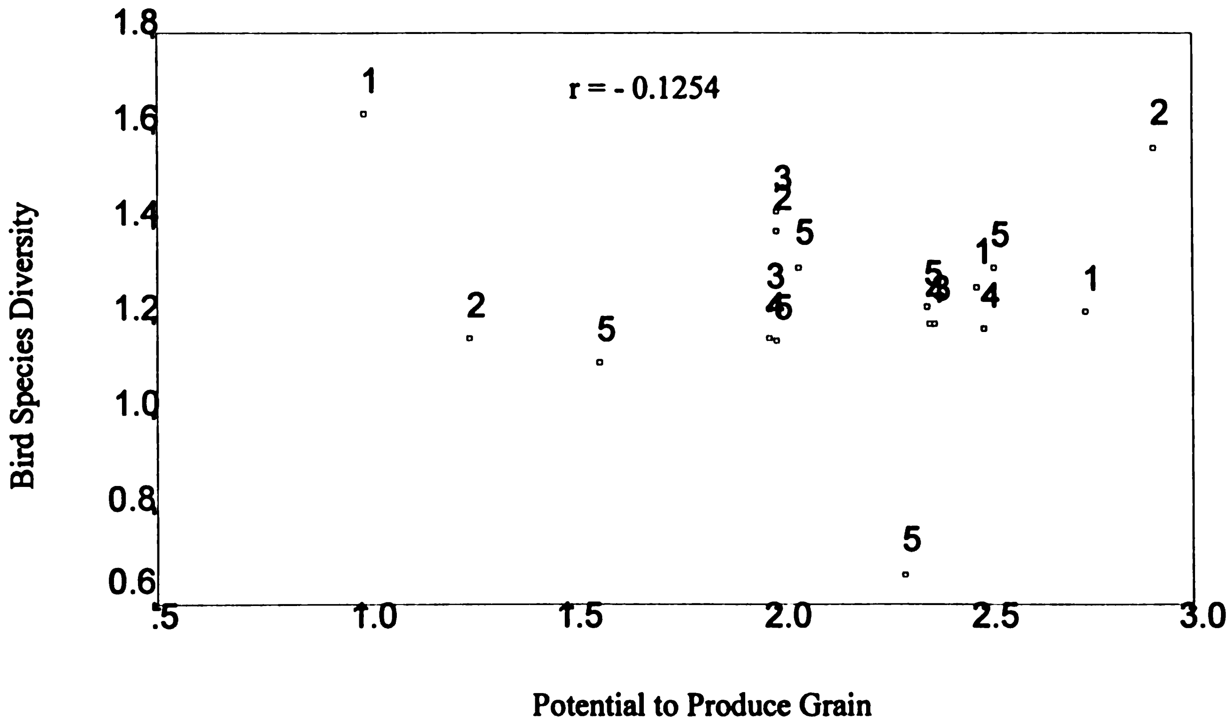

Figure 11. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the potential of soils on Conservation Reserve Program (CRP) study sites to support grain production (Fig. 4, Table 13). Number denotes the number of years study sites have been enrolled into CRP in Gratiot County, Michigan, 1992.

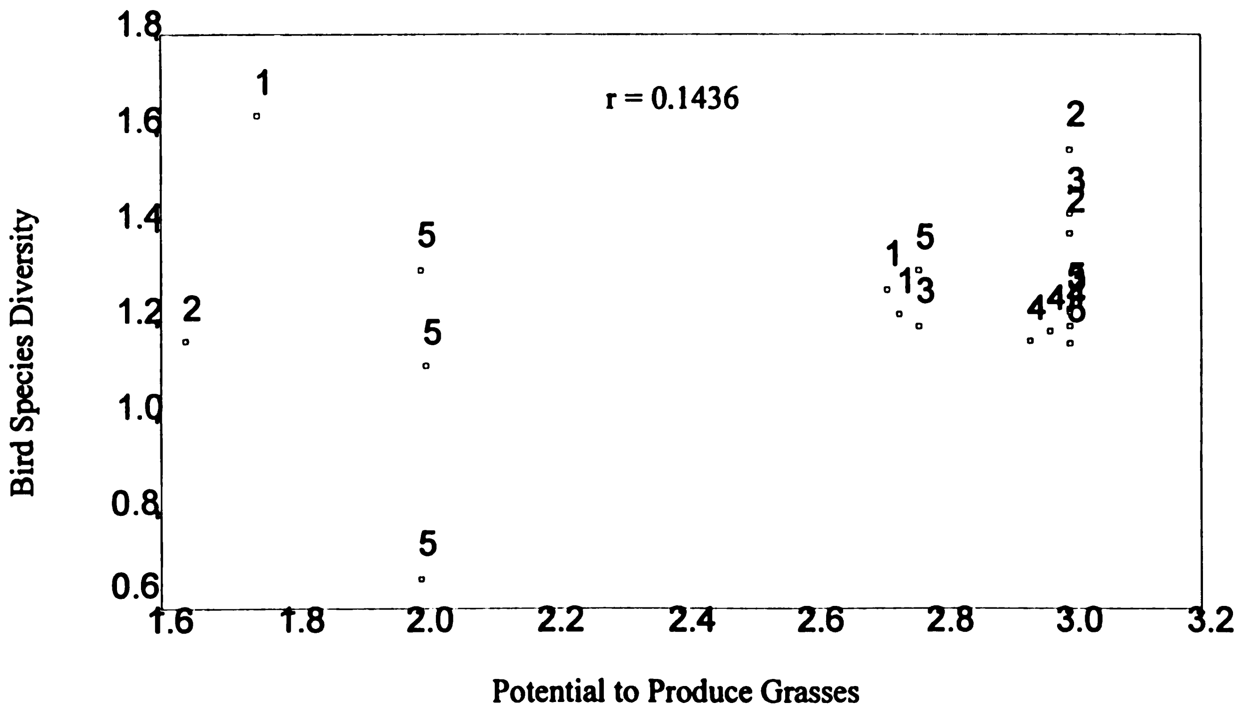

Figure 12. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the potential of soils on Conservation Reserve Program (CRP) study sites to support grass production (Fig. 4, Table 13). Number denotes the number of years study sites have been enrolled into CRP in Gratiot County, Michigan, 1992.

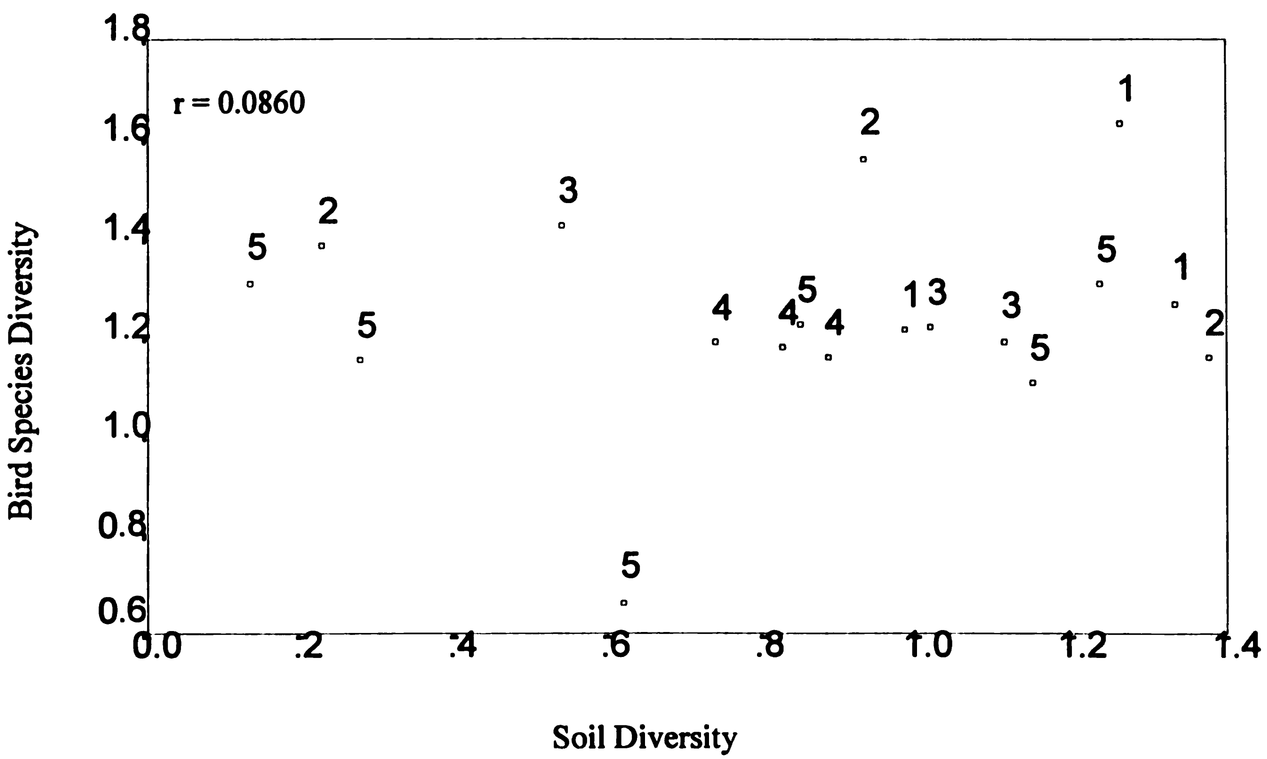

Figure 13. Correlation between bird species diversity (Shannon-Weaver Diversity Index) (Shannon and Weaver 1949) and the diversity of soils (Shannon-Weaver Diversity Index) found on Conservation Reserve Program (CRP) study sites. Number denotes the number of years study sites have been enrolled into CRP in Gratiot County, Michigan, 1992.

Impact of CRP Lands on Landscape Diversity

The average landscape derived from the 113 samples (259 ha) of Gratiot County contained 6% open fields, 3% residential area, 63% active agricultural production, 14% woodlots, and 13% CRP (Fig. 14). Within the 113 samples of the county, the proportion in open fields ranged from 0 to 38%, residential areas from 0 to 30%, agricultural production from 0 to 99%, woodlots from 0 to 87%, and CRP from 0 to 55%. Examining the samples with CRP reverted back to agricultural production, the average landscape composition contained 76% agricultural production, with the ranges for all classifications remaining the same except for CRP (Fig. 14).

The landscape diversity of each 259-ha sample area in Gratiot County was not different (paired-t, $P = 0.5567$) from the landscape diversity of the same samples recalculated with CRP lands classified as agricultural lands. The county was reexamined as 2 distinct regions based on the quantity of wooded vegetation and agricultural production, 1) the Maple River flooding region (dense woodlands) and 2) the remainder of the county (predominantly agriculture). The diversity of each 259-ha area was significantly different (paired-t, $P = 0.0984$) within the region outside Maple River flooding when CRP was examined once as grassland, then again as agriculture.

Models for Prediction of CRP Impact on Wildlife

The regression of the 17 landscape based variables against avian and mammalian relative abundance and diversity, invertebrate biomass and diversity, and the densities of the 4 grassland bird species yielded linear predictor models for the data (Appendix G). Bird diversity was predicted ($r^2 = 0.7375$, $P = 0.0160$) as a function of field size, field

A.

Percent of Landscape

B.

Percent of Landscape

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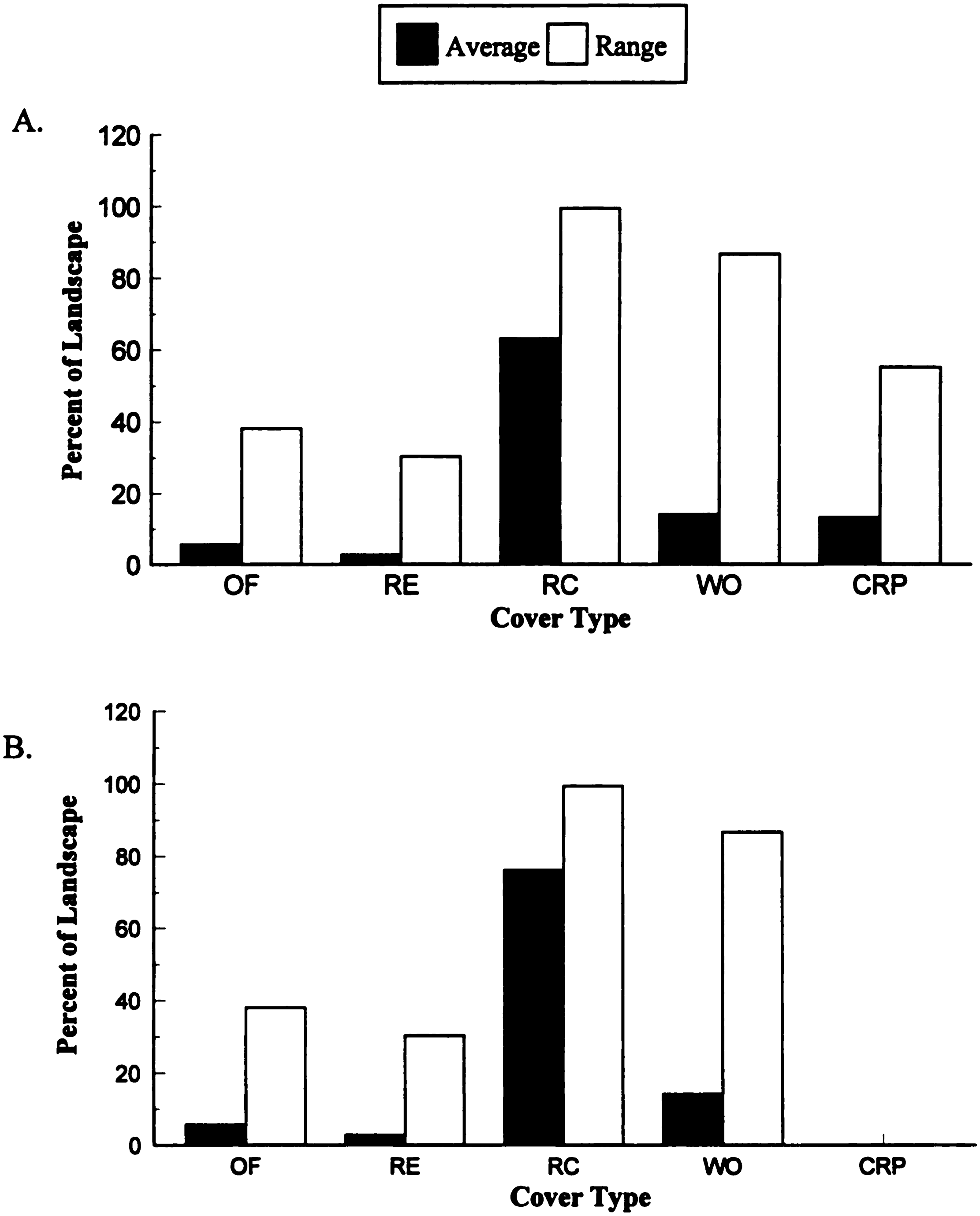

Figure 14. A) Landscape composition (mean and range) derived from one-hundred thirteen 259-ha samples of Gratiot County, Michigan with lands enrolled into the Conservation Reserve Program (CRP), 1992. B) Same landscapes without lands enrolled into CRP. OF = old field, RE = residential, RC = row crops, WO = woodlots.

age, the proportion of residential area in the landscape (259-ha), the proportional of open fields other than CRP and agriculture, the diversity of cover types adjacent to CRP study sites, and the amount of agriculture adjacent to the study area (Appendix G). The relative abundance of bird species was predicted ($r^2 = 0.8755$, $P > 0.0001$) as a function of the size and age of the study site, the proportion of agriculture and other CRP lands in the landscape, and the diversity of the landscape (Appendix G).

Mammal diversity was predicted ($r^2 = 0.9155$, $P = 0.0041$) to be a function of the potential of the study site soils to produce openland wildlife, the proportion of woodlots in the landscape, and the amount of open fields other than CRP and agriculture lands adjacent to study areas (Appendix G). The relative abundance of mammals was predicted ($r^2 = 0.8757$, $P = 0.0019$) by 2 variables, the proportion of woodlots in the landscape, and the proportion of agriculture in the landscape (Appendix G).

Four variables described invertebrate diversity ($r^2 = 0.7640$, $P = 0.0010$): the diversity of the soils on study sites, field age, the proportion of open fields in the landscape, and the amount of other CRP lands adjacent to study areas (Appendix G). Invertebrate biomass was described ($r^2 = 0.8410$, $P = 0.0004$) by the diversity of soils on study areas, the diversity of landscapes, and the age of study areas (Appendix G).

The models to predict the density of 4 grassland bird species did not always meet the assumption that all variables within the model were significant. The sedge wren and grasshopper sparrow models contained a variable that was not significant (Appendix G). In the sedge wren model ($r^2 = 0.5133$, $P = 0.0542$), the variable describing the proportion of CRP lands in landscapes was not significant ($P = 0.1705$); however, the age of study areas, diversity of soils on study areas, and the amount of CRP lands adjacent to study sites were significant ($P = 0.0247$, 0.0785, and 0.0330, respectively) (Appendix G). The proportion of open fields other than CRP and agriculture lands was not significant ($P = 0.1251$) in the grasshopper sparrow model ($r^2 = 0.7004$, $P = 0.0038$), where as the proportion of residential lands in landscapes, openland wildlife potential, and age of fields were significant ($P = 0.0534$, 0.0249, and 0.0961, respectively) (Appendix G).

The bobolink and savanna sparrow models met all the assumptions: the model and all variables in the model were significant, the error degrees of freedom were twice the regression degrees of freedom, and the model could be explained biologically. The density of bobolinks was predicted ($r^2 = 0.7990$, $P = 0.0004$) by the amount of residential areas surrounding study areas, the age of study areas, and the proportions of woodlots and residential areas in landscapes (Appendix G). Savanna sparrow abundance was a function of 5 variables: field age, diversity of landscapes and the proportion of woodlots, residential areas, and open fields other than CRP and agriculture in landscapes (Appendix G).

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DISCUSSION

Avian species diversity and abundance were discussed in detail by Millenbah (1993) and mammalian diversity and abundance were discussed by Furrow (1994). Both studies also examined the influence of age since enrollment on the vegetation structure of CRP fields (Millenbah 1993, Furrow 1994). Results and data from these studies form part of the baseline for modeling the impacts of surrounding landscape features on avian, mammalian, and plant communities associated with CRP fields.

Invertebrates

The life histories of the invertebrate orders encountered on CRP study sites indicate that younger fields with a greater diversity of plant species should have more invertebrate biomass than older (4- to 5-year-old), less diverse fields (Evans 1988, Parmenter et al. 1991). The data support this hypothesis (Tables 9 and 10). Lepidopteran, Coleopteran, and Homopteran biomass tended to be greatest on young fields (1- to 3-years-old) and decrease as fields aged (Table 10). This may be due to the greater forb component found on younger fields (Millenbah 1993). Many species within these orders have evolved to be host specific with vegetation for reproductive purposes (egg laying on or within plant fibers) (Daly et al. 1978), the greater number of forb species on younger fields may provide more sites for reproduction, thereby, enhancing productivity. The overall biomass of these orders would decrease as fields age, reducing the number of invertebrate species supported by the vegetation (Anderson 1964, Kemp et al. 1990a, Kemp et al. 1990b).

The remaining differences in invertebrate biomass may also be functions of life history traits within each order. Arachnid biomass showed significant differences among age classes only in August (Table 9). Trends in the data indicate that 1-, 2-, 4-, and 5-year old fields had fewer spiders than did 3-year-old fields. This could be a function of colonization rate and Arachnid life requisites. First, spiders may be slower than other invertebrates to colonize entire CRP fields because they do not fly, therefore, not reaching maximum numbers for 3 years. Secondly, with the relatively short life cycle of arachnids, going through several generations each year (Daly et al. 1978), the decrease in biomass after 3 years may be a function of the lower biomass of arachnid prey found on older (4- to 5-year-old) fields (Table 10).

Lepidopteran biomass tended to decrease throughout the summer, with significant declines from June to August on 3- through 5-year-old fields (Table 9). The consistent decline in Lepidopteran biomass may be due to the life cycle of many Lepidoptera. The life cycle of Lepidoptera is similar to many other invertebrates, an adult lays eggs that hatch into larva, which develop into pupae before emerging as adults. Lepidoptera go through diapause over winter, with adults emerging in early summer (June) to lay eggs and die (Daly et al. 1978). This increasing adult mortality may explain the relatively large biomass found in June and subsequently lower biomass throughout the summer.

Orthopteran biomass showed a steady increase in biomass throughout the summer (Table 9). The life history of the short-horned grasshopper (Acrididae) may help explain these results. Based on anecdotal observation, short-horned grasshoppers were the most abundant family in the samples. Grasshoppers mate in August, then deposit eggs into the ground. The eggs hatch in early spring, where the young spend the entire summer maturing before reproducing in August (Daly et al. 1978). Therefore, the period of greatest abundance for grasshoppers should be August and the least, June (McQuillan and Treson 1981).

Orthopteran biomass was also significantly greater on 2-year-old fields than 1-year-old fields, with less biomass detected as fields aged (Table 9). One-year-old CRP fields would contain mostly adults that have migrated from neighboring fields because of the recent disturbance of the soil. The reduced biomass on 2-year-old fields may be a function of the reproductive habits of grasshoppers. Grasshoppers lay their eggs in the soil in August to over winter (Daly et al. 1978). If large amounts of plant litter were present on the field, this may hinder egg deposition and reproduction. Millenbah (1993) demonstrated a trend in increasing litter depth as fields aged.

Hemipteran biomass was significantly greater in early summer (June) than in July or August on most age classes of fields (Table 9). One common family of grassland Hemiptera, Lygaeidae (chinch bugs), over winters in groups at the base of vegetation (Daly et al. 1978). In the spring, invertebrates disperse from winter roost sites to lay eggs and die. The trend of greater biomass in June may be a function of this migration. Biomass would decrease throughout the summer as adult mortality increases.

Dipteran biomass was significantly greater on 3-year-old fields than on other age classes (Table 10) and was generally more abundant in June than in July and August

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(Table 9). One common family of flies, Techinidae, lay eggs on emerging leaves early in the summer (Daly et al. 1978). This behavior allows eggs to be eaten by caterpillars throughout the summer. The eggs hatch inside the caterpillar, where the larva feed internally on its host before emerging (Daly et al. 1978). The activity of adults in June, laying eggs on vegetation and dying, may explain the results from the data. The difference in biomass between 3-year-old fields and other age classes may simply be a function of the very low biomass encountered across all fields (Table 10). Diptera are a hard order to sample with sweep nets because individuals tend to escape readily (S. Gage, Michigan State University, Department of Entomology, pers. commun.).

Within Age Class Comparisons

Within each age class (1-5), fields with similar adjacent cover types exhibited differences in plant structure (Table 11). Young fields have been recently disturbed, and are highly susceptible to invasion by other plant species from adjacent vegetation types, including roadsides, abandoned fields, brushy pastures, and logged woodlots within the surrounding landscape (Janzen 1983). The relatively flat topography of the region (Feenstra 1979) may allow long distance movement of wind-born plant seeds. Similarly, effects of fencerows and hedgerows could not be accounted for due to small sample sizes within each age class. Hedgerow effects may be important, having been found to support seed sources capable of invading highly disturbed soils (Best et al.1990).

Soil type or quality on each field may have influenced influence plant species composition (Beirne 1995). Twenty-two soils were found on the 18 study sites, with as many as 7 different soils occurring on a single study site (Table 12). A greater diversity of soils on a single field may result in a high degree of variability in plant structure across a field. Soil quality has been found to influence the composition, structure, and growth of different plant species (Beirne 1995). Therefore, differences in plant structure among fields with different diversities of soils would be expected, as was seen in this study. Finally, the existing seed source available in the soil may be important to the establishment of exotic species such as Queen Anne's lace (*Daucus carota*). These species were abundant in early age classes of CRP fields (Millenbah 1993, Furrow 1994).

The low number of replicates in each age class and the influence of surrounding vegetation could account for much of the variability in the horizontal and vertical structure within age classes (Table 11). The encroachment of woody species was evident by the accumulation of woody plant cover found predominantly on 5-year-old fields (Millenbah 1993). Also, different initial planting mixtures within the 5-year-old fields (1987 enrollment) (Table 2) may have influenced structure. Fields 1, 8, 9, and 10 were planted with 6.7 kg/ha of grasses (timothy and orchard grass) and 3.3 kg/ha of forbs (alfalfa and sweet clover), field 12 was planted with 5.7 kg/ha of grasses and 4.4 kg/ha of forbs, and field 11 was planted with 3.4 kg/ha of grasses and 4.4 kg/ha of forbs (Table 2). The greater proportion of grasses seeded into fields 1, 8, 9, and 10 may provide a relatively denser grass canopy the first growing season. Conversely, the heavier forb to grass seeding on fields 11 and 12 may produce a denser forb canopy that may persist longer than on the fields planted with proportionally more grass.

Similarly, the time or season of initial planting may also effect initial development and germination of species (G. Dudderar, Michigan State University, Department of Fisheries and Wildlife, pers. commun.), however, information on this attribute was not collected in this study. Fields initially planted in the fall could have lower germination rates than fields planted in the spring due to over winter seed mortality, small mammal herbivory, and wind dispersal of seeds. Lower germination rates on fall planted fields could produce fields with regions of both sparse and dense vegetation.

Soils

As the diversity of soils on a study site increased, it would seem intuitive that the diversity of plant species would also increase because exploitation rates of species differ among soils (Beirne 1995). However, results of this study indicate similar trends do not exist on CRP study sites (Fig. 5). This may be a function of the distribution of soils across fields and the corresponding sampling strategy. If the interspersion of soils on fields with fewer soil types was greater than fields with a greater diversity of soils, the systematic sampling strategy used for sampling vegetation may have crossed more soil types on the low diversity fields than the high, resulting in more vegetation species being identified on the fields with lower soil diversity. Visual estimation of soil distribution and interspersion indicates a high degree of variation and interspersion among study sites (Appendix Ea-r). Similarly, the differences among soils on high soil diversity sites may be slight, meaning, the 2 adjacent soils are very similar in the plant species they will support, while low soil diversity sites may have very different soils adjacent to one another that allow for a greater number of plants species to exist, however, no data was collected in this study to look at this attribute. For instance, a high soil diversity field may contain 5 soils that are all loamy soils that support similar plant species. A low soil diversity field may only have 3 soils, but each soil is different from the other 2, one soil being a sand, one a loam, and one a clay soil. Finally, the vegetation surrounding CRP sites may influence the number of species available for establishment (Janzen 1983). Those fields surrounded by many different cover types may contain more species due to immigration than fields surrounded by 1 or 2 cover types.

Bird Species Diversity

Avian diversity varies with vegetation structure that develops following disturbance (Cody 1985). CRP fields are highly disturbed lands that may be idled from production for a 10-year period. Young fields, the most recently disturbed, had the greatest avian diversity values, while older fields supported a lower diversity of bird species (Fig. 6). Millenbah (1993) noted that avian diversities showed no significant correlation with individual vegetation variables. The correlation of avian diversity to field age showed a significant negative correlation (Fig. 6). Although the correlation was significant, only 48% of the variation in the data was explained by the successional stage of the fields. Much of the remaining variation maybe a function of the surrounding landscape (Appendix G).

There are many examples indicating that increased plant complexity in a landscape is associated with greater avian diversity (MacArthur and MacArthur 1961, Cody 1968, Karr and Roth 1971). Similarly, it is often accepted that a greater diversity of cover types within a landscape will contain a greater number of fundamental ecological niches, allowing for greater species diversity (Hunter 1990, Robbins et al. 1992). Data indicated that the diversity of the surrounding landscape had minimal association with bird species diversity on CRP fields (Fig. 7). As areas of habitats (cover types) are reduced in size they are increasingly susceptible to significant immigration of animal and plants from nearby vegetation types (Janzen 1983). A diverse landscape of very small habitat patches may be "homogenized" by the immigration and emigration of species among all cover types to meet their life requisites. Similarly, as habitat patches decrease in size, the ability of that patch to maintain a viable population for any “interior” species also decreases (Janzen 1983).

Bird species diversity showed a nonsignificant positive correlation with the potential of CRP study sites to produce openland wildlife and grass (Figs. 8 and 12) and a negative association with the fields ability to produce forest wildlife, trees, and grain (Figs. 9-11). This indicates that enrolling lands with high openland and grass production potential into CRP rather than fields with low openland and grass production potentials would provide greater bird diversity for the set-aside dollar.

Similarly, no association was detected between bird species diversity and soil diversity on study sites (Fig. 13). If bird species diversity is affected by plant species diversity and/or field age (Millenbah 1993), and soil diversity did not impact plant diversity (Fig. 5), then it would follow that no relationship between bird species diversity and soil diversity would exist.

Landscape Area Defined

When relating species densities and distribution to habitats within a landscape, the choice of appropriate scale is often overlooked (Fry 1989). One limitation of many studies in agricultural settings is the focus on detailed studies of small plots with little regard to the management of the surrounding landscape or home range of species being investigated. This is probably due to the fact that within any landscape there are many landowners managing small parcels of land for different objectives.

The regression of the landscape diversity values from the various sized samples extracted from the county against the log of the area of each sample yielded the regression equation; $\text{Diversity} = -0.196 * \log(\text{Area})^{0.671}$. An analysis of the regression line indicates that approximately 259-ha (640 ac) is the optimal management unit area for resource managers to address. This may be expected since most animals found in agricultural landscapes tend to have home ranges < 259-ha (Cody 1985).

Management of areas of 259-ha presents unique problems for resources managers because animal species in agricultural landscapes rely on lands under multiple ownership for fulfillment of life requisites in these areas. The average farm size in Gratiot County in 1987 was 113 ha, with 52% of farms ranging from 20 - 73 ha (U.S. Dept. of Agric. 1987b).

Figure 15 illustrates an example of how CRP impacts the diversity of wildlife species within agricultural landscapes. The diversity of cover types expected within the landscape when CRP is present is listed on the upper right hand corner of the figure. Comparatively, if the land enrolled into CRP was diverted back into agricultural production, the landscape diversity would be reduced (difference = 0.19). Results demonstrate the ability of the CRP to fragment the continuous expanses of agricultural fields and diversify the landscape. The increases in the diversity of cover types within a

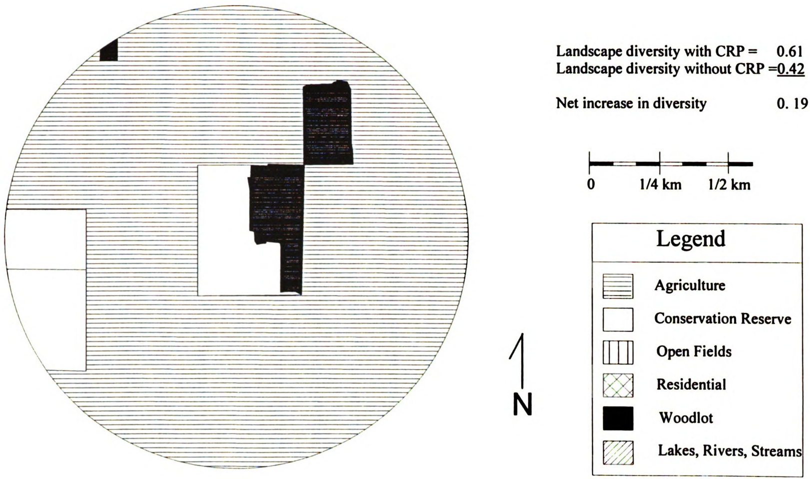

Figure 15. Impact of the Conservation Reserve Program (CRP) on the wildlife diversity of the landscape in a low diversity ecosystem. Net increase in diversity is the difference in diversity values with CRP fields and with CRP replaced into agricultural production.

landscape would positively alter the composition and diversity of wildlife species in that landscape (Robbins et al. 1992).

Some regions (NW and Maple River regions) of Gratiot County, however, are ecologically very complex (Fig. 16), being composed of numerous soil and vegetation types and wildlife species. These regions are characterized by many small, contiguous woodlots interspersed among wetlands and grasslands. The diversity of species in these areas is greater than regions of intensive agriculture (Fig. 15), however, CRP could still potentially increase bird species diversity nearly 10%. In regions of greater diversity, CRP fields of various age classes could be interspersed throughout geographic areas to maintain grassland specific wildlife species which require a diversity of grassland successional stages. Although the diversity of species may be high in some regions, the lack of grasslands within these areas prevents the presence of species that utilize grassland habitats. Therefore, if maintaining biodiversity is a management goal, natural resource managers from all agencies and organizations should work in conjunction with landowners to identify and maintain cover types which are limited in the landscape (Westman 1990).

All too often resource managers attempt to manage species or communities in total isolation from the surrounding landscape (Fry 1989). Terrestrial landscapes in Michigan are a mosaic of heterogeneous land forms, vegetation types, and land-uses (Urban et al. 1987). Human dominated landscapes may change according to non-ecological factors such as the price of commodities or transfer of ownership, disrupting

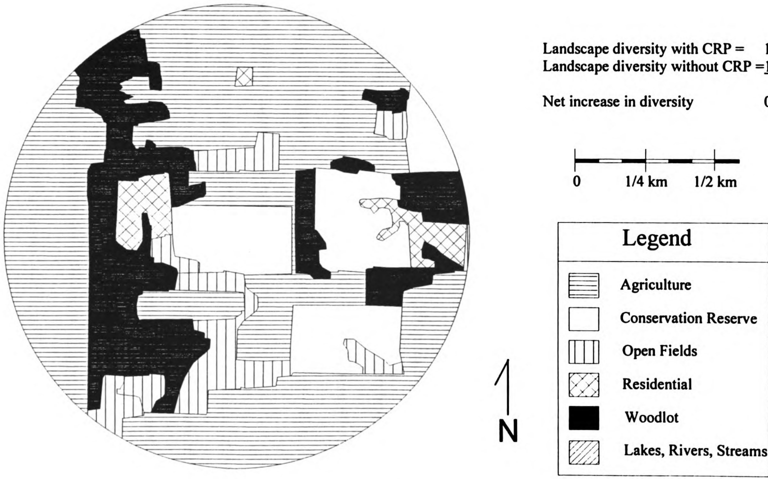

Figure 16. Impact of the Conservation Reserve Program (CRP) on the wildlife diversity of the landscape in an already highly diverse ecosystem. Net increase in diversity is the difference in diversity values with CRP fields and with CRP replaced into agricultural production.

ecosystem processes and/or structure, leaving only habitat generalist species (Urban et al. 1987). An integration of small-scale detailed studies with investigations of larger-scale processes will increase the effectiveness of natural resource managers. Use of the field level analysis of the vegetation structure and wildlife composition of CRP fields by Millenbah (1993) and Furrow (1994), integrated with the examination of the landscape scale vegetation patterns, provides a more complete picture of the impacts of changing land-use patterns on wildlife and plant dynamics.

Human dominated landscapes can provide natural experiments from which we can learn a great deal about ecological scaling in natural systems (Urban et al. 1987). Specifically, studies of man dominated landscapes may indicate how inter-patch distance, connectivity, and spatial configuration modify patch interactions to enhance or deter species diversities and abundance's (Urban et al. 1987). Specifically, CRP offer researchers the opportunity to examine the positive and negative effects of fragmentation and patch dynamics.

Impact of CRP Lands on Landscape Diversity

Within any landscape, vertebrate species are distributed as a function of the plant cover types that constitute their habitat (Hunter 1990). Therefore, a landscape may be viewed as a mosaic comprised of patches of differing vegetation types. This mosaic fluctuates with successional changes and land-use practices. Examination and management of these mosaics for a variety of vegetation types may have a significant impact on regional biota. Also, a diverse avian community is often associated with complex plant communities distributed over broad geographical areas (Robbins et al. 1992).

Habitat fragmentation, the breaking up of habitat into non-contiguous segments, may pose the single most significant challenge to natural resource managers for the management of interior wildlife species (Temple and Wilcox 1986). Clearing of large tracts of forested land for agriculture was largely responsible for the initial population increases and geographical range expansions of many grassland bird species in the eastern United States (Hurley and Franks 1976, Andrle and Carroll 1988). Today, the impact of intensive agricultural practices that may threaten the existence of grassland birds may partially be alleviated through the CRP because CRP can provide relatively large units of undisturbed grasslands required for nesting and brood rearing (Griscom and Snyder 1955, Laughlin and Kidde 1985). Therefore, the potential impact of CRP on the regional diversity of avian species may be significant.

The landscape diversity of the 259-ha samples of the county was not significantly different (P = 0.5567) from the landscape diversity when CRP fields were reclassified as agricultural lands and landscape diversity recalculated. The CRP fields were examined both as grasslands and agricultural land to determine the impacts on landscape diversity if landowners remove their lands from CRP at the expiration of the 10-year Farm Bill contracts. Putting CRP lands back into agricultural production after contracts expire has been noted by other researchers as a potentially common practice (Kurzejeski et al. 1992). Missouri researchers documented that 95% of all landowners with land enrolled in the CRP intend to divert enrolled fields into agricultural production at the termination of the

10-year contracts (Kurzejeski et al. 1992). Similarly, only 12% of the landowners of the CRP fields studied in Gratiot County plan to maintain the fields in grass, without haying or mowing (Millenbah 1993).

Although Gratiot county has shown a large and continued enrollment of agricultural lands into CRP, the distribution of these lands has not been even across the county. The southeastern corner of the county is composed of the Maple River State Game Area and, therefore, is dominated by dense woodlands. Agriculture is very limited within the regions around the flooding. Therefore, the county was stratified into 2 regions, the Maple River flooding region and the remainder of the county. Thirteen of the 259-ha samples within the flooding region were removed from the original data set because they fell into the Maple River flooding region and the analysis with and without CRP rerun. The diversity of the landscape was significantly different ($P = 0.0984$) outside the Maple River region when CRP was examined once as grassland, then again as agriculture. Increasing the diversity of an agricultural landscape by enrolling lands into CRP can significantly increase the diversity of plants and animals within those landscapes (Figs. 15 and 16). This also indicates that bird species diversity in regions with vast expanses of woodland may not be significantly affected by enrolling lands into CRP. The relatively high diversity of bird species in woodlands could “mask” the effects of CRP, where as, the lower bird diversity of agricultural regions could be greatly enhanced by a CRP bird community.

Models

Individual bird species have long been associated with different plant communities (Adams 1908, Beecher 1942). More recent bird habitat studies have led to studies in which actual structural features within a habitat have been quantified and associated with different bird species (MacArthur and MacArthur 1961). Stages in plant community succession have also been associated with changing bird species composition (ex. Bond 1957, Anderson 1979, Millenbah 1993), however, most studies have focused primarily on forested ecosystems. The models developed from these data indicate that both landscape and field specific variables are important in predicting the diversity and abundance of birds, invertebrates and mammals. Models predicting overall avian diversity and abundance, invertebrate diversity and the abundance of the individual grassland bird species were partially dependent upon the successional development, or age of CRP fields. Nearly half the bird species abundance's in woodlots of Illinois were strongly influenced by vegetation variables (Blake and Karr 1984). Millenbah (1993) found bird species diversity to decrease as CRP fields aged. Similarly, she found bird densities to also decrease with field age (Millenbah 1993).

The models indicate that the age of CRP fields negatively influenced the densities of bobolinks, grasshopper sparrows and savanna sparrows, but enhanced sedge wren density. Younger CRP fields (1- to 3-years-old) are codified by a combination of forb cover and large quantities of bare ground, while older fields (4- to 6-years-old) were composed of grasses and deep litter cover (Millenbah 1993, Furrow 1994). Bobolinks build nests on the ground in dense stands of clover and alfalfa and utilize travel lanes to and from the nest through concealing vegetation (Harrison 1975). Large amounts of litter (> 40% cover) on older fields may inhibit movement of females along the ground, thus, impacting nesting. Savanna and grasshopper sparrows build nests in hollow depressions on the ground where the nest is well concealed by overhead vegetation (Harrison 1975). Grasshopper sparrows tend to prefer clover and alfalfa as concealing cover plants (Harrison 1975). The denser 2- through 4-year-old fields may provide the dense vegetation required for these species, while older fields may have too broken a canopy when fields develop into near monocultures of grass. Sedge wrens weave spherical nests of grass and sedge into grasses about 1 m above the ground (Harrison 1975). The greater proportion of forbs on younger fields may not be suitable for nesting conditions, while older fields that contain greater proportions of grass (Millenbah 1993) may be more suitable.

The regressions of bird diversity and abundance suggest that the size of CRP fields is important in determining the overall composition and abundance of grassland bird species (Appendix G). Both bird diversity and abundance showed a positive relationship with field size, indicating that larger fields support a greater abundance and diversity of birds. Similarly, field size was positively associated with both bird diversity and abundance in the models (Appendix G). The literature is replete with examples of isolated stands fitting the species area relationship developed by MacArthur and Wilson (1967). Therefore, maintaining landscape diversity using the largest possible blocks of CRP in the landscape would provide a greater abundance and diversity of grassland bird species than many small parcels.

Overall invertebrate diversity and biomass were both negatively influenced by field age, indicating that the greater diversity of plant species found on young CRP fields (1- to 3-years-old) may provide more microhabitats than the less diverse older fields. Webb and Hopkins (1984) found small heathlands in England to hold a greater richness of invertebrates due to the increased invasion of plant species from surrounding vegetation. Larger less diverse heathlands held few invertebrate species (Webb and Hopkins 1984). The negative relationships with both bird and invertebrate diversity to field age suggest that bird diversity could also be related to invertebrate diversity. Therefore, investigation of the relationship between bird diversity and invertebrate diversity could provide insight into factors other than plant characteristics influencing habitat selection by grassland birds.

Several models that incorporate varying degrees of landscape habitat heterogeneity have been proposed to explain the relationship between local and regional patterns in the distribution and abundance of species (Collins and Glenn 1990). Arnold (1983) found an increasing number of bird species in the landscape as the landscape became more diverse. Similarly, he found that the existence of some species was dependent on the availability of different cover types being present in the landscape (Arnold 1983). Land-use practices have been found to influence the distribution and abundance of loggerhead shrikes (*Lanius ludovicianus*) in Illinois (Smith and Kruse 1992). These examples indicate that variables other than stand or field variables may be influencing the composition and structure of flora and faunal assemblages on CRP fields. Often studies examine stands or fields without consideration of the surrounding la

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landscape. Regression equations developed in this study indicate landscape variables, such as the proportion and diversity of cover types in the landscape, are important in the determination of bird, mammal, and invertebrate diversity and abundance (Appendix G). They are also important factors in determining the relative abundance of specific grassland bird species (Appendix G).

The number of different cover types and the distribution of those cover types within the landscape influenced bird diversity positively (Appendix G). This supports Arnold's (1983) findings that some bird species require certain cover types within the landscape to exist. Large quantities of active agricultural production adjoining CRP fields (50-100% of field surrounded) negatively affected bird diversity. This may be due to the very low bird diversity values found on agricultural fields (0.76) as compared to the CRP fields (mean 1.27, range 0.67-1.63) (Campa et al. 1991, 1992, 1993). Examination of mean bird diversity of the landscape indicated a decline in bird diversity if the proportion of agriculture in the landscape increased with increasing landscape size (Fig. 17). Smith and Kruse (1992), however, found loggerhead shrike abundance was positively correlated with the amount of pasture-hay meadows and cover crops, and negatively correlated with the amount of harvested cropland and woodland in the Illinois landscape. This indicates that certain species could have adapted to or benefit from modern agricultural practices. None of the regressions of individual grassland bird species abundance indicate a positive relationship with increasing agricultural production (Appendix G).

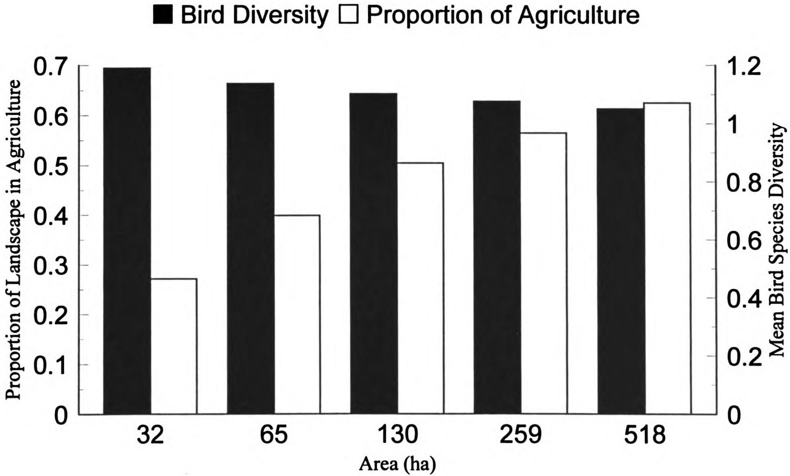

Figure 17. Mean bird species diversity per unit area and proportion of landscape in agricultural production in different size regions surrounding Conservation Reserve Program lands in Gratiot County, Michigan, 1992.

When open fields comprised 2/3 or more of the landscape near CRP fields the diversity of birds on CRP fields was reduced. This may be an artifact of reducing other, more highly diverse, cover types in the surrounding landscape, rather than the amount of open fields. If the diversity of birds on CRP is enhanced by the proximity of different cover types, the reduction of different cover types by increasing the amount of open fields would limit the source of species available to utilize the fields. For example, if woodlots acted as a source of non-grassland specific avian species that use CRP fields, the reduced amount of woody vegetation in the landscape due to large quantities of less, diverse open fields (Ryan 1986) would decrease the source of species available for using CRP fields.

Residential areas positively influenced the diversity of avian species on CRP fields. Many residential areas contained bird feeders and often bird houses, artificially enhancing the diversity and abundance of bird species. Many of these species associated with residential areas, such as tree swallows and American robins, ventured into CRP fields when they may not normally occur.

Overall bird abundance increased as the quantity of active agricultural lands and area of CRP increased, and the landscape diversified. Agricultural lands may act as feeding grounds, with an abundant food supply to support larger numbers of birds. Birds from grassland vegetation types have been documented feeding in surrounding agricultural fields in Illinois (Best et al. 1990).

The diversity of mammals on CRP fields was influenced mostly by soil quality or the ability of soils to produce openland wildlife (Feenstra 1979). Open fields adjacent to CRP fields enhanced small mammal diversity and seemed to act as population sources for seve

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several mammalian species. Woodlots, however, tended to reduce diversity values. Only *Peromyscus* spp. were common to both woodlots and CRP fields, as well as all the other cover types, all other small mammal species were specific to a single cover type (Furrow 1994).

The quantity of woodlots and agricultural production in the landscape surrounding study sites positively influenced mammalian abundance. *Peromyscus* spp. were the dominant species on younger (1- to 2-year-old) CRP fields (Furrow 1994). Similarly, they were the only species to be found across all adjacent cover types, including young CRP fields (Furrow 1994). Being such a ubiquitous species, they would be expected to populate the recently disturbed CRP fields before other, more habitat specific species. Therefore, woodlots, agricultural fields, and some other vegetation types may act as source populations of *Peromyscus* spp., with individuals immigrating onto young CRP fields.

Limitations

In most ecosystems, a few species are highly abundant while proportionally more species are rare (MacArthur and Wilson 1967). A species' relative abundance in samples may be influenced by many factors, including range of habitats sampled, home range or territory size, interactions with other species, and location of study site within the geographic range of the species. The less frequently a species is counted, the more variable its measured response to habitat parameters and less reliable the resulting model (Stauffer and Best 1990). This may be a consideration in this study, abundances of individual grassland bird species ranged from 0 birds seen/ha to a high of 2.65 birds seen/ha for savanna sparrows (mean = 0.75 birds seen/ha for savanna sparrows; 0.21 birds seen/ha for the 4 grassland species combined).

Delineating relationships between wildlife diversity and abundance and environmental features has become a major focus of concern among wildlife researchers and is gaining use by land managers (Stauffer and Best 1990). However, models of wildlife habitat relationships are often limited due to limited reliable and representative data. Additionally, the range of environmental conditions selected for study in developing models is often determined by constraints imposed upon the sampling design. Small samples sizes and limited number of fields sampled within the county prevented examination of many factors, such as fencerow impacts on CRP communities. Fencerows with large quantities of tall woody vegetation may impact grassland birds by providing habitat for parasitic species, such as cowbirds (*Molothrus ater*) (Best et al. 1990).

Application of the Models

Land managers have specific objectives for the production of wildlife species within a landscape. Depending upon those objectives, managers can achieve the greatest impact on wildlife for the government CRP dollar by determining the impact lands enrolled into the program will have on the wildlife community. Using validated models to provide simulations of the impacts of candidate fields on the wildlife community would allow managers to optimize the effects of CRP.

Often, more landowners request enrollment into CRP than funds can support. Government resource managers must determine which lands enrolled into CRP would best meet the objectives of CRP and resource managers. Models developed from these data allows resource managers to determine the impacts of enrolling different tracts of land into CRP. Using these models, examination of a selected section of Gratiot County surrounding a perspective CRP field where no CRP is currently enrolled would indicate the bird species diversity per unit area for the section (Fig. 18). In this example, bird diversity without CRP would be 1.22. If in this selected section, more than 1 field was available for enrollment into CRP, resource managers could examine the impacts of enrolling 1 or multiple fields into CRP by simulating different configurations of the landscape. If multiple fields were available for enrollment and only 4 could be enrolled, different combinations of fields enrolled could be examined (Fig. 19) until the maximum benefit to bird species diversity was obtained. Simulations of enrolling 4 fields into CRP indicates that a maximum mean bird species diversity for this section could reach 1.33, thereby, increasing diversity by 0.11 (Fig. 20).

Resource managers overseeing public lands are not the only individuals that may utilize these models. Private lands biologists could use these models to enhance and maintain species diversity within and across landscapes. If the landscape used above existed, the diversity of bird species that was enhanced by enrolling 4 fields into CRP (Fig. 19), over time, would decline steadily (Fig. 21). The diversity bobolinks, grasshopper sparrows, and savanna sparrows would show a trend similar to overall diversity; declining over time (Fig. 22). Millenbah (1993) and Furrow (1994) suggested manipulating CRP fields after 3-5 years or altering enrollment of fields to provide a diversity of age classes within the landscape. If the 4 fields were manipulated to provide

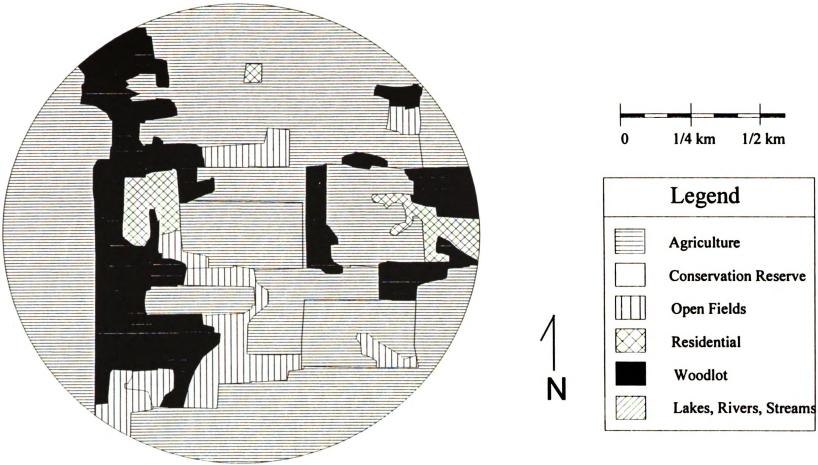

Figure 18. Randomly selected section of Gratiot County, Michigan without land enrolled into the Conservation Reserve Program (CRP). The mean avian diversity per unit area of this landscape is 1.22.

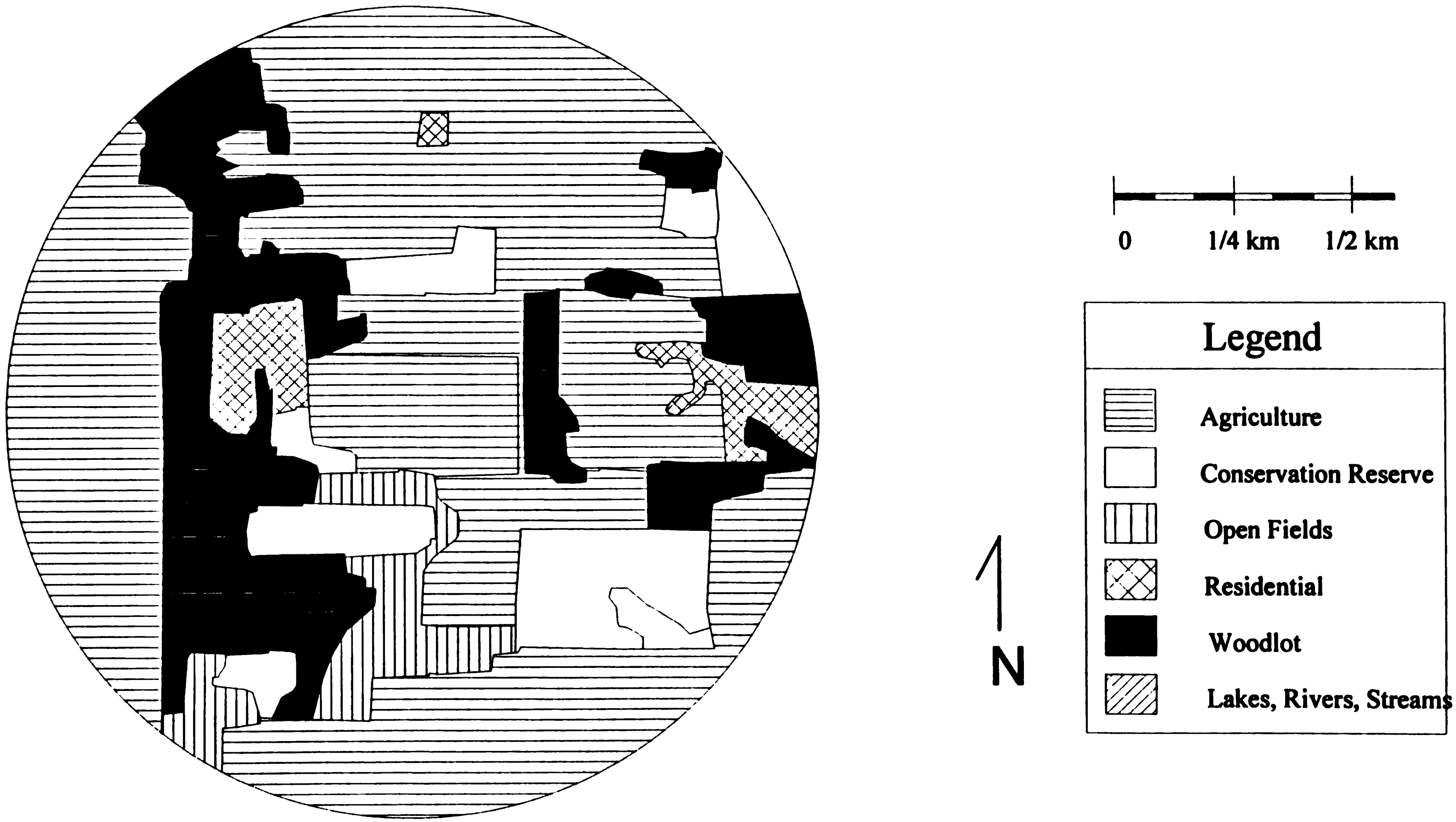

Figure 19. Simulation of enrolling 4 fields into the Conservation Reserve Program (CRP) in a randomly selected section of Gratiot County, Michigan that was originally devoid of CRP land. The mean avian diversity per unit area in this landscape would be 1.27.

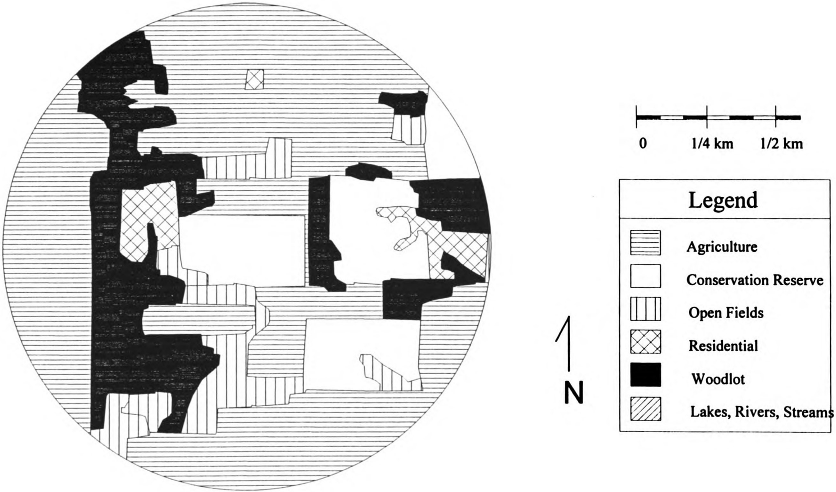

Figure 20. Simulation of enrolling 4 fields into the Conservation Reserve Program (CRP) in a randomly selected section of Gratiot County, Michigan that originally was devoid of CRP land. The mean avian diversity per unit area in this landscape would be 1.33.

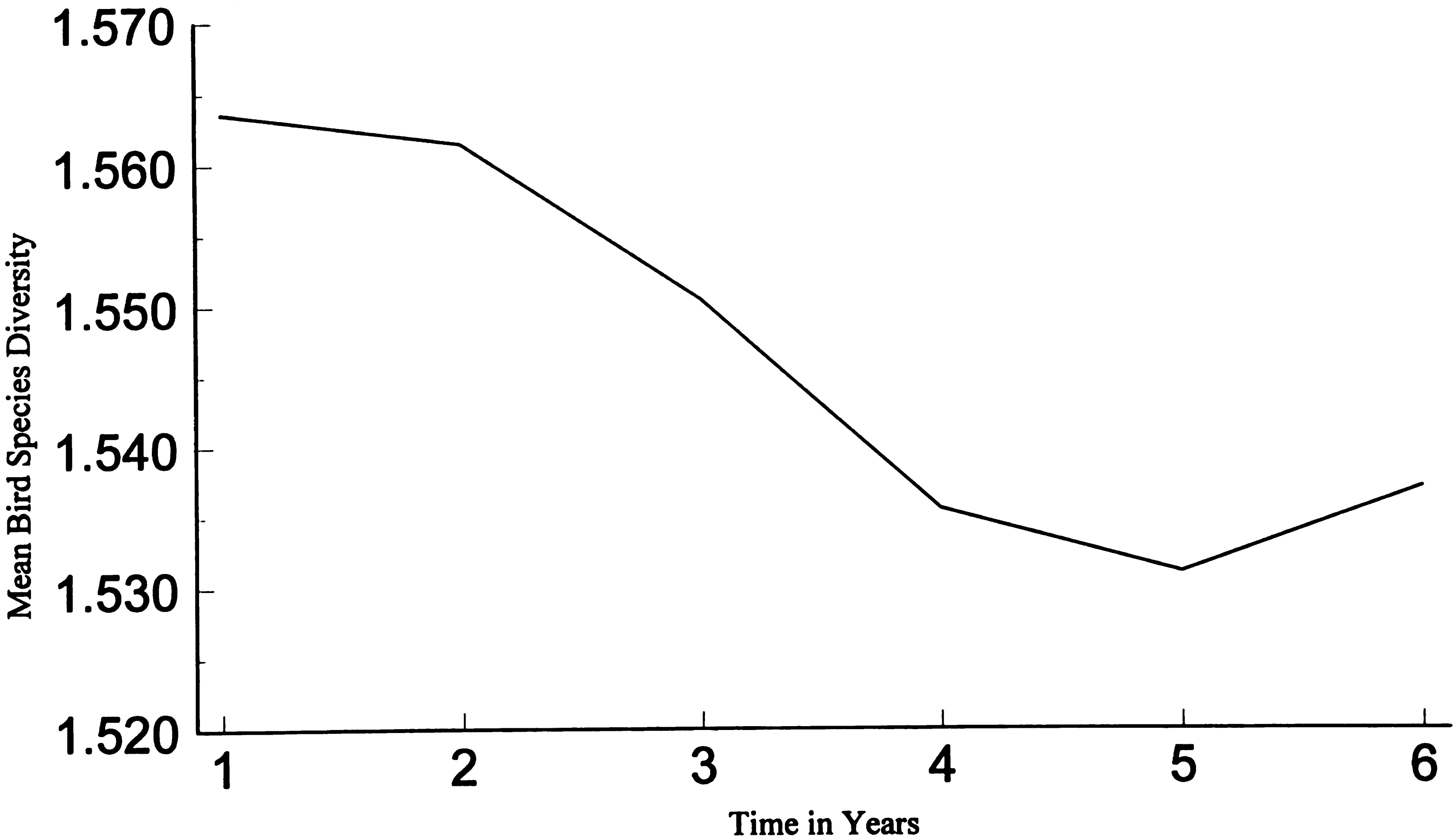

Figure 21. Mean bird species diversity over time for a randomly selected section of Gratiot County, Michigan, in which 4 fields have been enrolled into the Conservation Reserve Program at the same time.

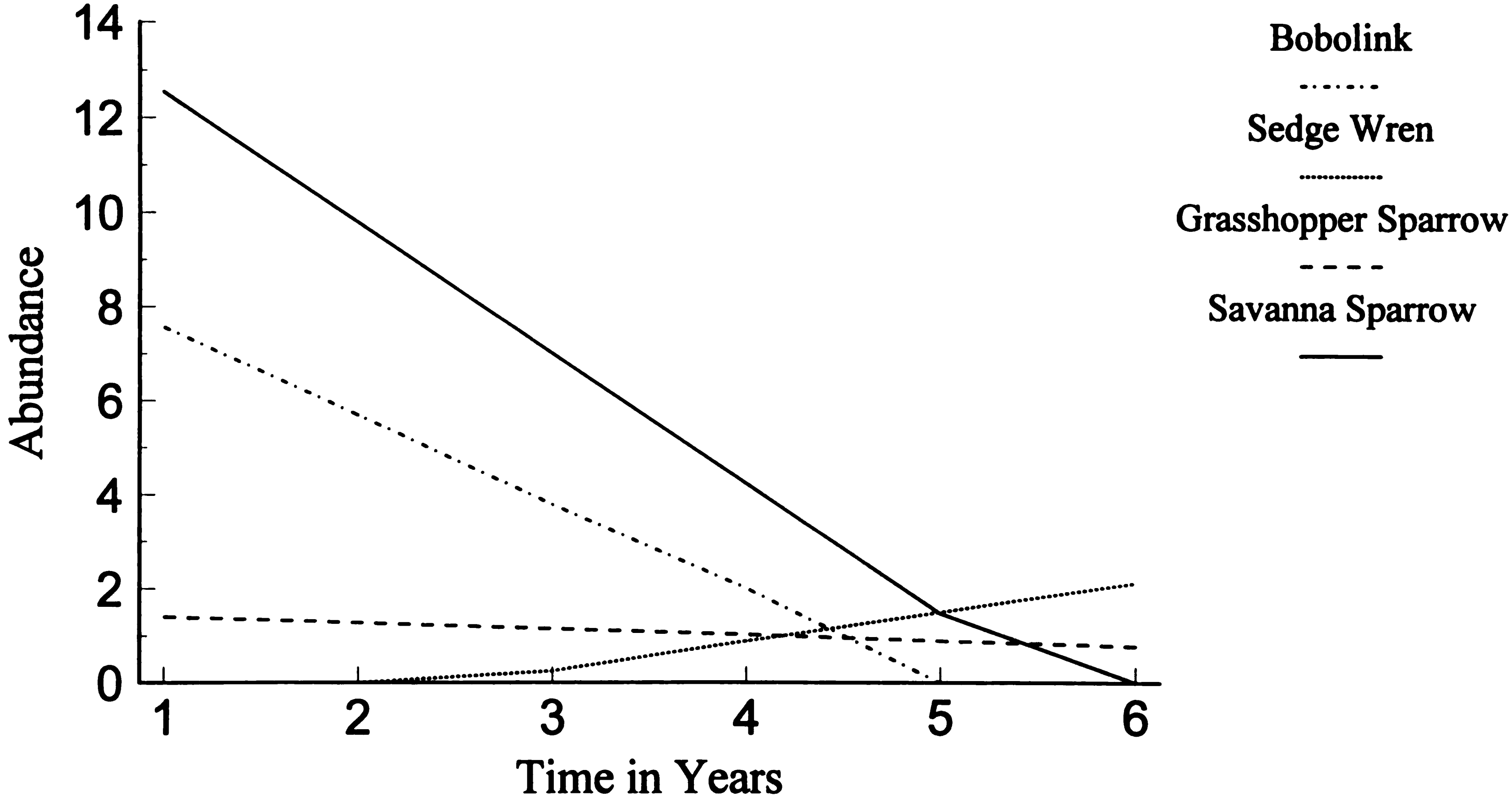

Figure 22. Abundance of 4 grassland bird species over time for a randomly selected section of Gratiot County, Michigan, in which 4 fields have been enrolled into the Conservation Reserve Program at the same time.

fields of different age classes, ranging from 1- to 5-years-old, the resulting bird diversity over time could reach and maintain a steadier value at 1.55 (Fig. 23). Similarly, more stable populations of grassland bird species that require both older fields (sedge wren) and younger fields (savanna sparrows) could be maintained over time (Fig. 24). Based on the objectives of the landowners and resource managers, simulations can be conducted for birds, mammals, invertebrates, or vegetation on how to best manage CRP lands within any given landscape to reach specific objectives.

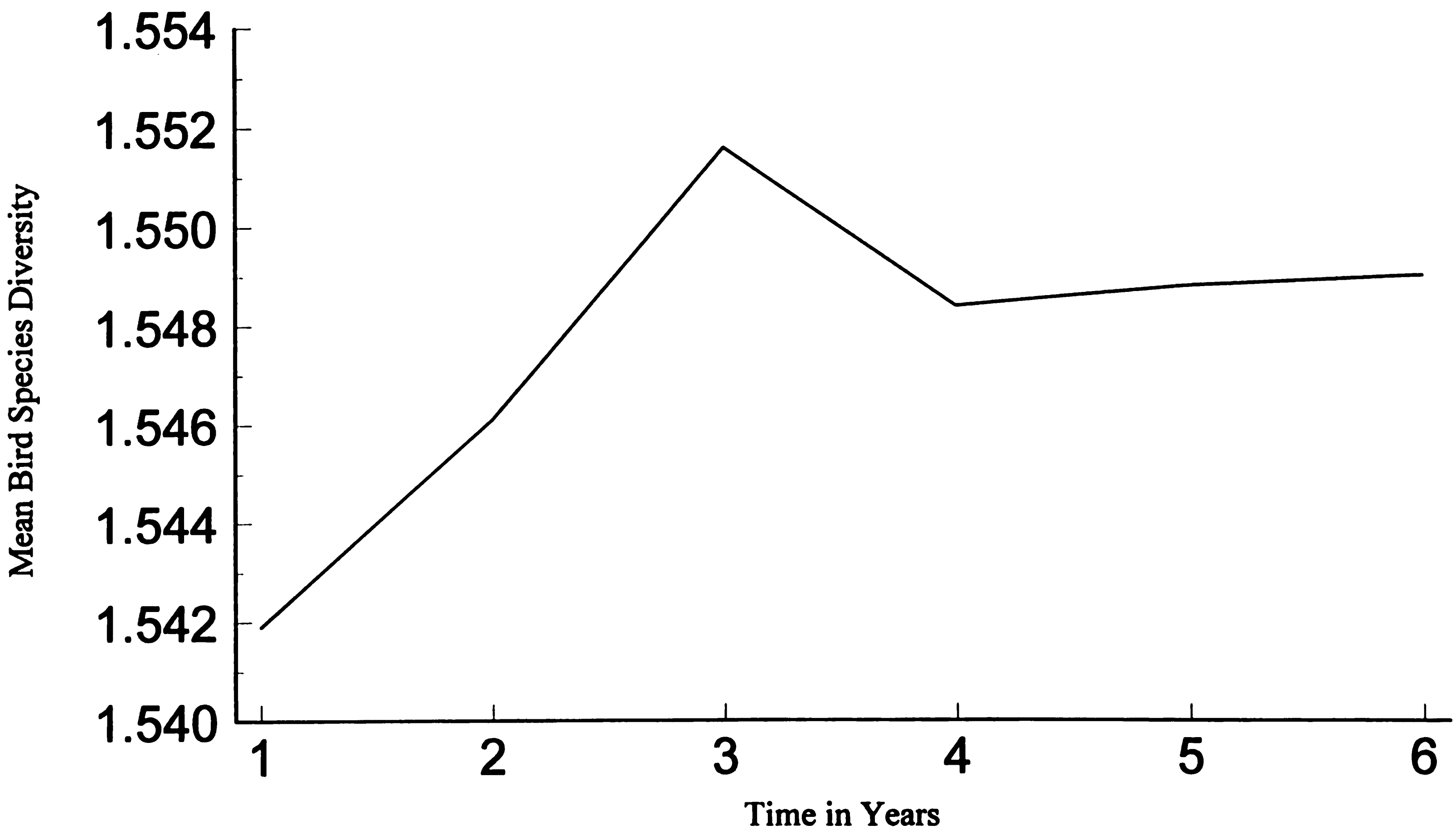

Figure 23. Mean bird species diversity over time for a randomly selected section of Gratiot County, Michigan, in which 4 fields have been enrolled into the Conservation Reserve Program at different enrollment years to maintain a diversity of age classes.

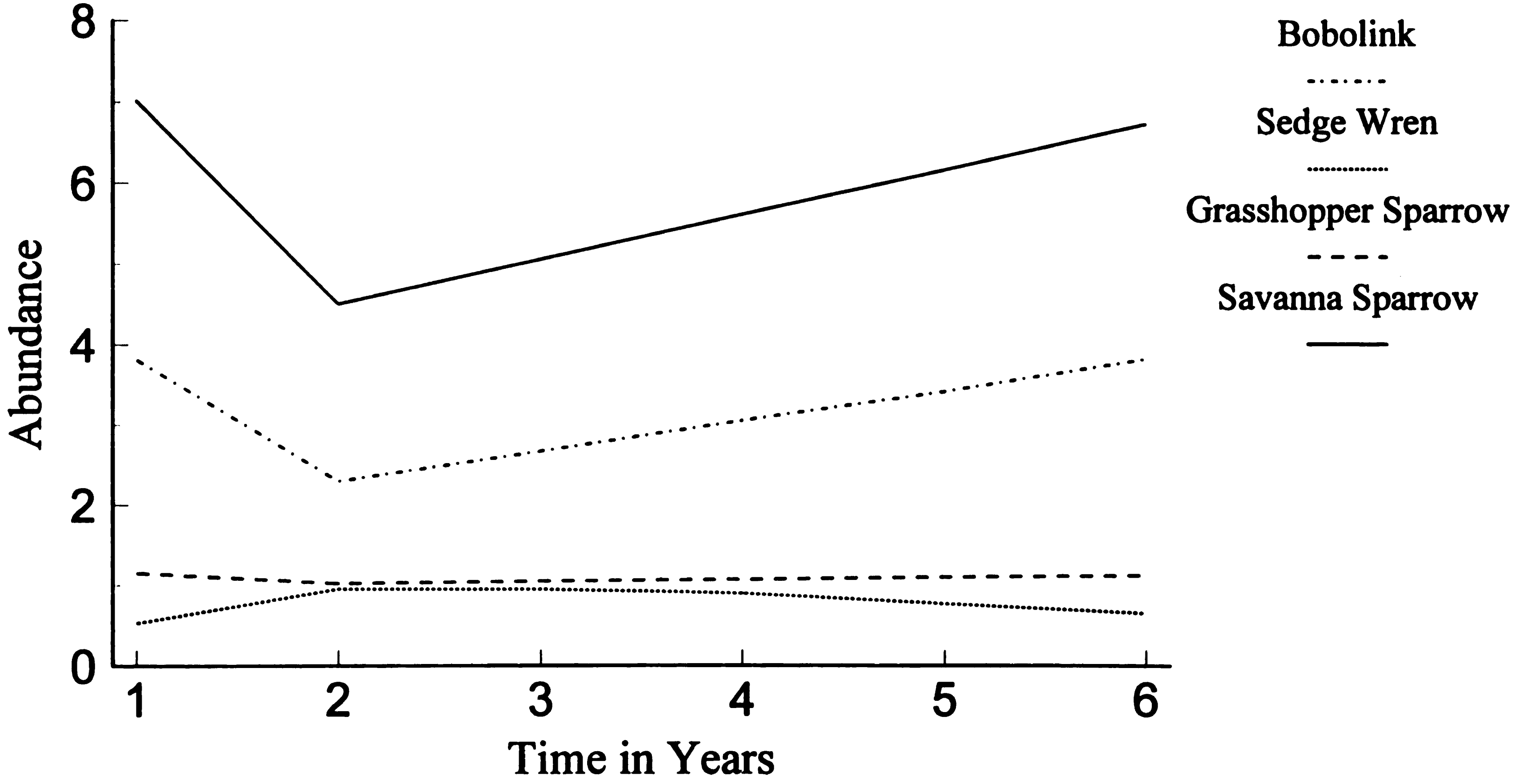

Figure 24. Abundance of 4 grassland bird species over time for a randomly selected section of Gratiot County, Michigan, in which 4 fields have been enrolled into the Conservation Reserve Program at different enrollment years to maintain a diversity of age classes.

RECOMMENDATIONS

With all models, validation is essential before they are used as management tools. These models were developed in an agricultural region of mid-Michigan. To access the reliability of any model in regions different from where the model was developed, resource managers need to ground truth model output with field data. Therefore, to validate these models, additional randomly selected fields should be sampled for avian, mammalian, and invertebrate diversity and abundance. Samples should be compared with a 90% confidence interval for each model to determine accuracy and reliability of each equation.

Successional changes on CRP fields result in decreased abundance and diversity of birds, invertebrates, and mammals (Millenbah 1993, Furrow 1994). Higgins et al. (1987) suggested that grasslands planted with mixtures similar to CRP fields did not maintain structural qualities for wildlife longer than 7 years. In communities dominated by highly sessile species that compete for space, such as tall grass prairies, dominance increases and richness decreases in the absence of disturbance (Collins 1987, Collins and Glenn 1987). This pattern is especially altered by disturbances because the dominant species appear often to be most sensitive to disturbance (Collins and Glenn 1987). Therefore, periodic manipulations of CRP fields by burning, mowing, or disking may be necessary for the long-term maintenance of relatively high avian, mammalian, and invertebrate diversity and abundance (Millenbah 1993, Furrow 1994).

Six variables were cited as significant influences on bird species diversity (Appendix G). Study sites that had the highest avian diversity were predominantly > 10.0 ha in size and in the 1- to 3-year-old age bracket (Appendix Ej-r). High avian diversity fields had between 10 and 20 % of the landscape in residential development (Appendix En-r). Open fields, other than CRP fields, usually comprised < 25% of the landscape and the diversity of cover types immediately adjacent to study sites was generally high. Fields with the highest bird diversity had no agricultural production immediately adjoining the field (Appendix En and q). Resource managers attempting to manage CRP fields to maintain avian diversity should consider the recommendations above and refer to the configuration of cover types surrounding fields 89A, 90B, and 91B (Appendix Ej, n, and q, respectively) for examples of landscapes producing high bird species diversity on CRP fields.

Models indicate bobolinks, grasshopper sparrows, and savanna sparrows were more abundant on younger (1- to 3-year-old) fields and negatively influenced by field age, where as sedge wrens were located exclusively on older (4- to 5-year-old) fields (Appendix G). Exclusion of either younger (1- to 3-year-old) or older (4- to 5-year-old) fields within a landscape may exclude 1 or several of these species from the landscape. This indicates that a diversity of age classes of CRP fields need to be maintained within the landscape to prevent exclusion of any of these grassland species (Millenbah 1993).

Most small mammal species do not require more than 1 habitat type to meet their life requisites (Grant 1972). Furrow (1994) suggested that mammals on CRP fields are no exception. Therefore, the quality of the soil should be a prime consideration in planning which CRP fields to enroll to enhance mammal diversity. Locating fields on sites with soils that have high potential to produce openland wildlife will maximize mammalian diversity. These sites should be dominated by soils with the highest openland wildlife potential, such as Capac, Ithaca, Marlette and/or Perrington loams, when possible. The highest mammalian diversities were encountered on fields entirely located on the soils mentioned above. Similarly, fields should be located in landscapes containing large quantities of either woodlands or row crop production, or both. CRP study sites having the highest mammal diversities had > 48% of the surrounding landscape in agricultural production or > 60% in woodlots. These factors tend to enhance numbers of mammals found on the study sites even though the overall increase in landscape diversity, and perhaps, the increase in other wildlife species, may be minimal.

Webb et al. (1984) determined that invertebrates tend to react to the plant structure within a single habitat type. Webb and Hopkins (1984) found that vegetation surrounding heathlands in England showed additional influence on the diversity of some invertebrates found on the heathlands. Data from this study also indicate CRP field age and soil quality are significant factors in determining invertebrate diversity and biomass, with the vegetation surrounding fields also showing influences. Younger fields with high soil diversity held the greatest invertebrate diversity and densities. Maintaining a diversity of age classes of CRP fields within a landscape would maintain larger quantities of invertebrate biomass. Maintaining large quantities of invertebrates would provide a stable food base for other wildlife species while maintaining biodiversity within the landscape. Manipulation of fields after 3-5 years could prevent the decline in invertebrate biomass found on older fields by setting back the successional stage of vegetation development on CRP lands (Millenbah 1993, Furrow 1994).

Maintaining biological diversity is essential, whether for agricultural or forested ecosystems because all species have value, ecologically and directly to humans (Pimental et al. 1992). To date, one approach to maintain biological diversity has focused on the creation of large nature preserves and natural parks (Wilson 1988 , Pimental et al. 1992). However, nearly 95% of the terrestrial environment of the earth exists as human managed agricultural or forested ecosystems and human settlements (Western and Pearl 1989). Nearly 80% of the earth's species are located in these managed land areas (Pimental et al. 1992). This exemplifies the need for regional conservation plans to be developed and implemented that consider multiple land-use objectives and multiple land ownership (Pimental et al. 1992).

Resource managers who are constrained to working with a few fields owned by cooperative landowners are able to integrate the management of CRP fields into a landscape based management plan for the enhancement of all wildlife species. Fields that were once unavailable for direct management applications are able to be integrated into a complete landscape plan. Therefore, resource managers can merge their objectives with those of private landowners and conservation groups to meet multiple-use objectives in agricultural landscapes.

LIST OF REFERENCES

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Adams, C. C. 1908. The ecological succession of birds. Auk 25:109-153.

Allen, A. W. 1992. Wildlife habitat considerations under a reduced Conservation Reserve Program (CRP). Paper presented to the Great Plains Council, June. 10pp.

Anderson, N. L. 1964. Some relationships between grasshoppers and vegetation. Annals Ent. Soc. Amer. 57:736-742.

Anderson, S. H. 1979. Changes in forest bird species composition caused by transmission-line corridor cuts. Am. Birds 33:3-6.

_____. 1981. Correlating habitat variables and birds. Pages 538-542 in C. J. Ralph and J. M. Scott eds. Estimating numbers of terrestrial birds. Allen Press, Inc. Lawrence, Kan.

Andrle, R. F. and J. R. Carroll. 1988. The atlas of breeding birds in New York State. Cornell Univ. Press. Ithaca, N.Y. 551pp.

Arnold, G. W. 1983. The influence of ditch and hedgerow structure, length of hedgerows, and area of woodland and garden on bird numbers on farmland. J. Appl. Ecol. 20:731-750.

Bartlett, E. T., and J. E. Mitchell. 1991. Research questions related to the conservation reserve program. Pages 50-57 in Joyce L. A., J. E. Mitchell, and M. D. Skold, eds. The conservation reserve-yesterday, today and tomorrow. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. RM-203.

Beecher, W. J. 1942. Nesting birds and the vegetation substrate. Chicago Ornithological Soc., Chicago, Ill. 69pp.

Beirne, M. 1995. Effects of site characteristics on the distribution and nutritional qualities of native and introduced grasses in the Hiawatha National Forest, Michigan. M.S. Thesis, Michigan State Univ., East Lansing. 94pp.

Berner, A. H. 1988. The 1985 farm act and its implications for wildlife. Pages 437-465 in W. J. Chandler and L. Labate, eds. Audubon wildlife report 1988/1989. The National Audubon Society., New York, N.Y.

Best, L. B., R. C. Whitmore, and G. M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. Am. Midl. Nat. 123:84-99.

Blake, J. G., and J. R. Karr. 1984. Species composition of bird communities and the conservation benefit of large versus small forests. Biol. Conserv. 30:173-187.

Bond, R. R. 1957. Ecological distribution of breeding birds in upland forests of southern Wisconsin. Ecol. Monogr. 27:351-384.

Burgess, R. L., and D. M. Sharpe. 1981. Forest island dynamics in man-dominated landscapes. Springer Verlag, New York, N.Y. 310pp.

Campa, H., III, S. R. Winterstein, K. F. Millenbah, and R. B. Minnis. 1991. Wildlife and plant response to diverted agricultural lands in Gratiot County, Michigan.

_____, _____, _____, _____. 1992. Wildlife and plant response to diverted agricultural lands in Gratiot County, Michigan.

_____, _____, _____, _____, L. T. Furrow, and A. J. Pearks. 1993. Wildlife and plant response to diverted agricultural lands in Gratiot County, Michigan.

Canfield, R. H. 1941. Application of the line intercept method in sampling range vegetation. J. For. 39:388-394.

Cody, M. L. 1968. On the methods of resource division in grassland bird communities. Amer. Mid. Nat. 102:107-147.

_____. 1985. Habitat selection in birds. Academic Press, Inc. Orlando, Fla. 558pp.

Collins, S. L. 1987. Interaction of disturbances in tallgrass prairie: a field experiment. Ecology 68:1243-1250.

Collins, S. L., and S. M. Glenn. 1990. A hierarchical analysis of species' abundance patterns in grassland vegetation. American Nat. 135:633-648.

Daly, H. V., J. T. Doyen, and P. R. Ehrlich. 1978. Introduction to invertebrate biology and diversity. McGraw-Hill, Inc. New York, N.Y. 564pp.

Daubenmire, R. F. 1959. A canopy coverage methods of vegetational analysis. Northwest Sci. 33:43-64.

Evans, E. W. 1988. Grasshopper (Invertebratea: Orthoptera: Acrididae) assemblages of tallgrass prairie: influences of fire frequency, topography, and vegetation. Can. J. Zool. 66:1495-1501.

Feenstra, J. E. 1979. Soil survey of Gratiot County, Michigan. U.S.D.A. Soil Conservation Service. 141pp.

Fry, G. L. A. 1989. Conservation in agricultural ecosystems. Pages 415-443 in Spellerberg, I. F., F. B. Goldsmith, and M. G. Morris, eds. The scientific management of temperate communities for conservation. Blackwell Scientific Publ., Boston.

Furrow, L. T. 1994. The influence of field age on mammalian relative abundance, diversity, and distribution on Conservation Reserve Program lands in Michigan. M.S. Thesis, Michigan State Univ., East Lansing. 118pp.

Grant, P. R. 1972. Interspecific competition among rodents. Annu. Rev. Ecol. and Sys. 3:79-107.

Griscom, L., and D. E. Snyder. 1955. The birds of Massachusetts. Anthoensen Press, Portland, Maine. 295pp.

Gysel, L. W., and L. J. Lyon. 1980. Habitat analysis and evaluation. Pages 305-328 in S. D. Schemnitz, ed. Wildlife management techniques manual. The Wildl. Soc., Washington, D.C.

Harris, L. D. 1984. The fragmented forest: island biogeography theory and the preservation of biotic diversity. Univ. Chicago Press. Chicago, Ill. 211pp.

Harrison, H. H. 1975. A field guide to birds' nests: United States east of the Mississippi river. Houghton Mifflin Co. Boston, Mass. 257pp.

Hassel, M. P. 1980. Some consequences of habitat heterogeneity for population dynamics. Oikos 35:150-160.

Herkert, J. R. 1994. The effects of habitat fragmentation in midwestern grassland bird communities. Ecol. Soc. Amer. 4:461-471.

Higgins, K. F., D. E. Nomsen, and W. A. Wentz. 1987. The role of the Conservation Reserve Program in relation to wildlife enhancement, wetlands, and adjacent habitats in the northern great plains. Pages 99-104 in J. E. Mitchell, ed. Impacts of the Conservation Reserve Program in the great plains. U. S. For. Serv. Gen. Tech. Rep. RM-158.

Hunter, M. L. 1990. Wildlife, forests, and forestry: principles of managing forests for biological diversity. Prentice Hall, Inc., Englewood Cliffs, N.J. 370pp.

Hurley, R. J., and E. C. Franks. 1976. Changes in the breeding ranges of two grassland birds. Auk 93:108-115.

Isaacs, B., and D. Howell. 1988. Opportunities for enhancing wildlife benefits through the conservation reserve program. Trans. N. A. Wildl. and Nat. Res. Conf. 53:222-231.

Janzen, D. H. 1981. An integrated approach to management of land resources. Pages 164-192 in R. T. Dumke, G. V. Burger, and J. R. March, eds. Proceedings of symposium: Wildlife management on private lands. Wisc. Chap. the Wildl. Soc., Madison.

_____. 1983. No park is an island: increase in interference from outside as park size decreases. Oikos 41:402-410.

Karr, J. R., and R. R. Roth. 1971. Vegetation structure and avian diversity in several New World areas. Amer. Nat. 105:423-435.

Kemp, W. P., S. J. Harvey, and K. M. O'Neill. 1990a. Habitat and invertebrate biology revisited: the search for patterns. Amer. Ent. 36:44-49.

_____, _____, and _____. 1990b. Patterns of vegetation and grasshopper community composition. Oecologia 83:299-308.

Klopatek, J. M., R. J. Olson, C. J. Emerson, and J. L. Jones. 1979. Land-use conflicts with natural vegetation in the United States. Environ. Conserv. 6:191-200.

Kurzejeski, E. W., L. W. Burger. Jr., M. J. Monson, R. Lenkner. 1992. Wildlife conservation attitudes and land-use intentions of Conservation Reserve Program participants in Missouri. Wildl. Soc. Bull. 20:253-259.

Laughlin, S. B., and D. P. Kidde. 1985. The atlas of breeding birds of Vermont. University Press of New England. Hanover, VT. 456pp.

Lay, D. W. 1938. How valuable are woodland clearings and bird life? Wilson Bull. 45:254-256.

Lowe, P., G. Cox, M. MacEwan, T. O'Riordan, and M. Winter. 1986. Countryside conflicts: the politics of farming, forestry, and conservation. Grower Publishing Co. Aldershot, England. 378pp.

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

_____, and E. O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press, Princeton, N. J. 203pp.

_____, and H. S. Horn. 1969. Foliage profile by vertical measurements. Ecology 50:802-804.

McQuillan, P. B. and J. E. Treson. 1981. Some aspects of the invertebrate fauna and its role in Tasmanian pastures. Pages 101-106 in K. E. Lee ed. Proceedings of the 3rd annual conference on grassland invertebrate ecology. Plympton, Australia.

Michigan Land Use Classification and Referencing Committee. 1979. Michigan land cover/use classification system. Div. Land Resour. Prog., Dept. Nat. Resour. 60pp.

Millenbah, K. F. 1993. The effects of different age classes of fields enrolled in the Conservation Reserve Program in Michigan on avian diversity, density, and productivity. M.S. Thesis, Michigan State Univ., East Lansing. 107pp.

Miller, R. P. 1980. Simultaneous statistical inferences. Second ed. Springer-Verlag, New York, N. Y. 299pp.

Morrill, W. I. 1987. Fee access views of a private wildlife management consultant. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 52:530-543.

Nudds, T. D. 1977. Quantifying the plant structure of wildlife cover. Wildl. Soc. Bull. 5:113-117.

O'Brien, R. 1990. Assessment of nongame bird habitat using forest survey data. U.S. For. Serv. Res. Pap. INT-431. 8pp.

Parmenter, R. R., J. A. MacMahon, and C. A. B. Gilbert. 1991. Early successional patterns of Arthropod recolonization on reclaimed Wyoming strip mines: The grasshoppers (Orthoptera: Acrididae) and allied faunas (Orthoptera: Gryllacrididae, Tettigoniidae). Environ. Entomol. 20:135-142.

Pielou, E. C. 1977. Mathematical ecology. Wiley, New York, N. Y. 385pp.

Pimental, D., U. Stachow, D. A. Takacs, H. W. Brubaker, A. R. Dumas, J. J. Meaney, J. A. S. O'Neil, D. E. Onsi, and D. B. Corzilius. 1992. Conserving biological diversity in agricultural/forestry systems. Bioscience 42:354-362.

Robbins, C. S. 1979. Effects of forest fragmentation on bird populations. Pages 198-212. in R. M. DeGraaf and K. E. Evans, eds. Management of north central and northeastern forests for nongame birds: workshop proceedings. USDA Forest Serv. Gen. Tech. Report, NC-51.

_____, D. K. Dawson, and B. A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildl. Monogr. 103.

_____, B. A. Dowell, D. K. Dawson, J. A. Colon, R. Estrada, A. Sutton, R. Sutton, and D. Weyer. 1992. Comparison of Neotropical migrant landbird populations wintering in tropical forest, isolated forest fragments, and agricultural habitats. Pages 207-220 in J. M. Hagan III and D. W. Johnson, eds. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Wash.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. J. Range Manage. 23:295-298.

Ruesink, W. G., and D. L. Haynes. 1973. Sweepnet sampling for the cereal leaf beetle. Environ. Entomology. 2:161-172.

Ryan, M. R. 1986. Nongame management of grassland and agricultural ecosystems. Pages 117-136 in J. B. Hale, L. B. Best, and R. L. Clawson, eds. Management of nongame wildlife in the Midwest: A developing art. Proc. Symp. 47th Midwest Fish & Wildl. Conf., N. Cent. Sect. Wildl. Soc.

SAS Institute Inc. 1988. SAS user's guide: statistics, version 6.0 edition. SAS Institute Inc., Cary, N.C. 956pp.

Shannon, C. E. and W. Weaver. 1949. The mathematical theory of communication. Univ. Illinois Press, Urbana. 177pp.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., Inc., N.Y. 312 pp.

Smith, M. H., R. H. Gardner, J. B. Gentry, D. W. Kaufmam, and M. H. O'Farrell. 1975. Density estimators of small mammal populations. Pages 25-53 in F. B. Golley, K. Petrusewicz, and L. Ryszkowski, eds. Small mammals: Their productivity and population dynamics. Cambridge Univ. Press.

Smith, E. L. and K. C. Kruse. 1992. The relationship between land-use and the distribution and abundance of Loggerhead Shrike in south-central Illinois. J. Field Ornith. 63:420-427.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry: the principles and practice of statistics in biological research. W. H. Freedman and Co., N.Y. 859p.

Spellerberg, I. F. 1989. Biogeographical basis for conservation. Pages 293-321 in Spellerberg, I. F., F. B. Goldsmith, and M. G. Morris, eds. The scientific management of temperate communities for conservation. Blackwell Scientific Publ.

Stauffer, D. F. and L. B. Best. 1990. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:1-15.

Temple, S. A., and B. A. Wilcox. 1986. Predicting effects of habitat patchiness and fragmentation. Pages 261-2 in Verner, J., M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates.

U.S. Dept. of Agriculture. 1987a. Environmental assessment and final regulatory impact and flexibility analysis for the highly erodible land conservation provisions of the Food Security Act of 1985. Soil Conservation Service. Washington, D. C. 55pp.

U.S. Dept. of Agriculture. 1987b. Agricultural census data for Gratiot county, Michigan. Soil Conservation Service. Washington, D. C. 4pp.

Urban, D. L., R. V. O'Neill, and H. H. Shugart. 1987. Landscape ecology. Bioscience 37:119-127.

Walton, M. T. 1981. Wildlife habitat preservation programs. Pages 193-208 in R. T. Dumke, G. V. Burger, and J. R. March, eds. Proceedings of symposium: Wildlife management on private lands. Wisc. Chap. The Wildl. Soc., Madison.

Webb, N. R., R. T. Clarke, and J. T. Nichols. 1984. Invertebrate diversity on fragmented Calluna-heathland: effects of surrounding vegetation. J. Biogeography 11:41-46.

______, and P. J. Hopkins. 1984. Invertebrate diversity on fragmented Calluna-heathland. Unpublished manuscript.

Western, W. E., and M. C. Pearl, eds. 1989. Conservation for the twenty-first century. Oxford University Press, New York, N.Y. 365pp.

Westman, W. E. 1990. Managing for biodiversity. Bioscience 40:26-33.

Wilson, E. O. 1988. The current state of biological diversity. Pages 3-20 in E. O. Wilson and F. M. Peter, eds. Biodiversity. Natl. Acad. Press, Washington, D.C.

APPENDICIES

Appendix A. Michigan Resource Information System (MIRIS) for classification of land-use in Michigan (Michigan Land Use Classification and Referencing Committee 1979).

Urban and Built Up Lands
- 111 Multi-family residential - medium to high rise
- 112 Multi-family residential - low rise
- 113 Single family/duplexes
- 115 Mobile home park
- 12 Commercial services and institutional
  - 121 Primary/central business district
  - 122 Shopping center/malls
  - 124 Secondary/neighborhood business district
  - 126 Institutional
- 13 Industrial
  - 138 Industrial parks
  - 141 Air transportation
  - 143 Water transportation
  - 145 Communications
  - 146 Utilities
- 17 Extractive
  - 171 Open pit
  - 172 Underground
  - 173 Wells
  - 179 Other Extractive
- 19 Open land and other
  - 193 Outdoor recreation
  - 194 Cemeteries

Agricultural Lands
- 21 Croplands
- 22 Orchards, bush fruit, vineyards, and ornamental horticulture areas
- 23 Confined feeding operations
- 24 Permanent pasture
- 29 Other agricultural lands

Nonforested Lands
- 31 Herbaceous openland
- 32 Shrubland
- 33 Pine or oak opening (savanna)
- 39* Conservation Reserve Program lands

Forested Land
- 41 Broad-leaved forest
  - 411 Northern hardwood
  - 412 Central hardwood
  - 413 Aspen, white birch and associated species
  - 414 Lowland hardwoods

Appendix A. (cont.)

- 42 Coniferous forest
  - 421 Pine
  - 422 Other upland conifers
  - 423 Lowland conifers
  - 429 Managed Christmas tree plantation

Water Bodies

- 51 Streams and waterways
- 52 Lakes
- 53 Reservoirs
- 54 Great lakes

Wetlands

- 61 Forested wetlands
  - 611 Wooded wetland
  - 612 Shrub/scrub wetland
- 62 Nonforested wetlands
  - 621 Aquatic bed wetland
  - 622 Emergent wetland
  - 623 Flats

Barren Land

- 72 Beaches and riverbanks
- 73 Sand dunes
- 74 Bare exposed rocks

* Added to the MIRIS classification system for this project.

Appendix B. Plant species on Conservation Reserve Program (CRP) study sites and in adjacent vegetation types in Gratiot County, Michigan, summer 1992.

Species	Scientific Name
Alfalfa	*Medicago spp.*
Aster spp.	*Aster spp.*
Bedstraw*	*Galium spp.*
Black Medick	*Medicago lupulina*
Bloodroot*	*Sanguinaria canadensis*
Blue Vervain	*Verbena hastata*
Bouncing Bet	*Saponaria officinalis*
Bull Thistle	*Cirsium vulgare*
Burdock	*Arctium minus*
Canadian Mayapple*	*Podophyllum peltatum*
Canadian Thistle	*Cirsium arvense*
Chickory	*Cichorium intybus*
Coltsfoot*	*Tussilago farfara*
Common Chickweed	*Stellaria media*
Common Daisy	*Erigeron philadelphicus*
Common Groundsel	*Senecio vulgaris*
Common Mullien	*Verbascum thapsus*
Common Plaintain	*Plantago major*
Common St. John's Wart	*Hypericum perforatum*
Common Winter Cress	*Barbarea vulgaris*
Crowsfoot	*Ranunculus pennsylvanicus*
Curly Dock	*Rumex crispus*
Daisy Fleabane	*Erigeron annuus*
Dandelion	*Taraxacum officinale*
Deptford Pink*	*Dianthus armeria*
Enchanter's Nightshade*	*Circaea quadrisulcata*
English Plaintain	*Plantago lanceolata*
Field Bindweed	*Convolvulus arvensis*
Field Hawkweed	*Hieracium pratense*
Field Pennycress	*Thlaspi arvense*
Field Peppergrass	*Lepidium campestre*
Field Sorrel	*Rumex acetosella*
Fringed Gentian*	*Gentiana crinita*
Goldenrod	*Solidago spp.*
Green Amerath	*Amaranthus retroflexus*
Green Foxtail	*Setaria viridis*
Hoary Alyssum	*Berteroa incana*
Hog Peanut	*Amphicarpa bracteata*
Horsetail	*Equisetum spp.*
Indian Hemp*	*Apocynum cannabinum*
Indian Mallow*	*Abutilon theophrasti*
Interrupted Fern*	*Osmunda claytoniana*
Jack-in-the-pulpit*	*Arisaema atrorubens*
Jewelweed*	*Impatiens capensis*
Kentucky Bluegrass	*Poa pratense*
Knapweed	*Centaurea maculosa*
Lady's Thumb	*Polygonum persicaria*
Large-flower Trillium*	*Trillium grandiflorum*

Appendix B. (cont.)

Species	Scientific Name
Meadow Rue*	*Thalictrum polygamum*
Milkweed	*Asclepias syriaca*
moss	*moss spp.*
Moth Mullein	*Verbascum blattaria*
Orchard Grass	*Dactylis glomerata*
Path Rush	*Juncus tenius*
Pearly Everlasting	*Anaphalis margaritacea*
Peppermint	*Mentha piperita*
Quackgrass	*Gropyron repens*
Queen Anne's Lace	*Daucus carota*
Ragweed*	*Ambrosia artemisiifolia*
Red Clover	*Trifolium pratense*
Redtop	*Agrostis gigantea*
Rough Cinquefoil	*Potentilla norvegica*
Rough-fruited Cinquefoil	*Potentilla recta*
Round-lobed Hepatica*	*Hepatica americana*
Self Heal	*Prunella vulgaris*
Shrubby St. John's Wart	*Hypericum spathulatum*
Slender Brome	*Bromus spp.*
Smartweed	*Polygonum spp*
Smooth Brome	*Bromus inermus*
Soybean*	*Glycine spp.*
Stinging Nettles*	*Urtica dioica*
Sugar Beets*	*Beta spp.*
Sunflower*	*Heliantus annuus*
Sweet Cicely*	*Osmorhiza claytoni*
Switch Grass	*Panicum virgatum*
Teasel	*Dipsacus sylvestris*
Tick-trefoil*	*Desmodium canescens*
Timothy Grass	*Phleum pratense*
True Solomon Seal*	*Polygonatum canaliculatum*
Twisted Stalk*	*Streptopus amplexifolius*
Umbrella Sedge	*Cyperus spp*
Water Horehound	*Lycopus americanus*
Wheat	*Triticum spp.*
White Avens	*Geum canadense*
Whitlow Grass	*Draba verna*
Wild Blue Violet	*Viola papilionacea*
Wild Geranium*	*Geranium maculatum*
Wild Lettuce	*Lactuca canadensis*
Wood Strawberry	*Fragaria vesca*
Wormseed Mustard	*Erysimum cheiranthoides*
Yarrow	*Achillea millefolium*
Yellow Avens	*Geum aleppicum*
Yellow Goatsbeard	*Tragopogon pratensis*
Yellow Sweet Clover	*Melilotus officinalis*

* located only in adjacent vegetation types.

Appendix C. Avian species on Conservation Reserve Program (CRP) study sites and adjacent vegetation types in Gratiot County, Michigan, summer 1992.

Common Name	Scientific Name
Acadian Flycatcher*	*Empidonax virescens*
American Crow	*Corvus brachyrhynchos*
American Goldfinch	*Carduelis tristis*
American Robin	*Turdus migratorius*
Barn Swallow	*Hirundo rustica*
Black and White Warbler*	*Mniotilta varia*
Blue Jay	*Cyanocitta cristata*
Bobolink	*Dolichonyx oryzivorus*
Brown Thrasher	*Toxostoma rufum*
Brown-headed Cowbird	*Molothrus ater*
Chipping Sparrow	*Spizella passerina*
Common Flicker*	*Colaptes auratus*
Common Grackle*	*Quiscalus quiscula*
Common Yellowthroat	*Geothlypis trichas*
Downy Woodpecker*	*Picoides pubescens*
Eastern Bluebird	*Sialia sialis*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Meadowlark	*Sturnella magna*
Eastern Pheobe	*Sayornis phoebe*
Eastern Pewee*	*Contopus virens*
European Starling	*Sturnus vulgaris*
Field Sparrow	*Spizella pusilla*
Grasshopper Sparrow	*Ammodramus savannarum*
Gray Catbird*	*Dumtella carolinensis*
Hairy Woodpecker*	*Picoides villosus*
Horned Lark	*Eremophila alpestris*
House Finch*	*Carpodacus mexicanus*
House Wren	*Troglodytes aedon*
Indigo Bunting*	*Passerina cyanea*
Killdeer*	*Charadrius vociferus*
Mallard	*Anas platyrhynchos*
Mockingbird*	*Mimus polyglottos*
Mourning Dove	*Zenaida macroura*
Northern Bobwhite	*Colinus virginianus*
Northern Cardinal*	*Cardinalis cardinalis*
Northern Harrier	*Circus cyaneus*
Northern Oriole*	*Icterus galbula*

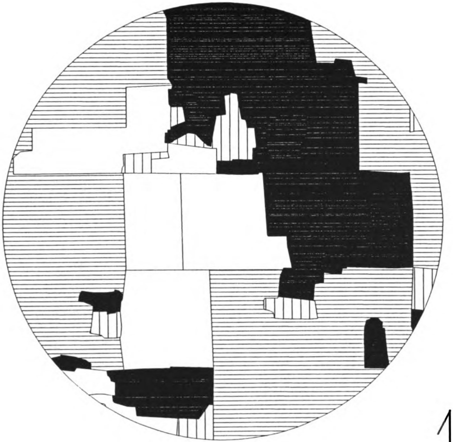
Appendix C. (cont.)

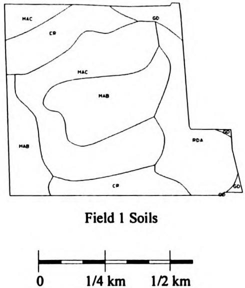
Species	Scientific Name
Olive Sided Flycatcher*	*Nuttallornis borealis*
Purple Martin*	*Progne subis*
Red-eyed Vireo*	*Vireo olivaceus*
Red-winged Blackbird	*Agelaius phoeniceus*
Ring-necked Pheasant	*Phasianus colchicus*
Rose-breasted Grossbeak*	*Pheucticus ludovicianus*
Ruby-throated Hummingbird	*Archilochus colubris*
Ruffed Grouse*	*Bonasa umbellus*
Savannah Sparrow	*Passerculus sandwichensis*
Sedge Wren	*Cistothorus platensis*
Slate Colored Junco*	*Junco hyemalis*
Song Sparrow	*Melospiza melodia*
Tree Swallow	*Tachycineta bicolor*
Tufted Titmouse*	*Parus bicolor*
Vesper Sparrow	*Pooecetes gramineus*
White Breasted Nuthatch*	*Sitta carolinensis*
Yellow Warbler	*Dendroica petechia*

* located only in adjacent vegetation types.

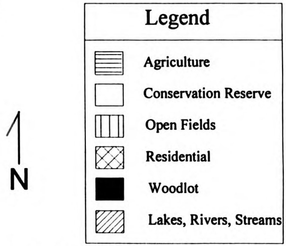
Appendix D. Small mammal species on Conservation Reserve Program (CRP) study sites and adjacent vegetation types in summer 1992 in Gratiot County, Michigan.

Species	Scientific Name
House Mouse	*Mus musculus*
Least Weasel	*Mustela nivalis*
Masked Shrew	*Sorex cinereus*
Meadow Jumping Mouse	*Zapus hudsonicus*
Meadow Vole	*Microtus pennsyvanicus*
Peromyscus spp.	*Peromyscus spp.*
Opossum	*Didephis virginiana*
Short-tailed Shrew	*Blarina brevicada*
Thirteen-lined Ground Squirrel	*Spermophilus tridecemlineatus*
Woodland Jumping Mouse	*Napaeozapus insignis*

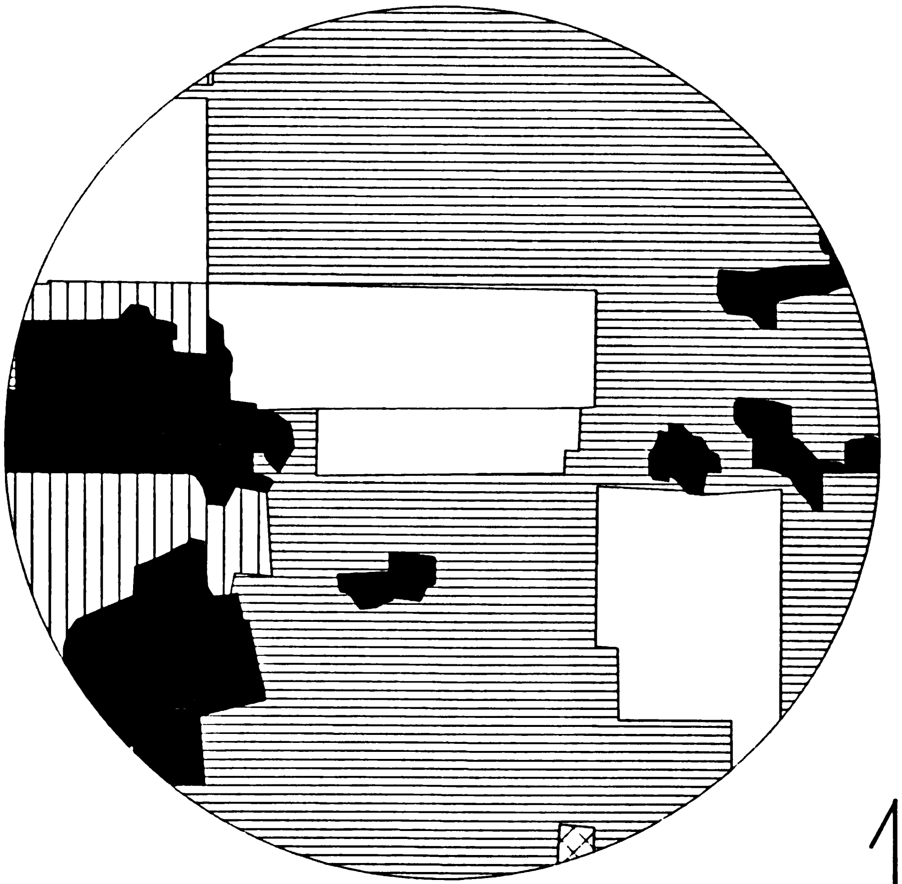




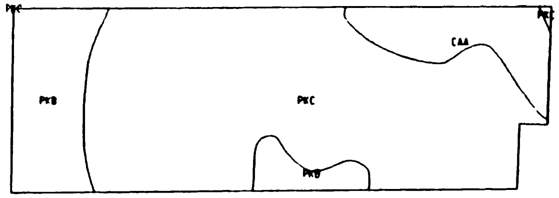
Landscape Diversity = 1.19
Landscape Mean Bird Diversity = 1.23
Field Bird Diversity = 1.31
Field Soil Diversity = 1.24



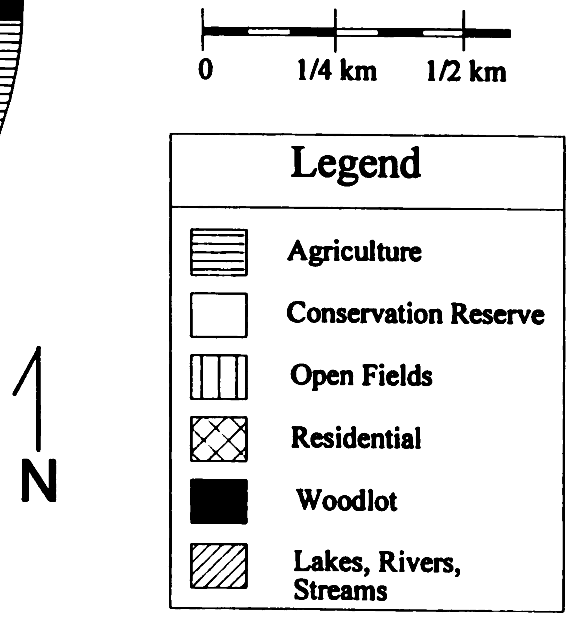
Appendix E. Landscape composition around CRP study sites in Gratiot County, Michigan, 1992. Area of landscape is 259 ha with field in center. (a). Field 1.



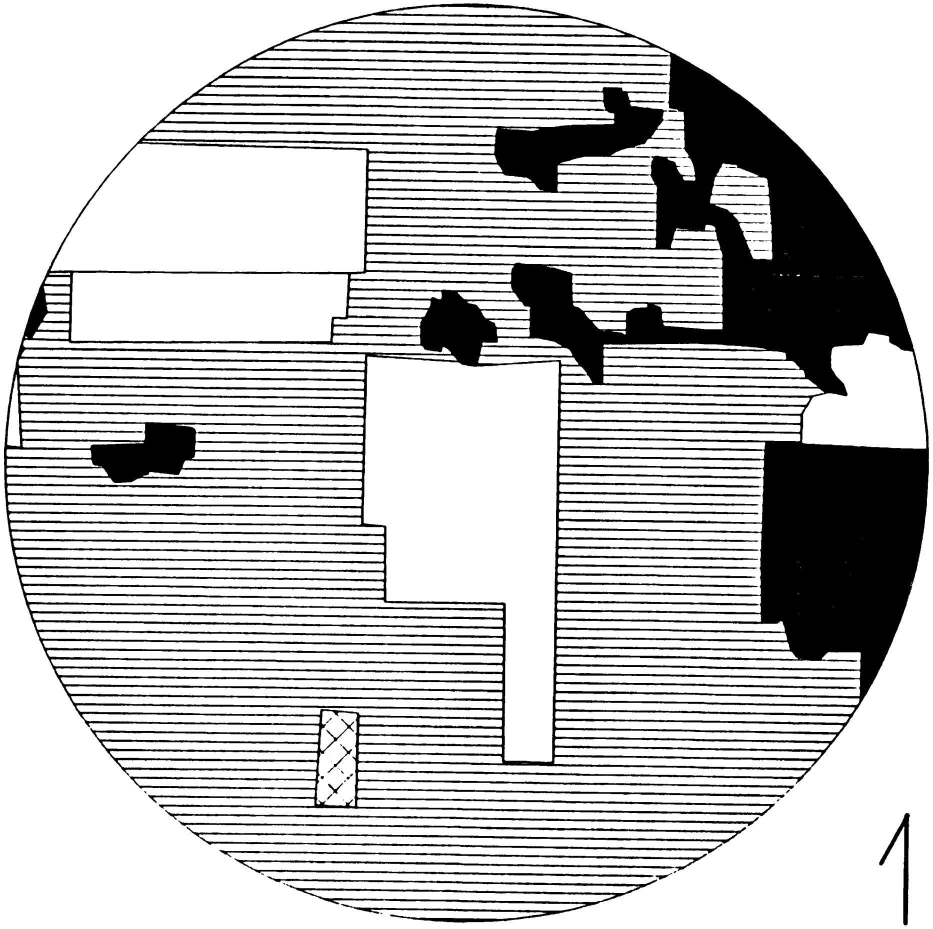
Landscape Diversity =1.13
Landscape Mean Bird Diversity =1.09
Field Bird Diversity = 1.19
Field Soil Diversity = 0.74

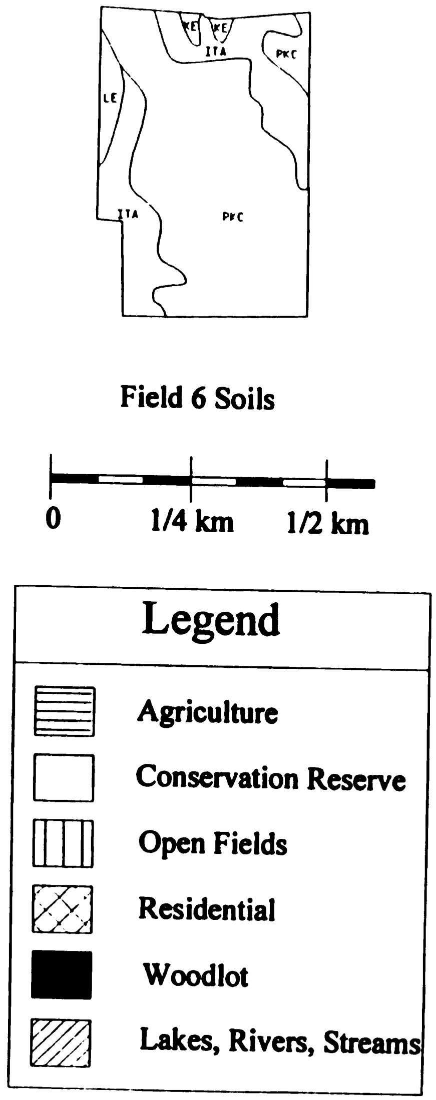


Field 5 Soils



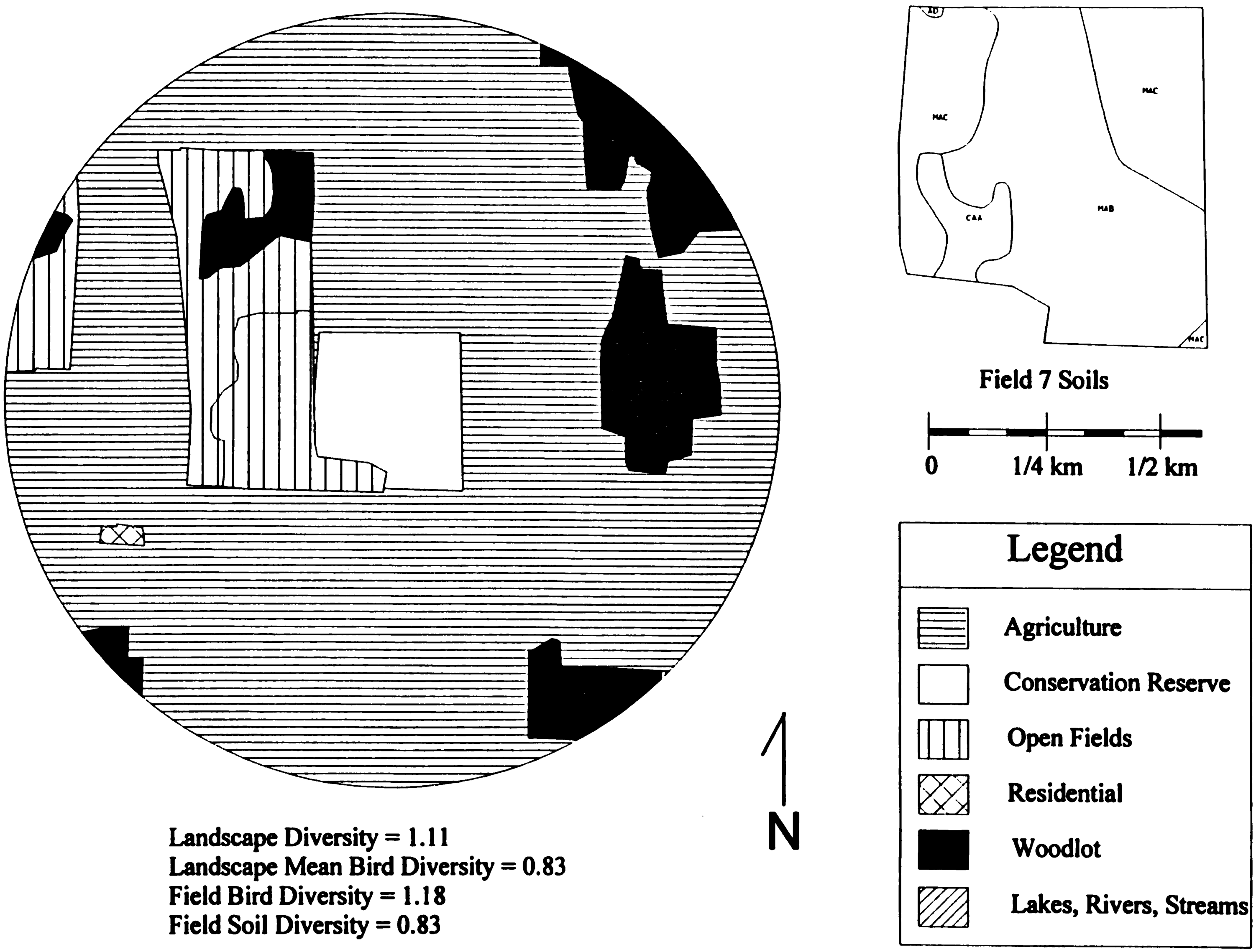
Appendix E. (cont.)(b). Field 5.





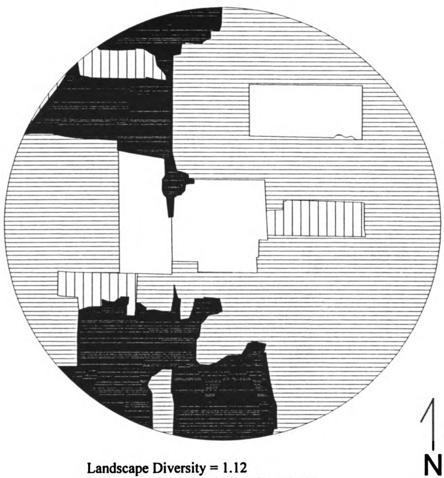
Landscape Diversity = 1.19
Landscape Mean Bird Diversity = 0.88
Field Bird Diversity = 1.16
Field Soil Diversity = 0.89

Appendix E. (cont.)(c). Field 6.

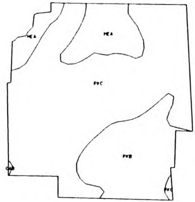


Landscape Diversity = 1.11
Landscape Mean Bird Diversity = 0.83
Field Bird Diversity = 1.18
Field Soil Diversity = 0.83

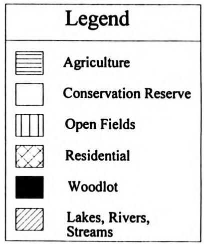
Appendix E. (cont.)(d). Field 7.



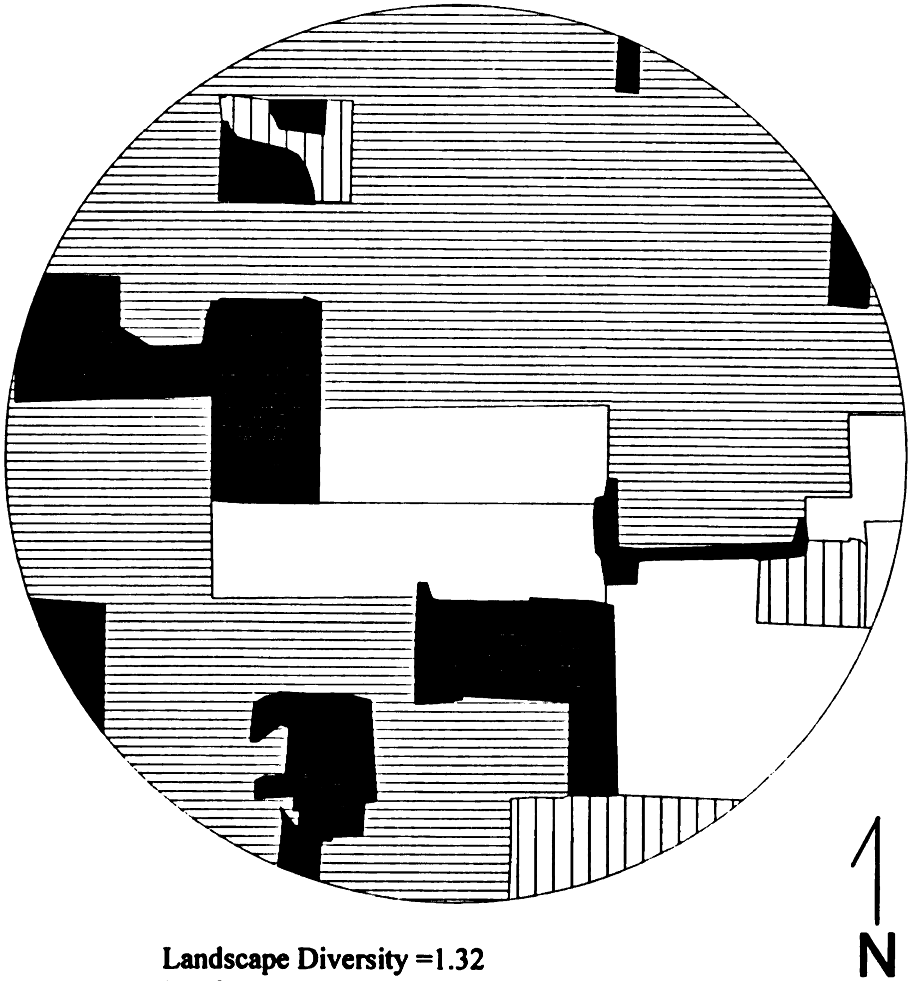
Landscape Diversity = 1.12
Landscape Mean Bird Diversity = 1.07
Field Bird Diversity = 1.23
Field Soil Diversity = 0.85

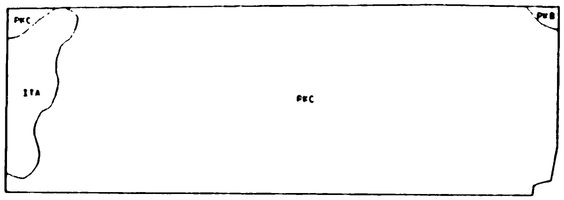


Field 8 Soils

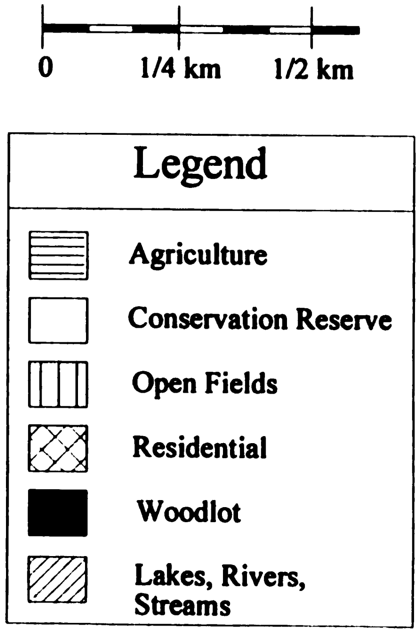


Appendix E. (cont.) (e). Field 8.



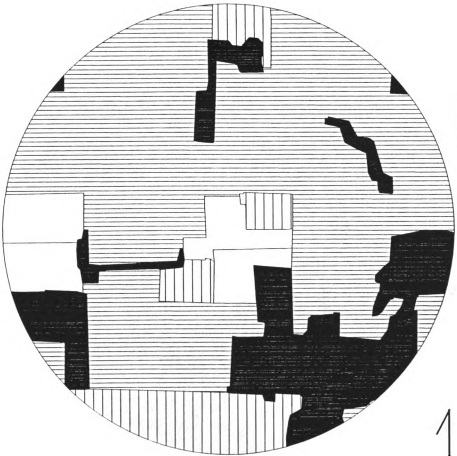


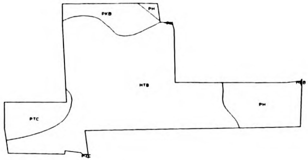
Field 9 Soils



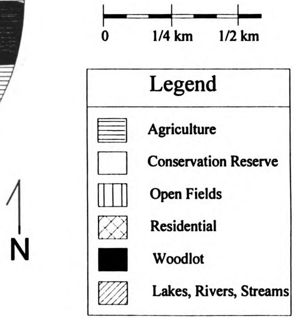
Landscape Diversity =1.32
Landscape Mean Bird Diversity = 1.06
Field Bird Diversity = 1.15
Field Soil Diversity = 0.28

Appendix E. (cont.) (f). Field 9.



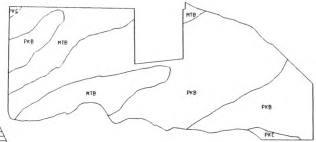


Field 10 Soils

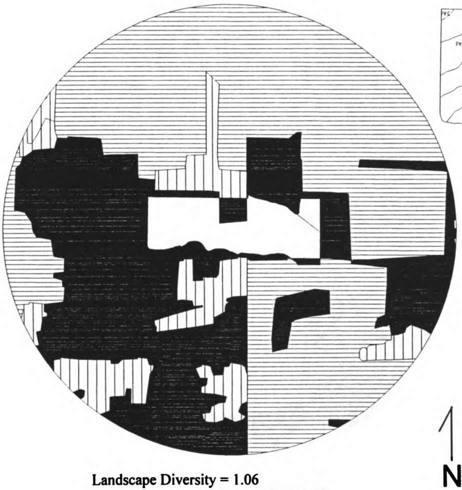


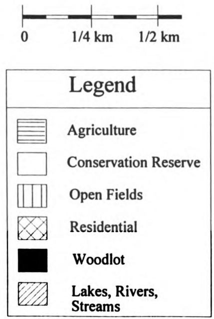
Landscape Diversity = 1.02
Landscape Mean Bird Diversity = 1.07
Field Bird Diversity = 1.11
Field Soil Diversity = 1.15

Appendix E. (cont.) (g). Field 10.



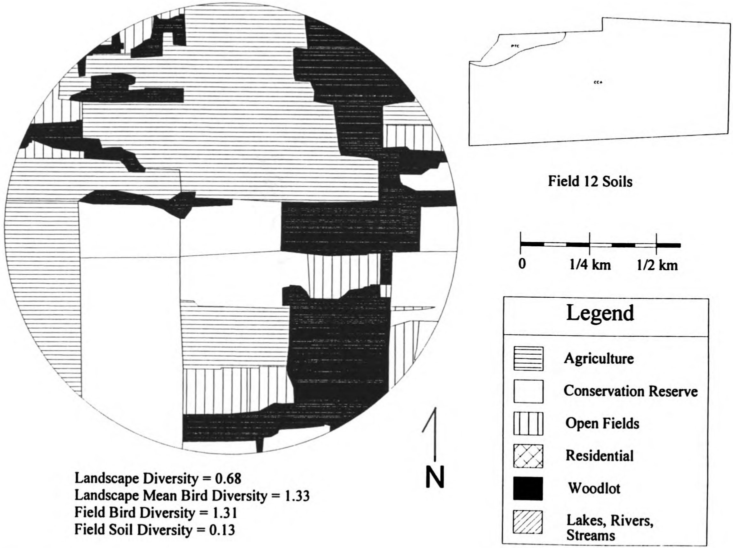
Field 11 Soils





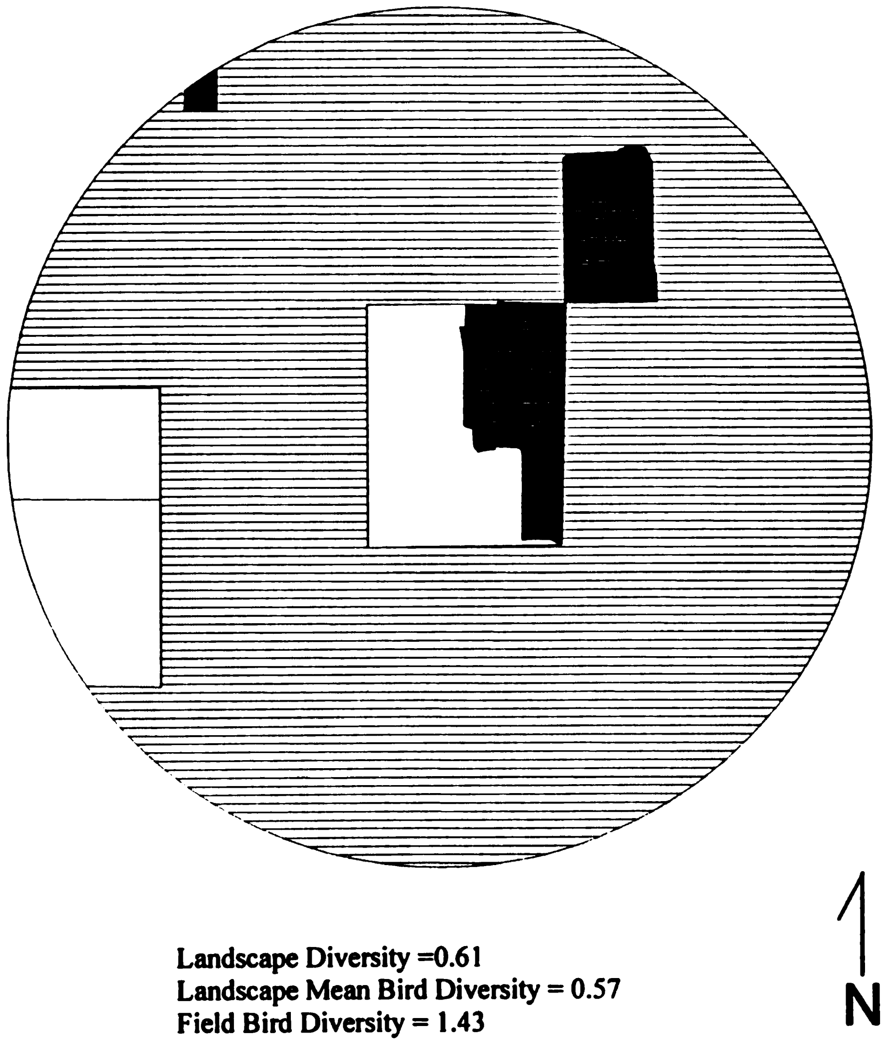
Landscape Diversity = 1.06
Landscape Mean Bird Diversity = 1.10
Field Bird Diversity = 0.67
Field Soil Diversity = 0.62

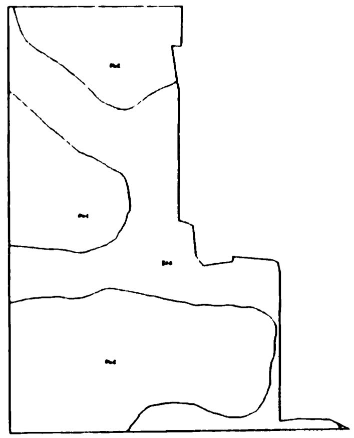
Appendix E. (cont.) (h). Field 11.



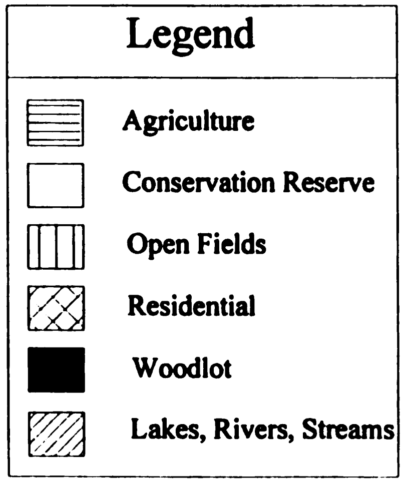
Landscape Diversity = 0.68
Landscape Mean Bird Diversity = 1.33
Field Bird Diversity = 1.31
Field Soil Diversity = 0.13

Appendix E. (cont.) (i). Field 12.



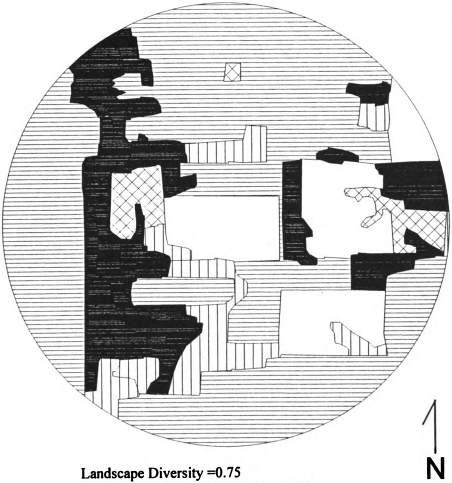


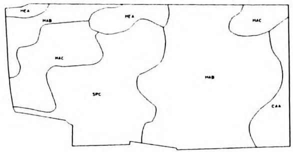
Field 89A Soils



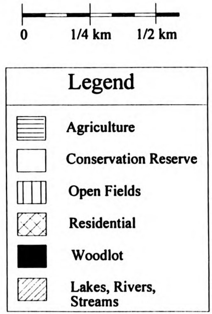
Landscape Diversity =0.61
Landscape Mean Bird Diversity = 0.57
Field Bird Diversity = 1.43
Field Soil Diversity = 0.54

Appendix E. (cont.) (j). Field 89A.



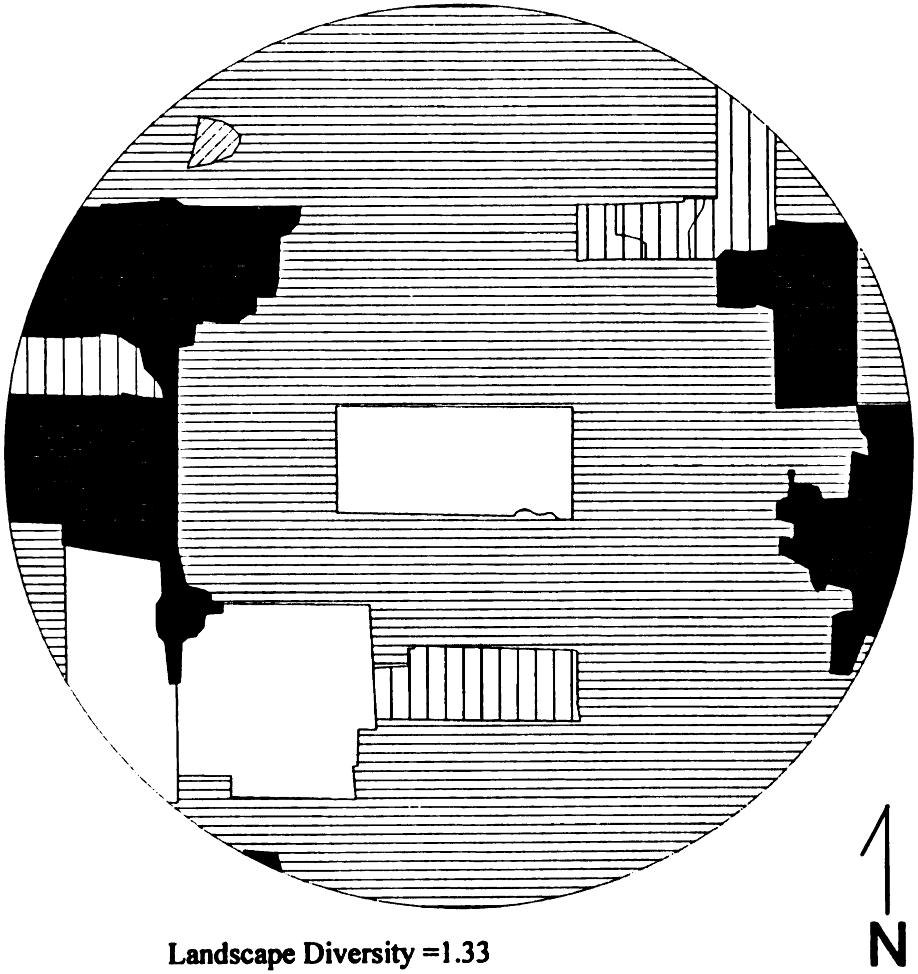


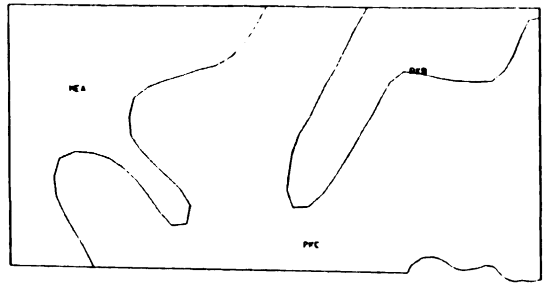
Field 89B Soils



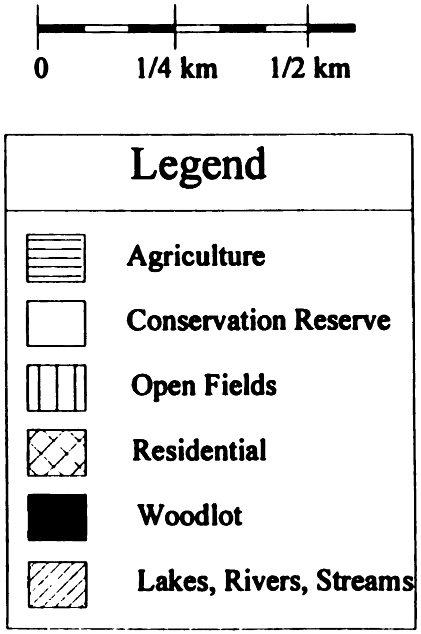
Landscape Diversity =0.75
Landscape Mean Bird Diversity = 1.28
Field Bird Diversity = 1.19
Field Soil Diversity = 1.11

Appendix E. (cont.) (k). Field 89B.



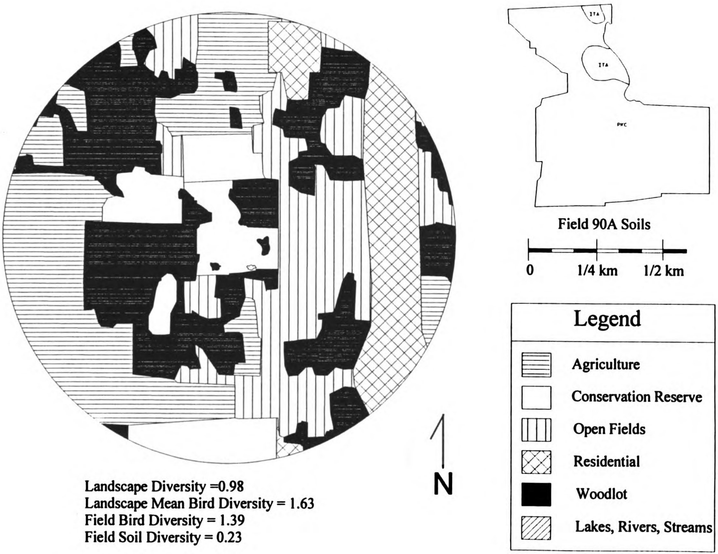


Field 89c Soils



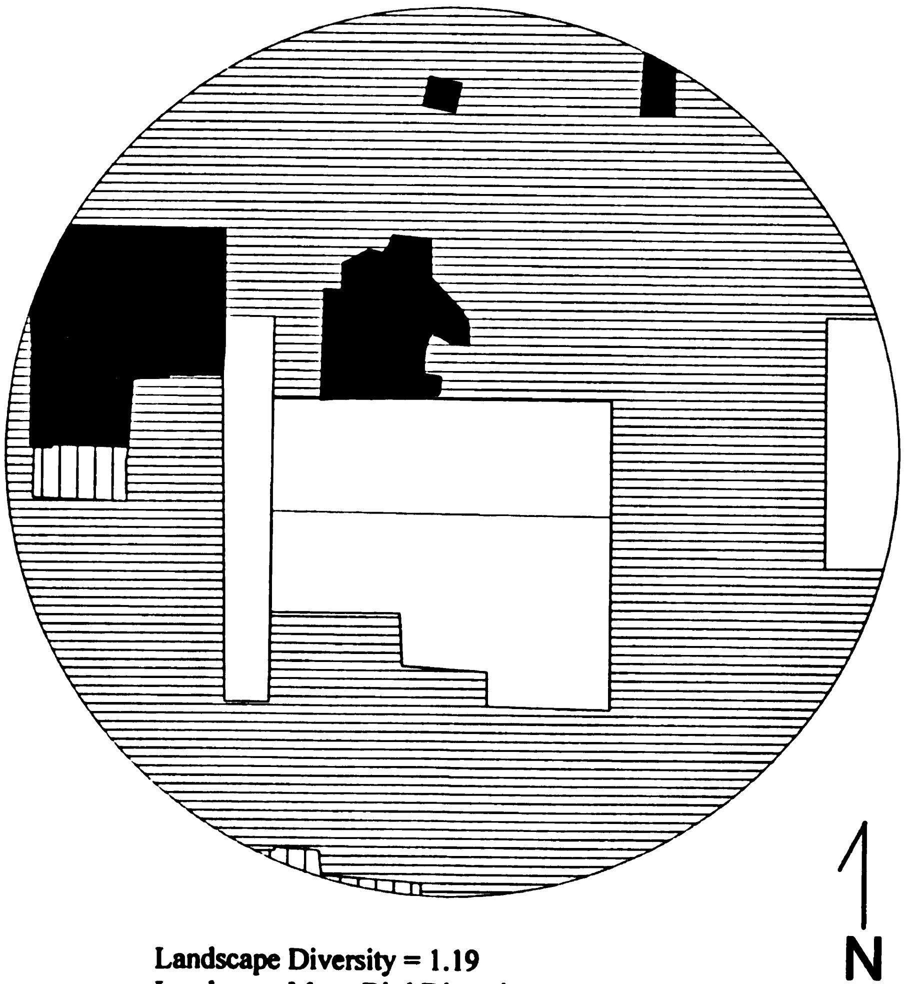
Landscape Diversity =1.33
Landscape Mean Bird Diversity = 1.00
Field Bird Diversity = 1.22
Field Soil Diversity = 1.02

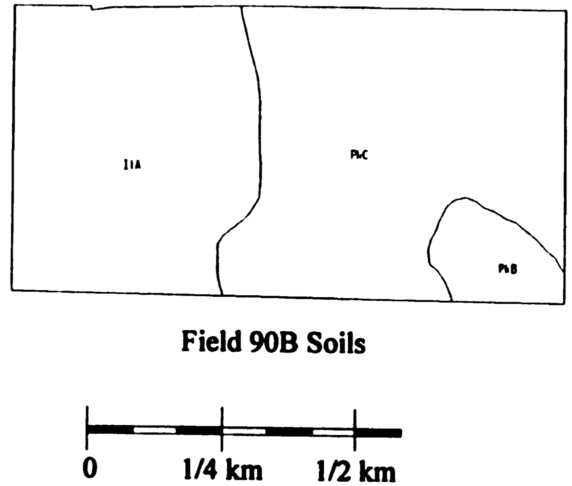
Appendix E. (cont.) (l). Field 89C.



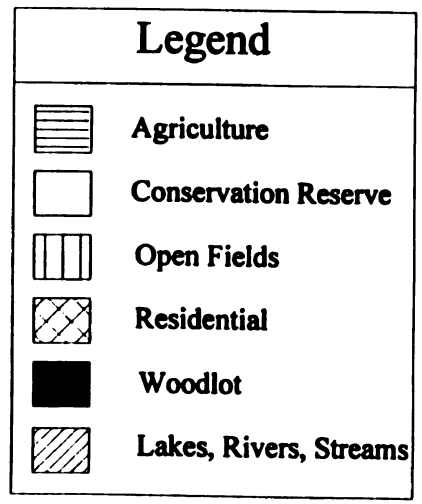
Landscape Diversity =0.98
Landscape Mean Bird Diversity = 1.63
Field Bird Diversity = 1.39
Field Soil Diversity = 0.23

Appendix E. (cont.) (m). Field 90A.



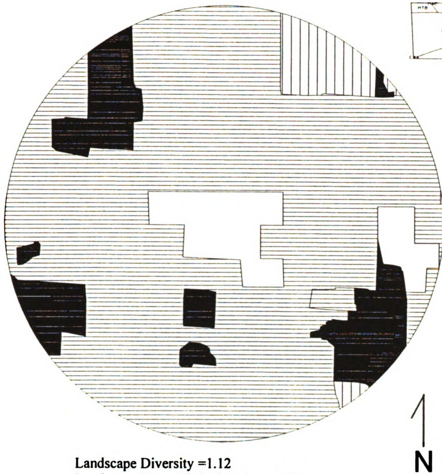


Field 90B Soils

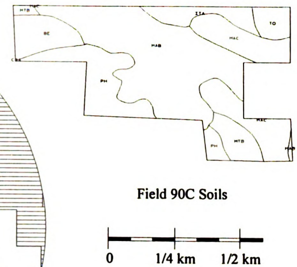


Landscape Diversity = 1.19
Landscape Mean Bird Diversity = 0.84
Field Bird Diversity = 1.56
Field Soil Diversity = 0.93

Appendix E. (cont.) (n). Field 90B.



Landscape Diversity =1.12
Landscape Mean Bird Diversity = 0.81
Field Bird Diversity = 1.16
Field Soil Diversity = 1.38

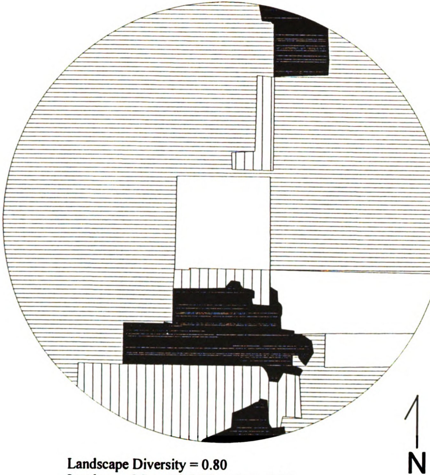


Field 90C Soils

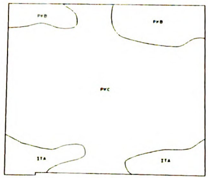
Legend

- Agriculture
- Conservation Reserve
- Open Fields
- Residential
- Woodlot
- Lakes, Rivers, Streams

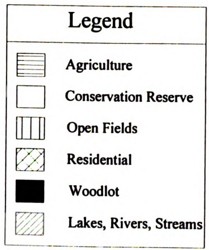
Appendix E. (cont.) (o). Field 90C.



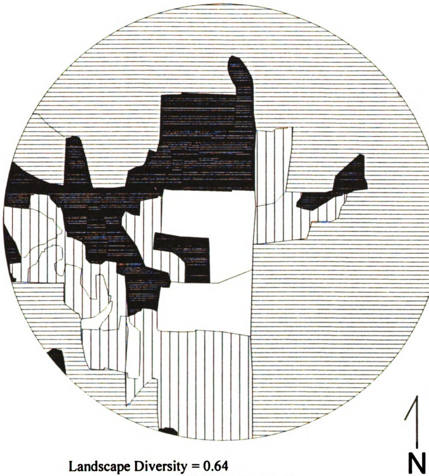
Landscape Diversity = 0.80
Landscape Mean Bird Diversity = 1.03
Field Bird Diversity = 1.22
Field Soil Diversity = 0.99

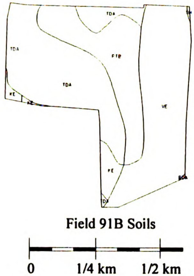


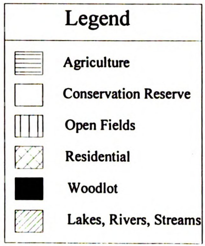
Field 91A Soils



Appendix E. (cont.) (p). Field 91A

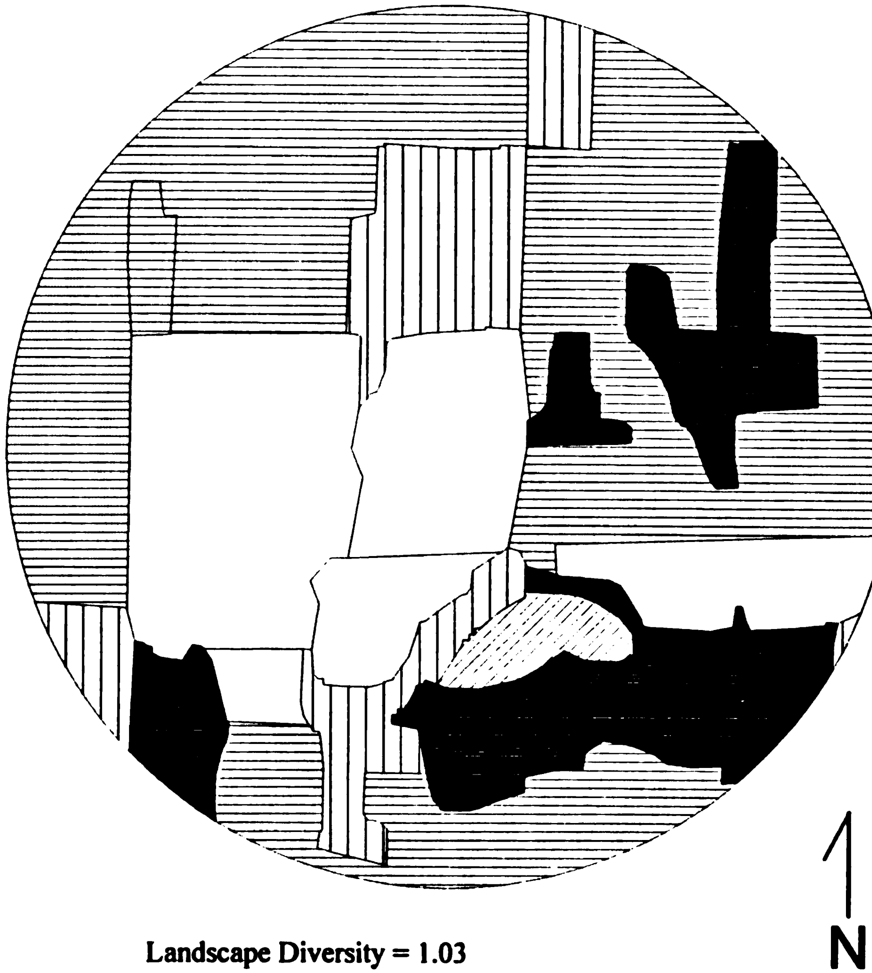


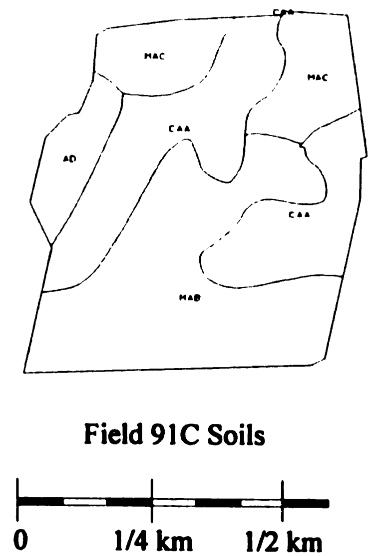


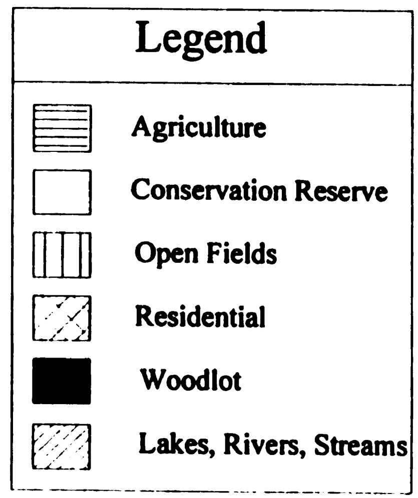


Landscape Diversity = 0.64
Landscape Mean Bird Diversity = 1.16
Field Bird Diversity = 1.63
Field Soil Diversity = 1.26

Appendix E. (cont.) (q). Field 91B







Landscape Diversity = 1.03
Landscape Mean Bird Diversity = 1.31
Field Bird Diversity = 1.27
Field Soil Diversity = 1.34

Appendix E. (cont.) (r). Field 91C.

Appendix F. Descriptions of soils found on Conservation Reserve Program study sites in Gratiot County, Michigan, 1992.

Soil	Soil Name	General Soil Description[a]
Ad	Adrian muck	Nearly level, poorly drained soil on lowlands and flood plains.
Be	Belleville loamy sand	Nearly level, poorly drained soil in broad flat areas and drainageways.
BoB	Boyer loamy sand	Nearly level to gently sloping, well drained soil on knolls and ridges.
CaA	Capac loam	Nearly level, poorly drained soil on low knolls and ridges.
CcA	Capac Variant complex	Nearly level, somewhat poorly drained soil on low, domelike mounds and ridges and poorly drained soil in depressions and drainageways.
Cr	Corunna sandy loam	Nearly level, poorly drained soil in broad flat areas and drainageways.
Ed	Edwards muck	Nearly level, very poorly drained soil on lowlands.
Gd	Gilford sandy loam, gravelly substratum	Nearly level, very poorly drained soil in broad flat areas, and drainageways.
ItA	Ithaca loam	Nearly level, somewhat poorly drained soil on low knolls and ridges.
Ke	Kingsville loamy sand	Nearly level, poorly drained soil in broad flat areas and drainageways.
Le	Lenawee clay loam	Nearly level, poorly drained soil in broad flat areas and drainageways.
MaB	Marlette B sandy loam	Gently sloping, well drained soil on foothills, ridges, and knolls.
MaC	Marlette C sandy loam	Moderately sloping, well drained soil on knolls and ridgetops.
MeA	Metamora-Capac sandy loam	Nearly level, somewhat poorly drained soil on low knolls and ridges.
MtB	Metea loamy sand	Nearly level to gently sloping, well drained soil on knolls and ridges.
Ph	Parkhill loam	Nearly level, poorly drained soil in broad flat areas and drainageways.
PkB	Perrington B loam	Gently sloping, well drained soil on foot slopes, knolls and ridgetops.
PkC	Perrington C loam	Moderately sloping to gently rolling, well drained soil on knolls and ridgetops.
PtB	Plainfield loamy sand	Moderately sloping to rolling, excessively drained soil on knolls and ridgetops.

Appendix F. cont.

Soil	Soil Name	General Soil Description[a]
RdA	Riverdale loamy sand	Nearly level, somewhat poorly drained soil on low knolls and ridges.
SeA	Selfridge loamy sand	Nearly level, somewhat poorly drained soil on low knolls and ridges.
SpC	Spinks loamy sand	Moderately sloping or gently rolling, well drained soil on knolls and ridgetops.
TdA	Tedrow loamy sand	Nearly level, somewhat poorly drained soil on low knolls and ridges.
Ve	Vestaburg loamy sand	Nearly level, poorly drained soil in broad, flat areas and drainageways.

[a] Taken from soil survey of Gratiot County, Michigan (Feenstra 1979).

Appendix G. Linear regression models of bird, mammal, and invertebrate diversities and relative abundances from Conservation Reserve Program (CRP) lands in Gratiot County, Michigan, 1992.

Dependent Variable	Linear Regression Equation	r^2	Probability
Bird Diversity	Field size (0.0114) - Field age (0.0843) + Proportion of residential area (1.4765) - Proportion of open fields (0.5150) + Diversity of cover types (0.5380) - Adjacent row crops (0.0037) + 1.6390	0.7375	0.0160
Bird Abundance	Field size (0.0307) - Field age (0.3952) + Proportion of row crops (1.7885) + Proportion of CRP (1.6089) + Diversity of landscape (2.1719) - 1.2176	0.8755	0.0001
Mammal Diversity	Potential to produce openland wildlife (0.7903) - Proportion of woodlots (0.4164) + Adjacent open fields (0.0086) - 1.8679	0.9155	0.0041
Mammal Abundance	Proportion of woodlots (30.3807) + Proportion of row crops (20.0158) + 0.1470	0.8757	00.0019
Insect Diversity	Diversity of soils (0.3277) - Field age (0.1210) - Proportion of open fields (0.7003) - Adjacent CRP (0.0033) + 1.5082	0.7640	0.0010
Insect Biomass	Diversity of soils (0.0198) - Diversity of landscape (0.0405) - Field age (0.0033) + Proportion of residential area (0.1161) - Proportion of CRP (0.0236) + 0.0678	0.8410	0.0004
Bobolink Abundance	Adjacent residential area (0.7189) - Field age (1.8884) - Proportion of woodlots (18.3713) - Proportion of residential area (68.8166) + 16.3270	0.7990	0.0004
Sedge Wren Abundance	Field age (0.6222) - *Proportion of CRP (3.4357) + Diversity of soils (1.9344) + Adjacent CRP (0.0522) - 3.1171	0.5133	0.0542
Grasshopper Sparrow Abundance	Proportion of residential area (2.6762) - Field age (0.1265) + *Proportion of open fields (0.9186) - Potential to produce openland wildlife (0.6769) + 2.0526	0.7004	0.0038
Savanna Sparrow Abundance	10.68724922 - Field age (2.7719) - Proportion of woodlots (8.6057) - Proportion of residential area (28.2254) - Proportion of open fields (12.7050) + Diversity of landscape (8.3524)	0.7570	0.0039

* Variable has $P < 0.10$.