ILLINOIS NATURAL HISTORY SURVEY

Section of Wildlife Research

ILLINOIS FARM PROGRAMS: LONG-TERM IMPACTS ON TERRESTRIAL ECOSYSTEMS AND WILDLIFE-RELATED RECREATION, TOURISM, AND ECONOMIC DEVELOPMENT

{ENR Contract No. EH16}
FINAL REPORT - PHASE I

1 November 1988

-By-
Richard E. Warner
Principal Investigator

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PHASE I

- by -

Richard E. Warner
Illinois Natural History Survey
607 E. Peabody
Champaign, Il. 61820

James R. Thompson, Governor
State of Illinois

Karen Witter, Director
Illinois Department of
Energy and Natural Resources

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INTRODUCTION

The 1985 Wildlife Habitat Commission Report in Illinois noted, "If reasonable consideration is given to wildlife in land use planning, the multiple benefits of reduced soil erosion, sustained production of food and fiber, improved water quality and reasonably healthy wildlife populations often are attainable." More recently, the Governor's Task Force On Recreation and Tourism observed that the enhancement of the state's natural resources can, and should, be a key to tourism and the future diversification of rural economies.

There has been a renewed political will during the 1980s to jointly address problems related to rural income and resource conservation (Jahn 1988). Some recent products of this political resolve include the Illinois "T by 2000" program outlining soil and water quality goals (Illinois Department of Agriculture 1985) and, on a national basis, the 1985 Food Security Act (farm bill). The Conservation Reserve Program (CRP) is an important facet of the 1985 farm bill, and includes 10-year leases to remove highly erodible land from crop production, as well as "sodbuster", "swampbuster", and the Conservation Compliance clause. Conservation Compliance mandates that in order for farms with highly erodible soils to be eligible to participate in future agricultural programs, plans for achieving soil loss standards must be developed by 1990--plans which must then be adopted by 1995.

These emerging legislative initiatives will have a pervasive, long-term effect on land use in Illinois, and have the potential for significantly enhancing natural resources. Ultimately, the degree to which natural resources are enhanced depends upon how these programs and policies do, or do not, work in concert to integrate resource conservation practices with agricultural land use (Office of Technology Assessment 1985, Miles et al. 1987).

For example, rather than addressing an array of critical natural resource issues, the Conservation Compliance clause is narrowly directed to protecting soil.

The guidelines by which many of these programs will be implemented at the local level are still in the formative stage; scientific input is appropriate before farm conservation plans are finalized and put into place. It should be emphasized that the window of opportunity for influencing how these programs affect the biological integrity of agricultural ecosystems will probably not exist beyond the early 1990s. Any benefits to natural resources resulting from farm programs are ultimately subject to more carefully defined land use specifications that will emerge over the next few years.

Goals and Objectives

The general goal of the project is to provide an analytical basis for evaluating the combined effects of agricultural policies and programs on natural resources in Illinois. The objectives are:

1. To define the potential directions and implications of major federal and state initiatives--including education, incentives, and mandatory compliance--affecting land use and natural resources in Illinois through the year 2000;

2. To describe the effects of potentially emerging land use scenarios on the integrity of agricultural ecosystems, as inferred by qualitative and quantitative measures of upland wildlife habitat;

3. To make recommendations for maximizing wildlife-related benefits to the economy through enhanced recreation (both consumptive and appreciative) and tourism that could result from long-term integrated farm conservation programs and policies in Illinois;

4. To suggest means for better defining and predicting linkages between agricultural land use and resulting wildlife recreation opportunities and the importance of such recreation to local economies;

5. To develop high-quality products (illustrations, reports, and articles for peer-reviewed scientific journals) that will make the findings of the study visible and functional for a variety of user groups.

Conceptual Model and Development of Phases I and II

The conceptual model for the study (Fig. 1) is based on the premise that farm policies and programs in Illinois affect land use and upland wildlife habitat. Further, the premise holds that there are measurable associations among farmland habitat, upland wildlife abundance, and the potential for wildlife-related recreation (Fig. 1).

The project is separated into 2 phases. Phase I (this report) emphasized the assembly and computer-archiving of data sets and development of preliminary predictive models. Thus, Phase I is directed primarily to Objectives 2 and 4. Moreover, Phase I is a test of the conceptual model (Fig. 1).

The primary work tasks for Phase I included (1) formation of an advisory board; (2) assembly and computer-archiving of data sets; (3) development of predictive models, and; (4) reporting and review of literature. This report primarily considers items 2-4. The Advisory Group (item 1) consisted of R.E. Warner (NHS), Gary R. Philo (ENR), Larry M. David (Illinois Department of Conservation), and Gene Barickman (Soil Conservation Service). This group convened in Champaign on 8 June 1988; there were also numerous informal interactions among group members. In addition to reports developed for ENR (item 2), 2 manuscripts were

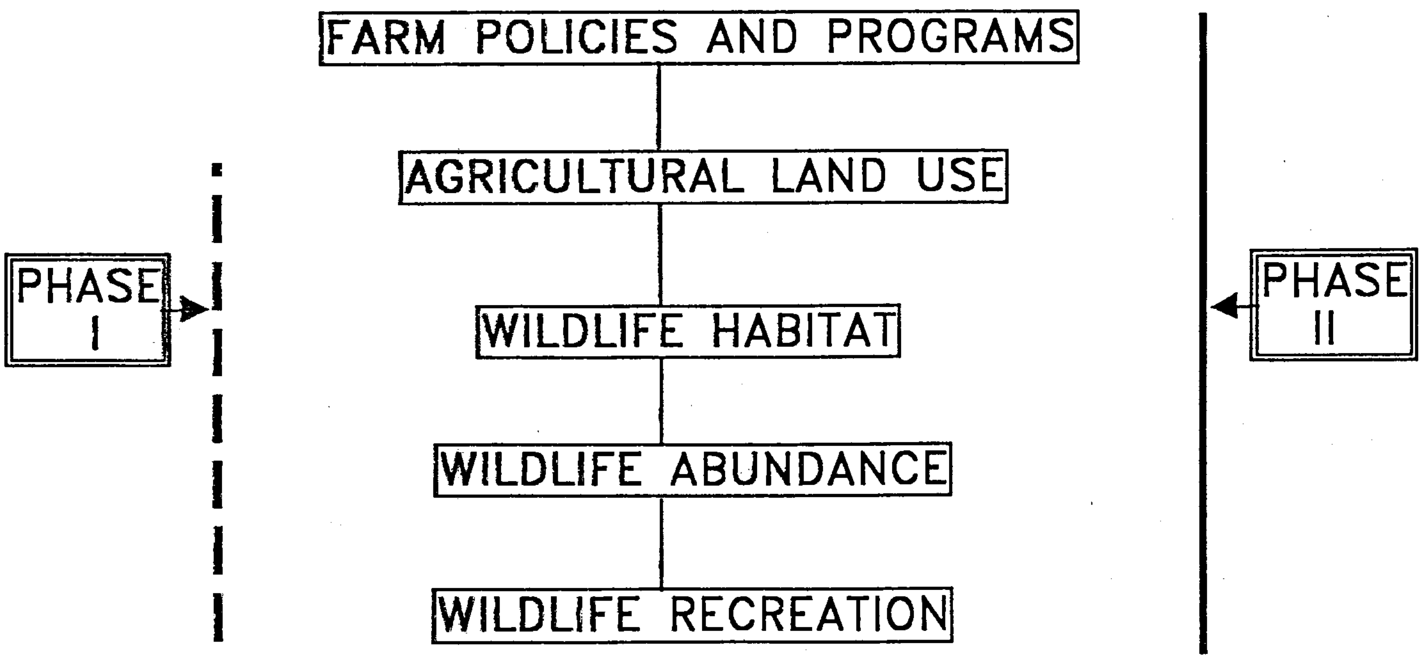

Fig. 1. A conceptual model describing farm policies and programs as they affect wildlife abundance and related recreation in Illinois, and the relevance of Phases I and II of the study.

drafted and have been submitted to scientific journals (Appendices B and C).

Phase II encompasses all 5 objectives, and will identify alternative policies and land use directions and, using predictive models, will project likely impacts of these alternative directions on habitat quality, the abundance of key wildlife species, and associated recreation. The ultimate goal of Phase II is to identify how farm programs can best be structured to achieve multiple and sustained benefits to society by addressing a broad range of natural resource issues (Jahn 1988). Recommendations will be made for structuring relatively cost-effective programs for integrating natural resource conservation needs, objectives, and benefits.

METHODS

Assembly and Computer-Archiving of Data Sets

Data sets assembled and used in this study are summarized in Table 1 and described in more detail in Appendix A. Data sets 5, 9, and 11 will not be used until Phase II. A computerized form of data set 5, describing trends in conservation tillage, will be ordered before the end of Phase I.

A computer listing of changes in relative abundance, 1967-87, recorded for each bird species as part of the Breeding Bird Survey (BBS, data set 3) for Illinois, was received in September 1988. However, a computer tape describing annual trends in abundance by species and route in Illinois did not arrive until 24 October 1988; because of the complex tasks associated with formatting and reducing the data set, there was not sufficient time for in-depth computer analysis during Phase I.

MULREG (number 13, Table 1) represents the most important data set for Phase I. This data set represents a combination, or

Table 1. Data sets identified and/or computer-archived during Phase I of the project (Appendix A describes these data sets in detail).

No.	Name	Period	Use Phase I
01	ILLHUNT	1974-87	Development of data set 2
02	UG	1956-86	Dependent variables describing trends in consumptive recreation associated with key upland game species in Illinois
03	BBS	1967-87	Indices of abundance used as dependent variables, including (1) all birds; (2) nongame grassland and other species sensitive to agricultural land use; and, (3) species included under item 2 plus pheasant and quail
04	SIBLEY	1955-88	Validation of the use of data sets 1 and 2 as indicators of trends in upland game abundance and habitat
05	T BY 2000	2000	N/A[1]
06	ILLAG	1945-198	Statewide summaries of land use--acres planted to various crops--used as independent variables describing habitat conditions
07	AGCENSUS	1949-81	Background description of land use changes in Illinois and surrounding states
08	DISTURB	1950-87	Hay cutting data used in development of manuscript (Appendix B)
09	NRI	1982	N/A
10	RMCC	1958-88	Validation of data set 2 as an indicator of pheasant abundance
11	GIS	Variable	N/A
12	CT	1981-87	Written report used in development of manuscript
13	MULREG	1955-86	Construction of predictive models

1 Not applicable for Phase I.

synthesis, of several larger data sets (Appendix A). MULREG includes all variables used in predictive analyses.

Construction of Variables - Phase I

Limitations and assumptions

This project emphasizes land use and habitat features that are most affected by, and responsive to, farm programs and policies (Office of Technology Assessment 1985, Jahn 1988). Likewise, the work considers representative wildlife species--"key species" that are highly sensitive to farming practices for which sufficient data exist for developing predictive models. Although terrestrial ecosystems will be given primary consideration, general implications of land use practices and controls on aquatic habitats, especially sedimentation (Bellrose et al. 1983, Pimentel et al. 1987, Osborne and Wiley 1988), will be considered in Phase II.

Given the data sets available for Phase I, the general approach to development of preliminary multiple regression models was to construct independent variables describing quantitative and qualitative changes in habitat. Dependent variables described trends in hunter kill and recreation associated with key upland game species in Illinois. Moreover, an appraisal was made of the validity of using these variables as indices of upland wildlife abundance.

Dependent variables associated with the taking of upland game were classified as consumptive forms of recreation. A preliminary assessment was also made of long-term associations between consumptive and appreciative wildlife recreation; this assessment was limited by the dearth of information available for appreciative recreation and associated economics (Illinois Department of Business and Economic Development 1965). Appreciative recreation was considered to be such activities as bird watching and feeding, wildlife photography, and "backyard" habitat development or landscaping for wildlife.

<u>Independent variables</u>

1. Quantitative measures of habitat in agricultural ecosystems
Quantitative variables described how much cover of a certain type (crop) existed in Illinois in a given year (Table 2). The variables CORN, SOYBEANS, WHEAT, OATS, BARLEY, RYE, and HAY represent acres harvested. The sum of these crops subtracted from the total acres in FARMLAND represents the variable UNCROP (uncropped land). Annual (short-term) variability in UNCROP primarily reflected participation in programs diverting cropland from production; long-term reductions in UNCROP appeared to indicate increased disturbances of highly erodible soils by intensive cropping. The variable ROWCROPS is the sum of CORN and SOYBEANS. Likewise, SMALLGRNS = WHEAT + OATS + BARLEY + RYE (Table 2).

2. Qualitative measures of habitat in agricultural ecosystems
Qualitative indices tended to reflect the manner in which agricultural technologies were applied to cropland habitats--the nature and extent of farming disturbances. The variables HERB (herbicide) and INSECT (insecticide) are the percentages of CORN receiving these pesticide applications for a given year. Acres of corn treated by herbicides and insecticides in Illinois have been quantified using various surveys and census data at least 6 times since the early 1950s (e.g., Economic Research Service 1968, Dover 1986). Because pesticide treatments have gradually increased since the early 1950s, percentages of corn receiving herbicide and insecticide applications for any given year could be estimated using equations for the best fit of a curve for the 6 known points in time. For the percent of corn treated with herbicides (Y), $HERB = -365.05 + 9.79X - 0.05X^2$,

Table 2. Independent variables describing wildlife habitat on farmland in Illinois.

Number	Name	Period	Units of measurement
Quantitative Factors			
1.	CORN	1945-87	acres (1,000s)
2.	SOYBEANS	1945-87	acres (1,000s)
3.	ROWCROPS	1945-87	acres (1,000s)
4.	WHEAT	1945-87	acres (1,000s)
5.	OATS	1945-87	acres (1,000s)
6.	BARLEY	1945-87	acres (1,000s)
7.	RYE	1945-87	acres (1,000s)
8.	HAY	1945-87	acres (1,000s)
9.	SMALLGRNS	1945-87	acres (1,000s)
10.	CROPLAND	1945-87	acres (1,000s)
11.	FARMLAND	1945-87	acres (1,000s)
12.	UNCROP	1945-87	acres (1,000s)
Qualitative factors			
13.	HERB	1950-87	% corn
14.	INSECT	1950-87	% corn
15.	PEST	1950-87	% corn
16.	CATTLE	1946-87	number (1,000s)
17.	MILKCOWS	1946-87	number (1,000s)
18.	BEEFCOWS	1946-87	number (1,000s)
19.	HOGS	1946-87	number (1,000s)
20.	SHEEP	1946-87	number (1,000s)
21.	CTLHOGS	1946-87	number (1,000s)
22.	CPI	1950-87	number
23.	YIELD	1945-87	number (bu. corn)
24.	TILL	1950-86	% (row crop acres)
25.	FARMSIZE	1950-87	acres

where X = year (beginning in 1950 enumerated as 50); r_2 = 0.985. For the percent of corn treated with insecticides (Y), INSECT = -69.43 + 1.41 X, where X = year (also enumerated beginning with 50); r^2 = 0.879. The variable PEST (for pesticides) = HERB + INSECT (Table 2).

The intensity of livestock disturbances is described by the variables CATTLE, MILKCOWS, BEEFCOWS, HOGS, and SHEEP. These variables reflect numbers of animals on inventory around 1 January; CATTLE represent cattle and calves of all types on farms (Table 2). The variable CTLHOGS = CATTLE + HOGS.

CPI is the crop production index for all farm commodities in Illinois with 1977 as a base; i.e., 1977 = 100. The CPI reflects all factors affecting yields including weather, cropland in production, and agricultural technologies. Because the CPI reflects changing agricultural technologies and agronomy, it was employed as an index of farmland disturbances (Table 2). Likewise the variable YIELD, average bushels of corn harvested per acre dry weight, represents a qualitative index of increasing chemical and mechanical disturbances of cropland associated with changing farm technologies. The variable TILL describes the percent of acres intended to be planted as ROWCROPS the following year, tilled by about 1 December. Up through the 1970s fall tillage was essentially moldboard plowing. Fall tillage in the late 1970s and 1980s represents a plethora of soil disturbance practices. FARMSIZE is also considered as a qualitative dimension of habitat, because increasing farm size reflects increasing sizes of fields (less diversity of cover) and fewer farms (less variability in farming practices at localized scales).

<u>Dependent variables</u>

1. Abundance of upland game and consumptive recreation

Indices of the abundance of pheasant, rabbit, and quail used as dependent variables were estimates of numbers of these species killed by hunters in Illinois, 1955-86. Variables describing numbers of animals killed are PHEASKIL, QUAILKIL, RABKIL; variables for numbers of days expended by hunters for each species are PHEASDAY, QUAILDAY, AND RABDAY. The dependent variables ALLKIL and ALLDAY represented the sum of animals killed and hunter-days, respectively, for the 3 species. ALLKIL was the primary dependent variable for multiple regression analysis.

The 5-year surveys of participation in wildlife-related recreation conducted by the U.S. Fish and Wildlife Service (1978, 1983) provided supplementary indicators of consumptive recreation. For example, these surveys estimated numbers of participants, and expenditures, pertaining to the taking of small game in Illinois.

2. Abundance of grassland passerines and appreciative recreation

Because of the delay in acquiring the BBS data (Table 1) on computer for Illinois, the abundance of grassland passerines could not be used as a dependent variable. However, the relative changes, 1967-87, in the abundance of key grassland species were computed. The magnitude of changes for various species and groups could be compared with those of game species, both from BBS data and Illinois data sets, as a preliminary appraisal of how well trends in game abundance could be used as indicators of trends in abundance for grassland passerines.

There is not sufficient information available to form a continuous variable describing the amount of recreation associated with appreciative forms of wildlife recreation in Illinois. However, the U.S. Fish and Wildlife Service (1978, 1983) has periodically recorded numbers of individuals and days of participation associated with primary residential "wildlife observation"--activities such as wildlife photography, bird feeding, and observation within 1 mile of a participant's residence. Most recent (1985) summaries for Illinois have not been released. About 73% of the participants in primary residential wildlife observation in Illinois do not hunt (U.S. Fish and Wildlife Service 1983).

Multiple Regression Models

Regression models were constructed for 1956-86, the period for which data were available every year for nearly all variables. With a sample size of 31 years, 3-4 independent variables represent the maximum number that should be included in multiple regression models (Tatsuoka 1971).

Two multiple regression models were considered using ALLKIL as the dependent variable. The first model (Model A) allowed for step-wise selection of up to 4 independent variables (Table 2) using a P of < 0.05 for F-values of variables entering the equation; for variables taken out of the equation $P < 0.01$, with a tolerance of 0.01 (Norusis 1988).

Model B included up to 4 independent variables, with forced entry of TILL and UNCROP; step-wise selection procedures otherwise followed those of Model A. Although only exploratory, Model B was designed to consider the viability of predicting impacts of changing tillage practices and removing land from crop production. In some regions of Illinois, these practices could be important in strategies for addressing soil and water quality, and could have major implications for wildlife habitat and abundance (Edwards 1984, Brady 1985, Magelby et al. 1985, Office of Technology Assessment 1985, Odum 1987, Jahn 1988).

Further, ALLDAY was predicted by multiple regression using ALLKIL and the value for ALLDAY for the previous year. The assumption was made that hunter effort (ALLDAY) was in part related to hunter success and effort expended during the previous hunting season.

Multiple regression, and other statistical analyses, were computed using SPSS/PC+ (Norusis 1988). Regression equations are presented in the text using standardized regression coefficients (Beta weights) in order to indicate the relative importance of independent variables in the equations. Multiple regression equations in Figures show unstandardized regression coefficients.

FINDINGS AND DISCUSSION

Long-Term Changes in Wildlife Abundance

Long-term changes in the relative abundance of pheasants in Illinois are compared in Fig. 2 for surveys of upland game hunters (data set 2), the Sibley Study Area (data set 4), and Rural Mail Carrier Census information (data set 10). Hunter kill of pheasants (Fig. 2) represents PHEASKIL, which is included as part of the dependent variable ALLKIL. Thus, for the pheasant, kill statistics reflect relative abundance (Fig. 2).

The variables ALLKIL and ALLDAY also reflect trends in the relative abundance of other key upland game species (Table 3). The validity of these statistics as indicators of abundance in Illinois has been demonstrated for rabbits by Preno and Labisky (1971), Edwards et al. (1981), and Hubert (1986); and for bobwhite quail by Preno and Labisky (1971) and Roseberry (1984). Thus, although the estimates comprising ALLKIL are not necessarily precise, they accurately reflect relative changes in abundance.

Relative changes in abundance for some key species recorded as part of the BBS are shown in Fig. 3. Declines in numbers of pheasant and quail as indicated by the BBS data (Fig. 3) are similar to trends noted for the pheasant in Fig. 2. Taken together, the data sets suggest that resident upland game species

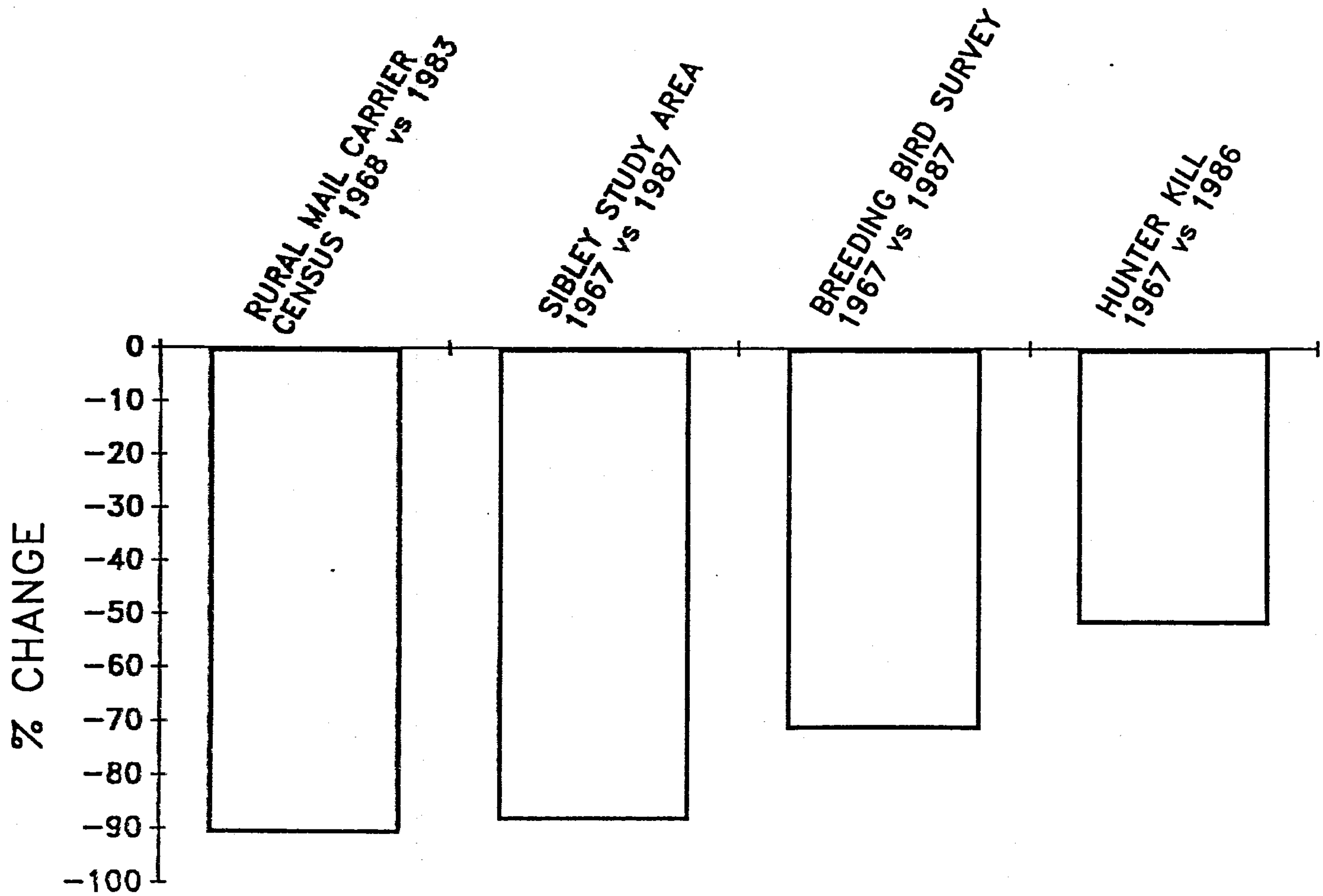

Fig. 2. Long-term changes in indices of pheasant abundance in Illinois as indicated from data sets 2, 3, 4, and 10 (Table 1).

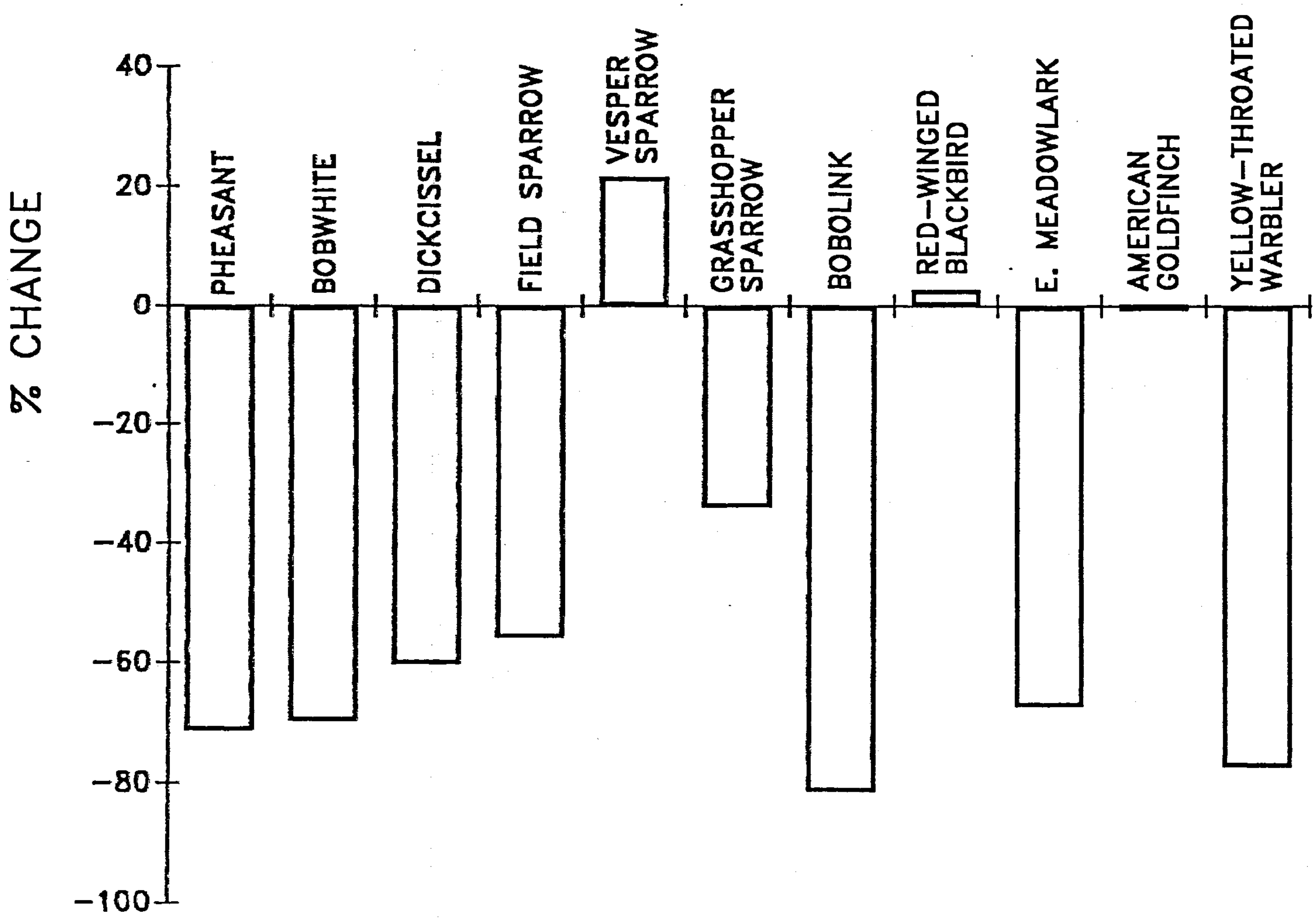

Fig. 3. Changes in the relative abundance of grassland species in Illinois, 1967-87, as indicated from data set 3 (Table 1).

Table 3. Summary statistics (numbers represent 1000s) for dependent variables describing consumptive recreation associated with pheasant, rabbit, and quail hunting in Illinois, 1956-86.

No.	Variable	Mean	Std. Dev.	Minimum	Maximum	N
1.	PHEASKIL	626.03	278.12	209	1,073	31
2.	PHEASDAY	936.94	274.57	534	1,496	31
3.	QUAILKIL	1,609.13	712.88	393	2,846	31
4.	QUAILDAY	756.23	184.15	462	1,113	31
5.	RABKIL	2,559.45	1,532.35	628	6,488	31
6.	RABDAY	1,670.71	493.89	978	2,761	31
7.	ALLKIL	4,794.61	2,345.16	1,238	9,703	31
8.	ALLDAY	3,363.87	833.34	2,004	4472	31

(pheasant, rabbit, quail) are most sensitive to changes in agricultural land use (Figs. 2 and 3). Although these species may be most suitable for developing models associating land use, habitat conditions, and wildlife abundance, the development of useful predictive models for grassland passerines also appears promising (Fig. 3). These migratory species have likewise been negatively affected by changing habitat conditions during breeding, and trends in relative abundance appear to reflect changing environmental conditions in Illinois (Graber and Graber 1976).

Long-Term Changes in Quantitative Measures of Habitat in Agricultural Ecosystems

Summary statistics for quantitative measures of habitat are listed in Table 4. The most important long-term changes in these factors are associated with expanded production of corn and soybeans, and the diminution of rotation farming, which fostered plantings of forage grasses and legumes (Fig. 4). Quantitative variables (Table 4) tend to be correlated with each other ($\underline{P} < 0.05$).

Long-Term Changes in Qualitative Measures of Habitat in Agricultural Ecosystems

Summary statistics for indices of farmland habitat quality are also listed in Table 4. Similar to quantitative measures of habitat, many qualitative factors have changed dramatically since the 1950s. For example, the total output of farm commodities (CPI) has increased exponentially, tracking expanded production of cash grains and increased chemical and mechanical disturbances (Fig. 5).

Associations of Wildlife Abundance and the Integrity of Agricultural Ecosystems

For regression Model A, ALLKIL = 1.04OATS - 0.61HAY-0.52ROWCROPS; R = 0.951, $\underline{P} < 0.001$, and S_y (standard error of

Table 4. Summary statistics for independent variables describing wildlife habitat on farmland in Illinois, 1956-86.

No.	Variable	Mean	Std. Dev.	Minimum	Maximum	N
1.	CORN	10,216.39	1,111.86	8,160	11,990	31
2.	SOYBEANS	7,231.97	1,714.81	4,649	9,720	31
3.	ROWCROPS	17,448.35	2,535.49	13,103	20,930	31
4.	WHEAT	1,491.65	324.73	750	1,964	31
5.	OATS	887.48	804.14	160	3,057	31
6.	BARLEY	30.65	39.77	0	148	31
7.	RYE	28.77	21.17	0	75	31
8.	HAY	1,511.00	474.14	1,037	2,532	31
9.	SMALLGRNS	2,438.55	1,029.12	910	4,891	31
10.	CROPLAND	2,1397.90	1,466.04	19,412	23,912	31
11.	FARMLAND	29,645.16	844.92	28,700	31,200	31
12.	UNCROP	8,247.26	2,139.16	4,888	11,181	31
13.	HERB	69.65	25.92	22	99	31
14.	INSECT	30.87	12.50	4	45	31
15.	PEST	100.52	38.11	26	144	31
16.	CATTLE	3,351.71	510.86	2,470	4,149	31
17.	MILKCOWS	402.42	203.67	216	858	31
18.	BEEFCOWS	733.32	73.58	616	868	31
19.	HOGS	6,601.19	733.06	5,100	7,748	31
20.	SHEEP	306.90	161.06	98	571	31
21.	CTLHOGS	9,952.90	1,132.89	7,570	11,726	31
22.	CPI	80.50	21.10	48.0	120.5	31
23.	YIELD	96.55	21.48	64	135	31
24.	TILL	51.48	18.11	17	91	31

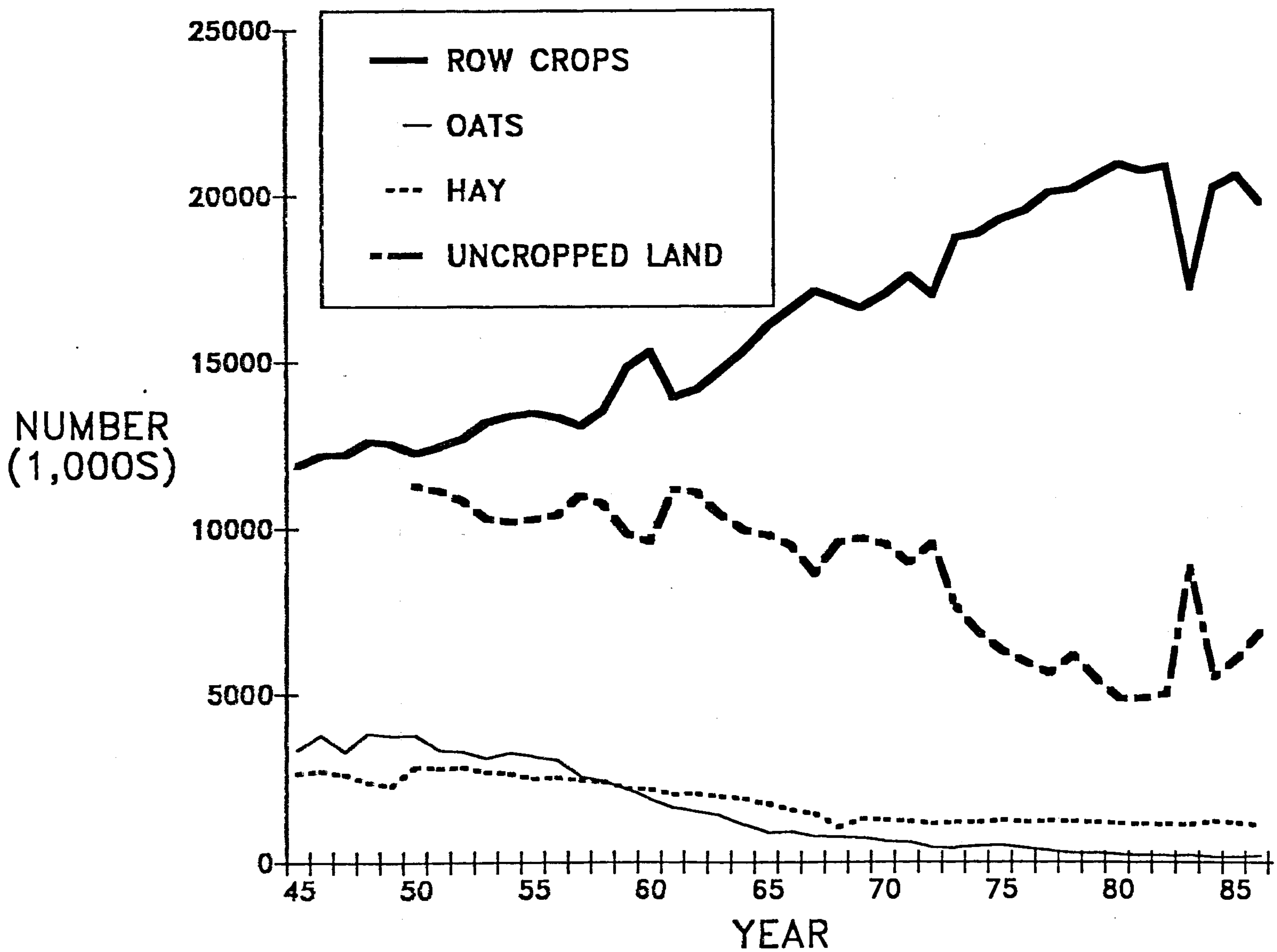

Fig. 4. Trends in selected factors describing quantitative features of habitat in Illinois agricultural ecosystems, 1956-86.

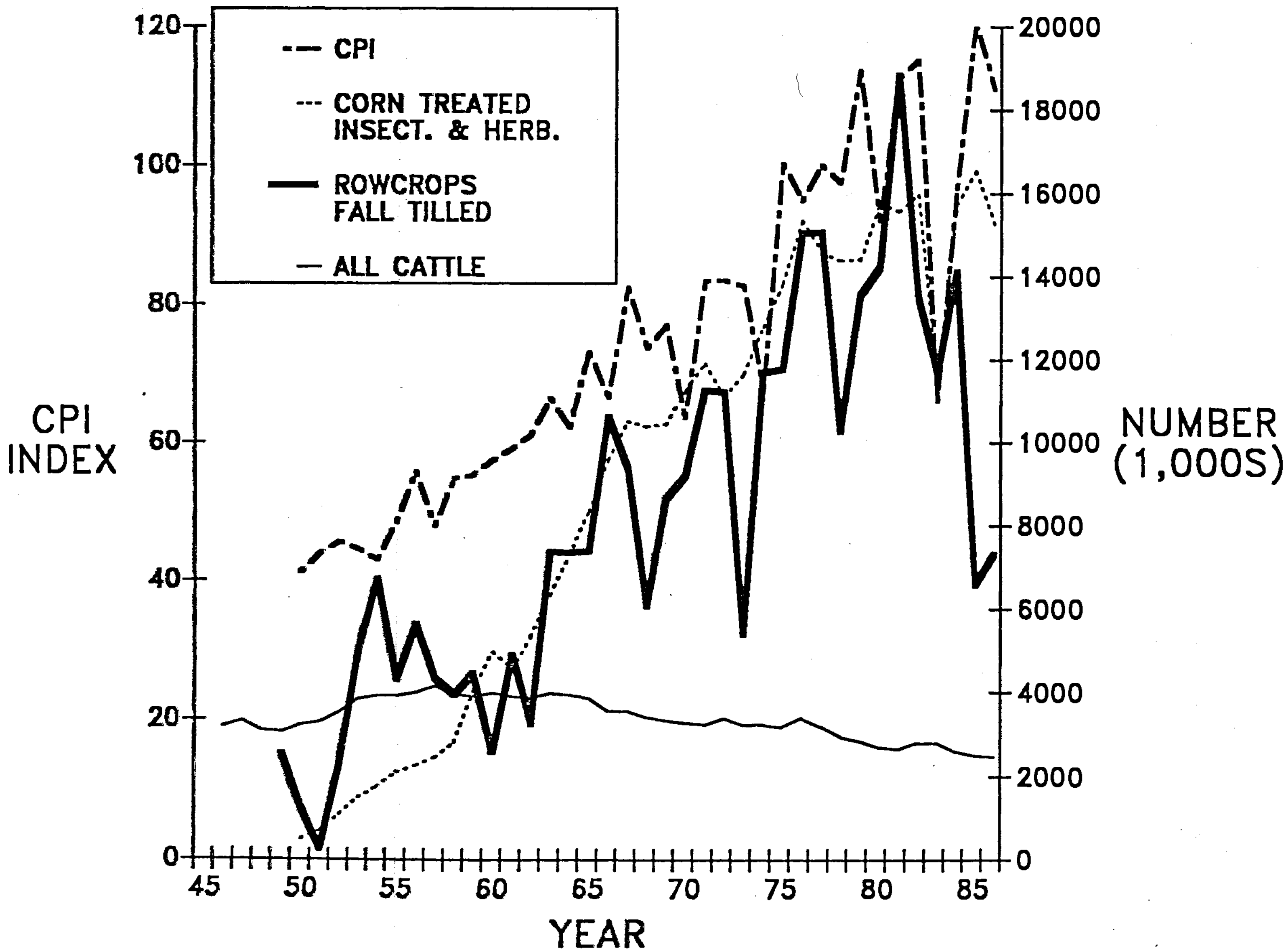

Fig. 5. Trends in selected factors describing qualitative features of habitat in Illinois agricultural ecosystems, 1956-86.

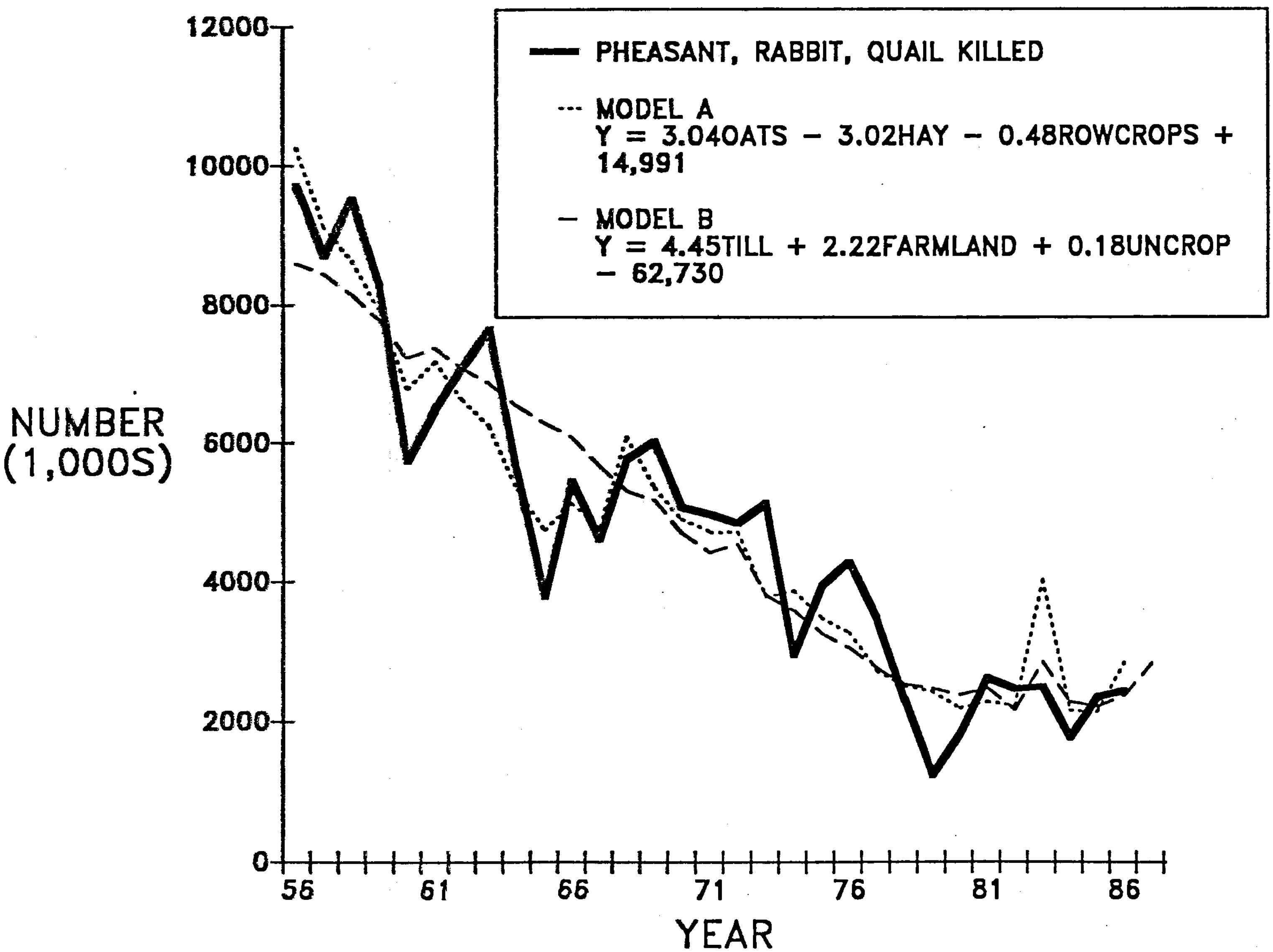

Fig. 6. Trends observed for ALLKIL (pheasants, rabbit, and quail killed), and predicted by multiple regression models.

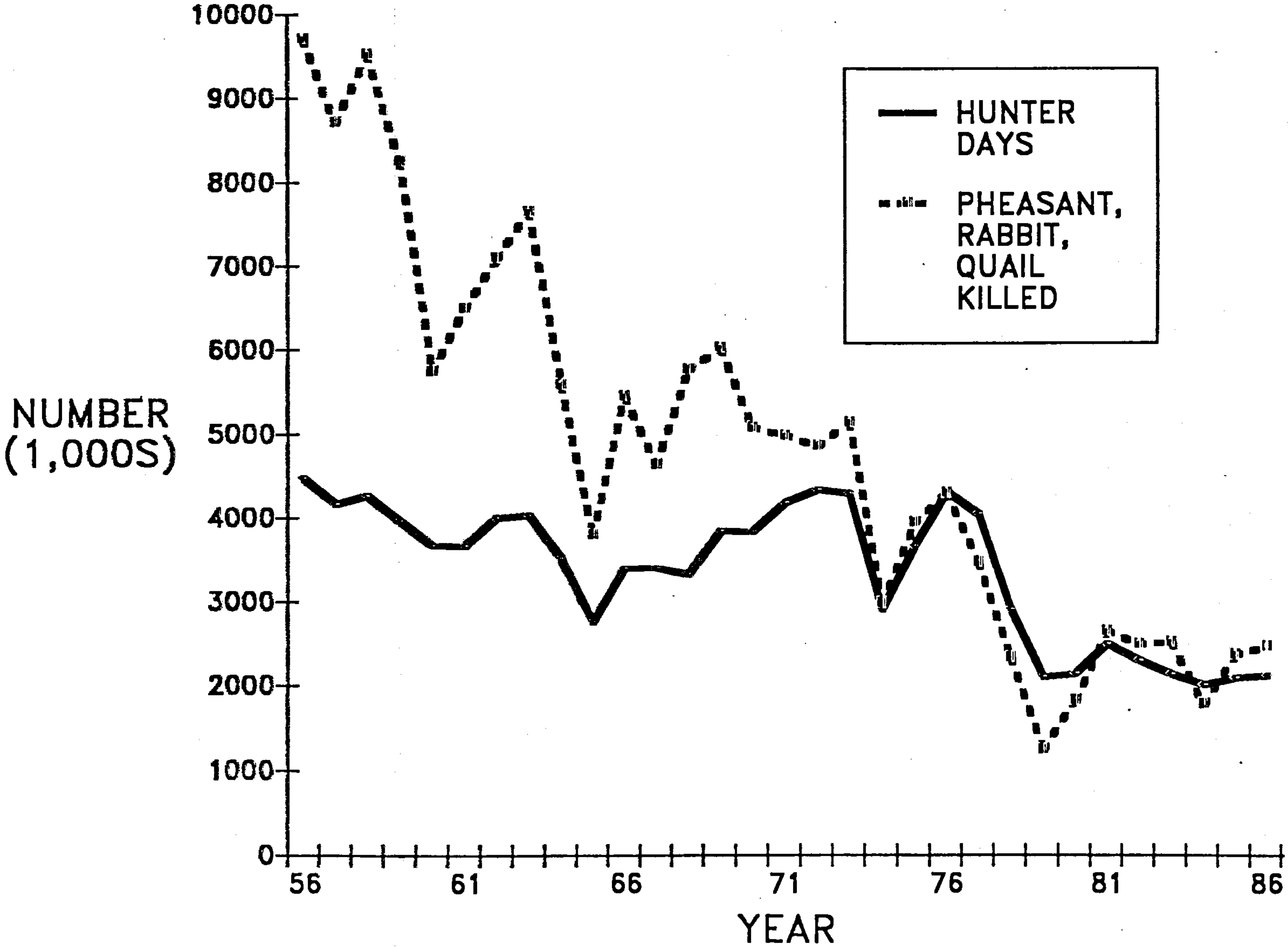

Fig. 7. Trends in the indices of consumptive recreation associated with key upland game species in Illinois, as indicated from data set 2 (Table 1).

estimate) = 762.91. This analysis indicates that the general expansion of row-crop farming and diminution of oat-hay rotations explains over 90% of the variation in small game taken by hunters in Illinois over the past 3 decades. These land use factors have been highly influenced by farm programs and policies since the 1950s, and are likely to be affected by future programs. A histogram of standardized residuals indicates a normal distribution of actual and expected $\underline{N}$ values for the observed residuals. Thus, Model A is a good predictor of ALLKIL throughout the range of observed values for independent variables; it should be a useful tool for exploring the impacts of future policy and land use directions (Fig. 6).

For Model B, ALLKIL = 0.80FARMLAND + 0.16UNCROP + 0.03TILL; R = 0.924, $\underline{P} < 0.001$, and $S_y = 943.78$. As indicated by the standardized regression coefficients, the variables UNCROP and TILL are of minor importance. Model B may have application in development of regional models that consider land use in regions where a considerable amount of land may be taken out of production, where tillage regimes are radically altered, or, where loss of farmland is potentially significant (Fig. 6).

Associations of Wildlife Abundance and Recreation on Private Lands

Using multiple regression, the variable ALLDAY = 0.32ALLKIL + 0.68ALLDAY (previous year); R = 0.967, $\underline{P} < 0.001$, $S_y = 436.10$. Thus, hunter effort the previous year was useful for predicting ALLDAY. Alternatively, this index of hunter effort could be predicted as ALLDAY = 2.26ALLKIL - 1.50ALLKIL^2; R = 0.87, $\underline{P} < 0.001$, $S_y = 431.98$.

The results of multiple regression analysis tend to substantiate the conceptual model (Fig. 1) for the project. However, linkages between game abundance and consumptive recreation (Fig. 7) are more clearly defined than for appreciative forms of recreation.

In addition to trends evident from data set 2 (Table 1), national surveys show a similar decline in participation in upland game hunting over time (U.S. Fish and Wildlife Service 1978, 1983). These surveys indicate that nearly 90% of small game hunting in Illinois occurs on private lands. Further, small game hunting in Illinois generated over $55 million in expenditures for equipment, licenses, and travel during 1980. Preliminary figures for 1985 suggest that the small game hunter spent about $13 per hunting trip. Although only about 5-6% of the state population over 16 years of age hunts small game, this recreation occurs primarily on farmland, and is very significant to local economies.

Many avian species that have traditionally been common in rural (and residential) environments of Illinois have declined dramatically in recent decades. During this period, participation in primary residential wildlife observation--activities within 1 mile of a participant's residence--has been increasing. In 1980 about 6 million people in Illinois were primary residential wildlife observers, more than double the number recorded in 1975 (1985 trends are not yet available).

Appreciative forms of wildlife recreation are, therefore, also important to local economies. In 1975 an estimated $35 million was spent on these activities in Illinois (U.S. Fish and Wildlife Service 1978). Although trends in participation in appreciative recreation may be related to wildlife abundance, other factors appear more important in the short term. These factors include a growing interest by the public in appreciative forms of wildlife recreation, and the availability of places where such activity may occur. In the future, the relative attractiveness of, and access to, farmland by the public may be critical for sustaining continued growth of appreciative recreation in Illinois. This implies not only the need for improving habitat quality and wildlife abundance, but addressing an infrastructure that will enhance tourism in rural sectors of the state (A Place To Hunt Committee 1988).

RECOMMENDATIONS FOR PHASE II

Enhancement and Completion of Data Sets

Data sets (Table 1) should be updated annually where possible. Information for 1987 should be available for all variables comprising data set 13 (Table 1) by the end of the year. Information describing trends in conservation tillage should be available early in Phase II. The BBS data (Table 1) should also be considered for use in predictive multiple regression models. As noted in Appendix A, several of the data sets will facilitate development of regional predictive models.

Future Farm Polices and Programs: Implications for Land Use and Agricultural Ecosystems

In addition to refined predictive models, Phase II will describe potential changes in land use based on farm policies and programs that are emerging. For example, there is no organized effort underway in the state to summarize plans submitted by farmers in order to ascertain what practices they intend to adopt to meet soil-protecting guidelines that will have to be met by 1995, as mandated by Conservation Compliance. Phase II should include means for preliminarily summarizing these plans, and for comparing the impacts of intended land use changes with other conservation alternatives that could be employed to address soil and water quality needs on farmland. Predictive modeling should consider (in concert) Conservation Compliance, CRP, annual set-aside programs, and T by 2000.

Development of Regional Predictive Models and Construction of Indices of Ecosystem Disturbances

The results of Phase I provide ample evidence that farm policies and programs affect upland wildlife habitat, which in turn affects wildlife abundance, associated forms of recreation, and local economies. Although economics should be included in Phase II, emphasis should be given to farm policies as they influence a spectrum of indices of environmental quality. Phase II has the potential for developing and integrating benchmark measures of environmental quality--not limited to wildlife habitat--that would have long-term application for evaluating agricultural policies and land use in Illinois.

Development of various measures of environmental quality should proceed along lines that will maximize the capability of evaluating policies and land use practices on a regional basis. For example, indices should be constructed which integrate information regarding the timing of field practices, and the nature of chemical, mechanical, and livestock disturbances. These farming practices vary among regions in Illinois, and indices of environmental disturbance should be developed to quantify and evaluate the implications of regional differences in agricultural land use relative to habitat quality.

CONCLUSIONS

Farm policies and programs since World War II in Illinois have fostered more intensive row-crop farming, the loss of upland wildlife habitat, a decline in abundance of wildlife once common on farmland, and a decline in participation in consumptive recreation on private lands. The demand for opportunities for appreciative forms of wildlife-related recreation by Illinois residents has been growing in recent decades. Annual expenditures related to all forms of wildlife recreation in Illinois are probably well over $100 million. Preliminary regression models and data sets assembled during Phase I of the present project indicate that the effects of farm policies and programs on the integrity of terrestrial ecosystems, as measured by the quality of upland wildlife habitat, can be quantified and predicted.

The farm policy-making environment of the 1980s and early 1990s is unique because there exists a planning phase for the integration of natural resource objectives with broader goals in agriculture. Therefore, Phase II of the present project should emphasize (1) delineation of likely future agricultural policies and programs as they will affect land use; (2) alternative means for addressing farm commodity programs and soil and water quality goals; (3) predicted implications of alternative pathways of land use change relative to environmental quality; and, (4) enhanced opportunities for wildlife recreation on a regional basis in Illinois.

Prepared By:

Richard E. Warner
Principal Investigator

Approved By:

Glen C. Sanderson, Head
Section of Wildlife Research

Date: 1 November 1988

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APPENDIX A. Data sets compiled during Phase I of the project.

NAME	Illinois Game
NUMBER	01
ABBREVIATION	ILLHUNT
SOURCE	Illinois Department of Conservation
PHASE I USE	Development of data set 2
PHASE II USE	Dependent variables for regional predictive models
DATA STORAGE	University of Illinois mainframe computer
FILE FORMAT	Ascii and dBASE III+
POTENTIAL UPDATES	Yes
PERIOD COVERED	1974-87
INTERVAL	Annual
DESCRIPTION	Describes hunting effort and the take of each game species by game management region in Illinois
REFERENCES	Ellis and Mahan 1987

NAME	Illinois Upland Game
NUMBER	02
ABBREVIATION	UG
SOURCE	Illinois Department of Conservation
PHASE I USE	Dependent variables describing trends consumptive recreation associated with key upland game species in Illinois
PHASE II USE	Same as Phase I
DATA STORAGE	Microcomputer
FILE FORMAT	dBASE III+
POTENTIAL UPDATES	Yes
PERIOD COVERED	1956-86
INTERVAL	Annual
DESCRIPTION	Number of hunter-days afield, and animals taken, for pheasant, rabbit, and quail in Illinois
REFERENCES	Preno and Labisky 1971; Ellis and Mahan 1987; J.A. Ellis, IDOC, personal communication

NAME	Breeding Bird Survey
NUMBER	03
ABBREVIATION	BBS
SOURCE	U.S. Fish and Wildlife Service
PHASE I USE	Indices of abundance used as dependent variables, including (1) all birds; (2) nongame grassland and other species sensitive to agricultural land use; and, (3) species included under item 2 plus pheasant and quail
PHASE II USE	Same as Phase I; potentially for regional predictive models
DATA STORAGE	Magnetic tape
FILE FORMAT	Ascii files of all data recorded by individual routes, species, and years in Illinois
POTENTIAL UPDATES	Yes
PERIOD COVERED	1967-87
INTERVAL	Annual
DESCRIPTION	Variables describing trends in abundance for birds observed and heard along 64 standardized routes in Illinois
REFERENCES	Robbins et al. 1986; S. Droge, U.S. Fish and Wildlife Service, personal communication

NAME	Sibley Study Area
NUMBER	04
ABBREVIATION	SIBLEY
SOURCE	Natural History Survey
PHASE I USE	Validation of the use of data sets 1 and 2 as indicators of trends in upland game abundance and habitat
PHASE II USE	Regional predictive models of alternative land use practices as they affect upland game habitat
DATA STORAGE	Diskette
FILE FORMAT	Annual trends in pheasant (and rabbit) abundance and habitat conditions in Microsoft Chart
POTENTIAL UPDATES	Yes
PERIOD COVERED	1955-88
INTERVAL	Annual
DESCRIPTION	Data describing relationships of land use and habitat to demographic trends and hunting--pheasant--on the Sibley Study Area, Ford County, Illinois
REFERENCES	Warner et al. 1987

NAME	Soil and Water Quality Goals for Illinois
NUMBER	05
ABBREVIATION	T BY 2000
SOURCE	Illinois Department of Agriculture
PHASE I USE	N/A
PHASE II USE	Structuring of independent variables describing (statewide) alternative pathways of land use change
DATA STORAGE	Not applicable or available (N/A) Phase I
FILE FORMAT	N/A
POTENTIAL UPDATES	No
PERIOD COVERED	Year 2000
INTERVAL	One-time summary
DESCRIPTION	Summary of land use changes (statewide) likely to occur if soil and water quality goals are met by the year 2000; county-level summary of acres categorized by rate of soil loss
REFERENCES	Illinois Department of Agriculture 1985, 1987b

NAME	Illinois Agricultural Land Use
NUMBER	06
ABBREVIATION	ILLAG
SOURCE	Illinois Department of Agriculture
PHASE I USE	Statewide summaries of land use acres planted to various crops for use as independent variables describing habitat conditions
PHASE II USE	Predictive models describing regional land use
DATA STORAGE	Diskette
FILE FORMAT	dBASE III+
POTENTIAL UPDATES	Yes
PERIOD COVERED	1945-1987
INTERVAL	Annual
DESCRIPTION	County and statewide statistics describing crop acreages and livestock production
REFERENCES	Illinois Department of Agriculture 1987a and earlier annual summaries

NAME	National Agricultural Land Use
NUMBER	07
ABBREVIATION	AGCENSUS
SOURCE	U.S. Department of Economic Research
PHASE I USE	Background description of land use changes in Illinois and surrounding states
PHASE II USE	Development of habitat quality models
FILE FORMAT	Ascii files
POTENTIAL UPDATES	Yes
PERIOD COVERED	1949-81
INTERVAL	Periodic; 5-year intervals
DESCRIPTION	County-level data for the U.S. describing land use and other farm statistics from the Census of Agriculture conducted at about 5-year intervals
REFERENCES	U.S. Department of Commerce 1985; Economic Research Service, USDA, Washington, D.C.

NAME	Chronology of Agricultural Disturbances
NUMBER	08
ABBREVIATION	DISTURB
SOURCE	Departments of Agriculture, Illinois and surrounding states
PHASE I USE	Hay cutting data used in development of manuscript
PHASE II USE	Development of habitat quality models describing agricultural disturbances
DATA STORAGE	Diskette
FILE FORMAT	dBASE III+
POTENTIAL UPDATES	Yes
PERIOD COVERED	1950-87 (variable starting dates among states)
INTERVAL	Annual
DESCRIPTION	Median date of all major field operations, and % of cropland tilled in fall, for Illinois, Iowa, Indiana, Minnesota, Missouri, and Wisconsin
REFERENCES	Illinois Department of Agriculture 1964 and 1987a describe reporting of the progression of field activities by week

NAME	National Resources Inventory
NUMBER	09
ABBREVIATION	NRI
SOURCE	U.S. Soil Conservation Service
PHASE I USE	N/A
PHASE II USE	Regional models predicting land use changes
DATA STORAGE	Magnetic tape
FILE FORMAT	Ascii file
POTENTIAL UPDATES	1987 NRI data will repeat the survey for the same locations
PERIOD COVERED	1982
INTERVAL	Periodic; 5-year intervals
DESCRIPTION	Characteristics of land use and vulnerability of fields to soil erosion measured on randomly selected sites stratified by physiographic region in Illinois
REFERENCES	U.S. Soil Conservation Service 1984; Steiner 1987; Hoekstra and Flather 1987

NAME	Rural Mail Carrier Census of Pheasants
NUMBER	10
ABBREVIATION	RMCC
SOURCE	Natural History Survey
PHASE I USE	Validation of data set 2 as an indicator of pheasant abundance
PHASE II USE	Regional models of wildlife abundance
DATA STORAGE	Magnetic tape
FILE FORMAT	dBASE III+ (1988); Prime computer Arc/Info files, NHS
POTENTIAL UPDATES	Yes
PERIOD COVERED	1958-88
INTERVAL	Periodic; 5-year intervals
DESCRIPTION	Pheasant census data using observations of rural letter carriers in Illinois; summaries of pheasant abundance at township, county, and state resolutions
REFERENCES	Warner 1981

NAME	Geographic Information for Illinois
NUMBER	11
ABBREVIATION	GIS
SOURCE	Natural History Survey
PHASE I USE	N/A
PHASE II USE	Regional and statewide map overlays
DATA STORAGE	Magnetic tape
FILE FORMAT	Prime Computer Arc/Info files, NHS
POTENTIAL UPDATES	Yes
PERIOD COVERED	Variable
INTERVAL	Summaries for 1 point in time
DESCRIPTION	Statewide coverages (maps) describing major soil classifications, climate, travel infrastructures, and geographic and political boundaries in Illinois
REFERENCES	Environmental Systems Research Institute 1984; Anderson 1970 (e.g., vegetation in Illinois prior to settlement)

NAME	Conservation Tillage
NUMBER	12
ABBREVIATION	CT
SOURCE	Conservation Tillage Information Center
PHASE I USE	Written report used in development of manuscript
PHASE II USE	Regional models describing habitat quality and land use
DATA STORAGE	Diskette (not acquired)
FILE FORMAT	Lotus 1-2-3
POTENTIAL UPDATES	Yes
PERIOD COVERED	1981-87
INTERVAL	Annual
DESCRIPTION	Tillage and planting practices (by acres treated) at a county level for the U.S.; available in diskette or written form for $200/state for the most recent year, and $100/state for earlier years
REFERENCES	Conservation Tillage Information Center 1984, 1987; Gebhardt et al. 1985; Magelby et al. 1985

NAME	Multiple Regression Model
NUMBER	13
ABBREVIATION	MULREG
SOURCE	Developed from data sets 2,3, and 6
PHASE I USE	Construction of predictive models
PHASE II USE	Construction of predictive models
DATA STORAGE	Diskette
FILE FORMAT	dBASEIII+ and SPSS/PC+
POTENTIAL UPDATES	Yes
PERIOD COVERED	1955-86 for all factors; data for some variables extend from 1945-87
INTERVAL	Annual
DESCRIPTION	Independent variables describing land use, habitat quality, and statistics pertaining to the hunting of pheasant, rabbit, and quail.

APPENDIX B. The ms. CONSERVATION TILLAGE AND WILDLIFE HABITAT QUALITY IN MIDWESTERN USA ROW-CROP ENVIRONMENTS, under review, The Journal of Environmental Management.

RELATIONSHIPS OF CONSERVATION TILLAGE TO THE QUALITY OF WILDLIFE HABITAT IN ROW-CROP ENVIRONMENTS OF THE MIDWESTERN UNITED STATES

Richard E. Warner and Stephen P. Havera

Illinois Natural History Survey, Champaign, Illinois, 61820

Received____________.

Conservation tillage has become a principal means for minimizing soil disturbances associated with intensive row-cropping in the Midwestern United States. In this paper, changes in cropping disturbances in Illinois were examined, and the abundance of waste corn and soybeans is used as a measure of the quality of wildlife habitat. From 1982-1987, an average of 40% of the corn stubble was left undisturbed after fall harvest. An average of 70% of the soybean stubble remained over winter--a sharp decrease in the fall disturbance of soybean stubble in recent years. Spring tillage and planting methods changed little during the 1980s, and about 20% of the cropland retained significant plant residues on the soil surface after planting. In the falls of 1982-1986 and the springs of 1983-1987, the corn habitat index (X/CV kg/ha dry weight) averaged 91.0/0.26 and 10.2/0.26, respectively; the soybean index averaged 35.3/0.27 and 1.9/0.28, respectively. Index values for these waste grains increased 27-50% during 1982-1987. The habitat index is sensitive to changes in tillage and planting disturbances--especially changes in spring till-plant methods. If federally mandated soil and water quality goals for the year 2000 are achieved in Illinois, spring habitat index values for soybeans and corn will increase two-to-threefold. The widespread adoption of conservation tillage will benefit wildlife species that are sustained by waste grains.

Keywords: Corn, soybeans, Illinois, soil conservation, tillage, wildlife habitat.

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1. Introduction

Intensive cropping of corn and soybeans has caused severe soil erosion and degraded water quality in the midwestern United States (U.S. Dept. Agric. (USDA), 1987). Conservation tillage and planting practices, the use of field implements that minimize soil disturbances, have become the principal means for addressing these problems. Indeed by the year 2000, conservation tillage may be applied on 50-70% of the cropland in the United States (Office of Technology Assessment (OTA), 1982; Gebhardt et al., 1985; Ill. Dept. Agric., 1985). The technologies used to reduce soil disturbances in the Midwest and throughout the United States are likely to spread to the intensively row-cropped regions of North and South America and Europe (Pimentel et al., 1987).

As commercial agriculture developed in the United States, seeds remaining on the soil after harvest (waste grains) helped to sustain many species of birds and mammals (Allen, 1938; Baumgrass, 1943; Yeatter, 1957; Korschgen, 1958; Anderson, 1959). Practices that disturbed crop stubbles, however, reduced that critical food resource. The impact of no-till planting on the food supply of small vertebrates has been studied (Warburton and Klimstra, 1984; Brady, 1985; Castrale, 1985; Basore et al., 1986), but little attention has been directed to the effects of tillage disturbance on the quality of wildlife habitat (OTA, 1985).

In this paper we examine row-cropped land in Illinois in order (1) to describe changes in crop residue associated with changes in tillage and planting methods, and (2) to evaluate the impact of row-crop tillage practices on wildlife habitat by using the abundance of waste grain as an index to habitat quality.

Illinois was selected for study due to the wealth of historic data describing its land use, because it has been a leader among states in the adoption of conservation tillage practices (Conservation Tillage Information Center (CTIC), 1987), because it accounts for about 15% of the annual corn and soybean production in the United States (U.S. Dept. Commerce, 1985), and in that it has approximately 4.2 and 3.7 million ha of land planted to these crops, respectively, (Ill. Agric. Statistics Service (IASS), 1986).

2. Definitions

The following terms are used in our discussion of tillage and planting systems (OTA, 1982; Brady, 1985; D'Itri, 1985; Gebhardt et al., 1985):

Conservation tillage. Non-inversion (intermediate) methods of soil preparation that--compared with conventional tillage--moderately disturb the soil surface; for example, disking and chisel plowing.

Conventional planting. Use of the moldboard plow followed by disking, harrowing, or other seedbed preparation.

Crop residues. Plant litter and waste grain on the soil surface following harvest.

Mulch-till. Any combination of conservation tillage and planting operations (other than no-till and ridge-till) that leaves >30% of the soil surface protected by residues after planting.

No-till. A method of planting that disturbs only slots where seeds are placed in crop stubbles or sod, with no subsequent tillage for weed control.

Ridge-till. A method of planting limited to continuous row-cropping that incorporates seeds in ridges of soil 10-20 cm high and uses a cultivator for weed control. (We included ridge-till in our analysis of no-till because both methods leave extensive residues on the soil surface after planting.)

Untilled fields. Fields not disturbed by implements in fall.

Waste grain. Seeds left at harvest with plant litter.

3. Long-Term Data Sets

Planting and harvest statistics have been summarized annually in Illinois since ~1900 (e.g., IASS, 1986). The cropland tilled in fall and early spring was reported to the IASS by farmers from 1949-1984 and has more recently been monitored by randomized surveys independently conducted by the Soil Conservation Service (SCS)(e.g. SCS, 1987) and by the CTIC (1987). Recent reports also include average amounts of crop residues remaining on the soil surface after various tillage practices in fall and spring (e.g., Dickerson, 1983).

Since 1976 statewide crop yields have been determined by the IASS by measuring biological yields (grain seeds on plants) and harvested yields. The difference between the two measurements indicates the amount of corn and soybeans left in the field after harvest. These randomized statewide surveys have included up to 100 soybean and 260 corn fields each year (J. Unger, IASS, unpub.).

3.1 WASTE GRAIN SURVEYS

The Illinois Natural History Survey (INHS) monitored the presence of waste corn and soybeans in randomly selected fields throughout central Illinois from 1981-1985. Climatic patterns and chronologies of farm operations in the region sampled approached an average for Illinois and the surrounding states.

Each waste grain sample was taken from three 0.5-m x 1-m rectangular plots positioned at the ends and midpoint of a 15.24-m rope extended 45^{o} to the direction of crop rows at a randomly selected point >15 m the edges of the field. Selections of fields and points within fields are described by Warner et al. (1985). Exposed grain seeds were removed from the plots. In cornfields, cobs with kernels were collected within a band 1 m wide bisected by the rope. Waste grain abundance is expressed in kg/ha dry weight (Warner et al. 1985). In order to normalize the data, we converted estimates of abundance to log(kg/ha + 1) and then transformed back to kg/ha.

The INHS studies also associated the abundance of waste corn and soybeans with plant litter on the soil surface. The percent of ground covered by litter was determined using the 15.24-m rope described above. The number of 100 evenly spaced knots along the 15.24-m rope that were directly over harvest litter >2-4mm wide were counted--a standard method for measuring the amount of crop residues on soils (Dickerson, 1983; Warner et al., 1985). The median dates of field sampling were about 1 December after harvest and when tillage operations had ceased for the winter, and about 1 April before spring field disturbances had begun.

3.2 CALCULATIONS OF HABITAT INDICES

In using the abundance of waste grain as an indicator of habitat quality, we considered two critical periods for wildlife: late fall (1 December), representing migration and the approach of winter, and spring (15 May), representing migration and breeding. Habitat indices were computed using abundance of waste grain at harvest (IASS statewide data), hectares of row crops (IASS statewide data) categorized by various tillage and planting methods (SCS and CTIC estimates), and persistence of waste grain over time (INHS data for central Illinois).

The surveys of waste grain did not document the disappearance of such grain related to planting; however, they did establish that the percent of crop residues eliminated (buried) by field disturbances, spring or fall, was a conservative but reliable estimator of the portion of waste grain *per se* eliminated (Warner et al., 1985, 1988). We, therefore, determined the percentages of litter destroyed by various spring planting methods (Dickerson, 1983) and used them to compute disappearance rates for waste grains relative to spring planting. The proportions of waste soybeans eliminated by the disturbance of spring planting were estimated at 20, 50, and 90% for no-till, mulch-till, and conventional-till, respectively; the proportions of waste corn eliminated were estimated at 10, 50, and 90%, respectively.

Persistence of waste grain over time for all computations (except planting) was based on average rates documented for 1981-1985 (Table 1). These calculations account for all disturbances through planting in Illinois, although 15 May is actually the median date of planting (IASS, 1986).

The wildlife habitat indices calculated for the 1980s used annual statewide figures for grain lost at harvest, hectares planted to corn and soybeans, and percentages of cropland subjected to major changes in field disturbance. Projected changes are based on 1982-1987 averages for these factors.

A sample calculation of the habitat index for untilled cornfields (1982) planted by no-till methods (1983) is 329 kg/ha waste corn at harvest x 0.638 (Table 1) = 209.9 kg/ha x 1,204,000 ha (26% of corn stubble untilled) = 252,722,000 kg on 1 December; 209.9 kg/ha x 0.583 (Table 1) = 122.4 x 139,000 ha (3% of stubble planted by no-till) = 17,010,000 kg available on 15 May in no-till corn. To compute an index (average) for all disturbance categories combined, values such as 252,722,000 and 17,010,000 kg for 1 December and 15 May, respectively, were added to the results of similar calculations for other disturbance categories and then divided by the total hectares of corn. Calculations of the abundance of waste grain after no-till planting in spring assumed that the stubble had been undisturbed in fall. For practices other than no-till, the average of waste grain on 1 December for all fall tillage practices was used as a basis for computing spring habitat index values.

4. Results of Post-World War II Tillage Disturbances

From about 1930 when the use of the tractor became widespread until the early 1950s approximately 25% of the corn stubble in the Midwest had been plowed by late winter (Leedy, 1939) (Fig. 1). Percentages ($\bar{X} \pm SD$) of row-crop land tilled in the fall were 25.0 ± 18.1 for 1950-1955, 50.6 ± 10.4 for 1965-1970, and 60.5 ± 22.2 for 1980-1986. The increasing disturbance of row crop stubble in fall since World War II (Fig. 1) has been accompanied by an increase in the plantings of these crops. If row-crop plantings had not expanded since the 1940s, there would have been some years in the 1970s and early 1980s when there would have been negligible amounts of row-crop stubble remaining over winter.

Waste corn on Illinois croplands has been increasing for three decades (Warner and Havera, unpub.), and these increases are reflected in the habitat index values. The technologies responsible for these increases, however, have also limited the growth of grassy weeds and forbs that provide wildlife with a mixture of high-protein seeds and arthropods (Allen, 1938; Warner et al., 1988).

Smartweed (Polygonum spp.) in winter corn and soybean stubble averaged 54 kg/ha in Ohio during the 1930s (Leedy, 1939). Cornfields in Connecticut during the 1940s were found to have 5-66 kg/ha of weed seeds (Bishop and Spinner, 1946). Bookhout (1958) found 16-22 species of seeds in southern Illinois cornfields during the early 1950s. Only about 10% of the corn in the Midwest received herbicide treatment in the early 1950s, but nearly 100% was treated by 1985 (OTA, 1982). Further, crop stubble decades ago had included a dense undergrowth of weedy grasses and forbs, as well as partially standing stalks, and these materials afforded animals protection from weather and concealment from predators. By contrast, modern harvest machinery shreds crop stalks in relatively weed-free fields, rendering stubble of little value for wildlife except for forage.

5. Characteristics of Row-Crop Environments of the 1980s

The amount of untilled stubble on row-crop land increased during 1982-1987 (Fig. 2). The average percentages of soybean stubble untilled, plowed, and receiving intermediate tillage in the falls of 1982-1987 were 71, 2, and 27, respectively; percentages for corn stubble were 40, 20, and 40, respectively. The percentage of row crops (corn and soybeans) planted from 1982-1987 by no-till, mulch-till, and conventional methods averaged 4, 18, and 78, respectively. By the mid 1980s about 20% of soybean stubble was tilled in fall, with <100,000 ha moldboard plowed--a trend toward less disturbance.

The habitat index, $\underline{X}/\underline{CV}$ (kg/ha dry) where ($\underline{CV}$ = $\underline{SD}/\underline{X}$), for corn during the 1980s for fall and spring was 91.0/0.25 and 10.2/0.26, respectively (Fig. 3). These values represented an average fall-to-spring decline of 89%. The habitat index for soybeans was 35.3/0.27 and 1.9/0.28 for fall and spring, respectively, a seasonal decline of 95% (Fig. 3). If we compare the first and last two years of the study (Fig. 3), we find that the fall and spring habitat index values increased by 27-50%.

6. Hypothetical Effects of Increased Conservation Tillage

The effects of hypothetical reductions in stubble disturbance associated with corn planting are shown in Figure 4. The spring corn habitat index would double if planting by mulch-till--presently used in ~18% of stubble--were increased to 90% (assuming that fall disturbances were at the $\underline{X}$ for 1982-1987). The same magnitude of increase could be expected if the amount of stubble planted by no-till methods increased from the present 4% to 16% (Fig. 4), and other disturbances remained at their average levels for 1982-1987.

Changes in spring planting practices in soybean stubble do not hold the same potential for large increases in the habitat index. If, for example, fall disturbances were not minimized, a moderate increase in spring no-till planting would have a negligible effect on the soybean habitat index (Fig. 5).

The difficulty in maximizing mulch-till planting in soybean stubble is apparent in Table 2. Before field operations (1 April), only untilled fields would have, on average, 50-60% of the soil surface covered by plant residues. No-till planting is probably the only subsequent operation that would leave >30% of the soil protected by residue after planting. The variation among intermediate tillage practices in the amount of residue and the habitat index values is also evident in Table 2.

The corn and soybean habitat indices averaged for 1982-1987 are compared with projected indices for the year 2000 in Figure 6. The projected scenario assumes that plantings, yields, and harvest losses of corn and soybeans will be comparable to those of the 1980s and, based on established goals (IDA, 1985), and that approximately 18%, 49%, and 33% of the crop stubble will be planted by no-till, mulch-till, and conventional-till, respectively. Under such conditions, the spring corn and soybean habitat index values would nearly triple and double, respectfully (Fig. 6). Thus, the corn index is likely to continue to increase. Because waste soybeans are prone to sprout and decay, the habitat index is for soybean fields will probably remain only a fraction of the corn index.

7. Future Importance of the Index of Habitat Quality

The habitat index is sensitive to disturbance patterns, especially spring till-planting systems (Figs. 4-6). Because the factors used in the index--harvest losses, rate of grain disappearance, field disturbance--have high variability (Warner et al., 1988), the index is best suited for evaluating changes in habitat quality over broad scales of time (minimally 3-5 years) and space. An appropriate spatial scale would be a physiographic region where soils and climate provide for similar patterns of crop yields and farming disturbances, for example, Illinois and surrounding states. Applied in such a manner, the habitat index enables us to monitor the effects on wildlife habitat in the Midwest, of changing tillage practices associated with mandated soil conservation and water quality goals.

We thank G. C. Sanderson, and A. S. Hodgins of the INHS for editorial support. S. J. Brady and R. L. Dickerson, SCS, reviewed the manuscript. This work was a contribution in part of the Ill. Dep. Energy and Nat. Resour., contract no. EH16.

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Table 1. Average percentages of corn and soybeans remaining on the soil surface in central Illinois from harvest through late fall (1 December), and from late fall through planting (15 May), 1981-1985. Percentages are based on average losses of residues by spring field operations (Dickerson, 1983) and on the fall-to-spring rates of grain disappearance reported by Warner et al. (1988).[1]

Crop and tillage practice	Percentage of grain remaining: Harvest to 1 December	1 December to 15 May[1]
Corn		
Untilled	63.8	58.3
Intermediate	12.8	20.5
Plow	0.6	4.1[2]
Soybeans		
Untilled	28.6	4.6
Intermediate	5.8	15.2
Plow	0.3	3.1[2]

1 Computed as the average rate of disappearance/day (Warner et al. 1988) x 166 days (average number of days from 1 December to the median point of planting in Illinois); disappearance/day was multiplied by 140 for untilled soybeans to compensate for diminishing rates of disappearance in late winter.

2 Rates of natural grain disappearance (decay, etc.) for moldboard-plowed soils were assumed equal to those documented for intermediate forms of tillage.

Table 2. Generalized comparisons of the amounts of soybean harvest residues and the soybean habitat index relative to season and types of intermediate tillage practices for central Illinois, 1981-1985[1]; 1 April is before spring planting disturbances occur.

Season & tillage practice	Ground cover (% residue)	Habitat index[2]
Harvest (~12 October)	85	126
Late fall (~1 December)		
Untilled	75	40
1-pass3	38	16
2-pass	19	4
Early spring (~1 April)		
Untilled	55	7
1-pass	33	6
2-pass	17	2

1 Based upon average dates of harvest and grain sampling; early winter predictions based upon Warner et al. (1988), $\underline{Y} = 0.003X_1 - 0.473X_2 + 1.5964$ where $\underline{Y}$ is log (kg/ha soybeans + 1), X_1 is the % residue, and X_2 is the number of the three 0.5-m^2 rectangles without grain ($\underline{R}^2 = 0.73$, $\underline{P} < 0.001$, $\underline{N} = 95$, $S_y = 0.35$). Early spring estimates are based upon average daily rates of grain and plant litter disappearance for various tillage practices.

2 Kg/ha waste grain, dry weight.

3 Intermediate tillage; typically tandem disk or straight-shank chisel implements.

LIST OF FIGURES

Fig. 6. Indices of the relative abundance (kg/ha) of waste corn and soybeans in Illinois after the completion of spring planting (15 May) averaged for 1982-1987 and projected for the year 2000. The projection is based upon the assumption that target goals for the reduction of soil erosion by use of conservation tillage are achieved.

FIG. 1

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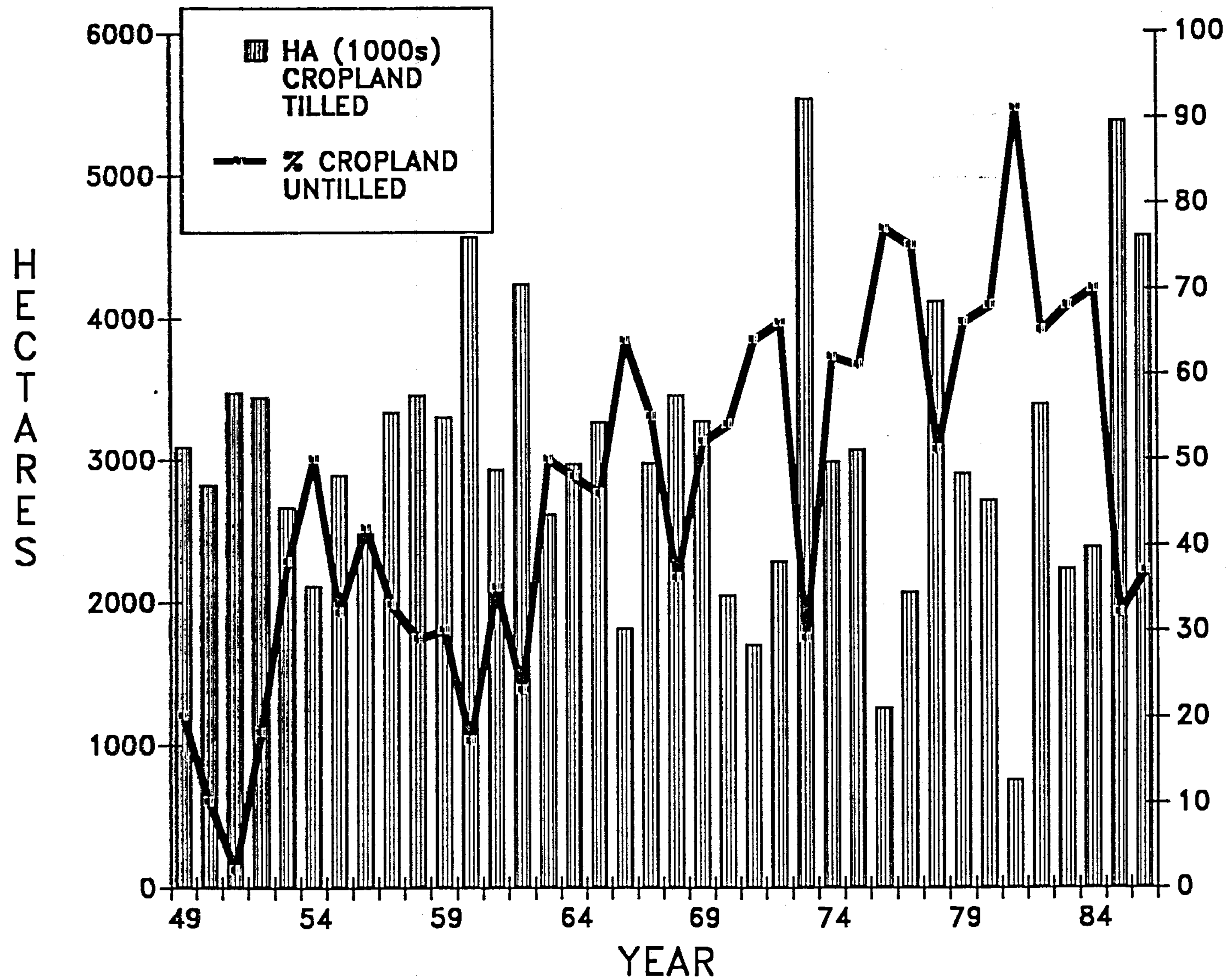

FiG. 2

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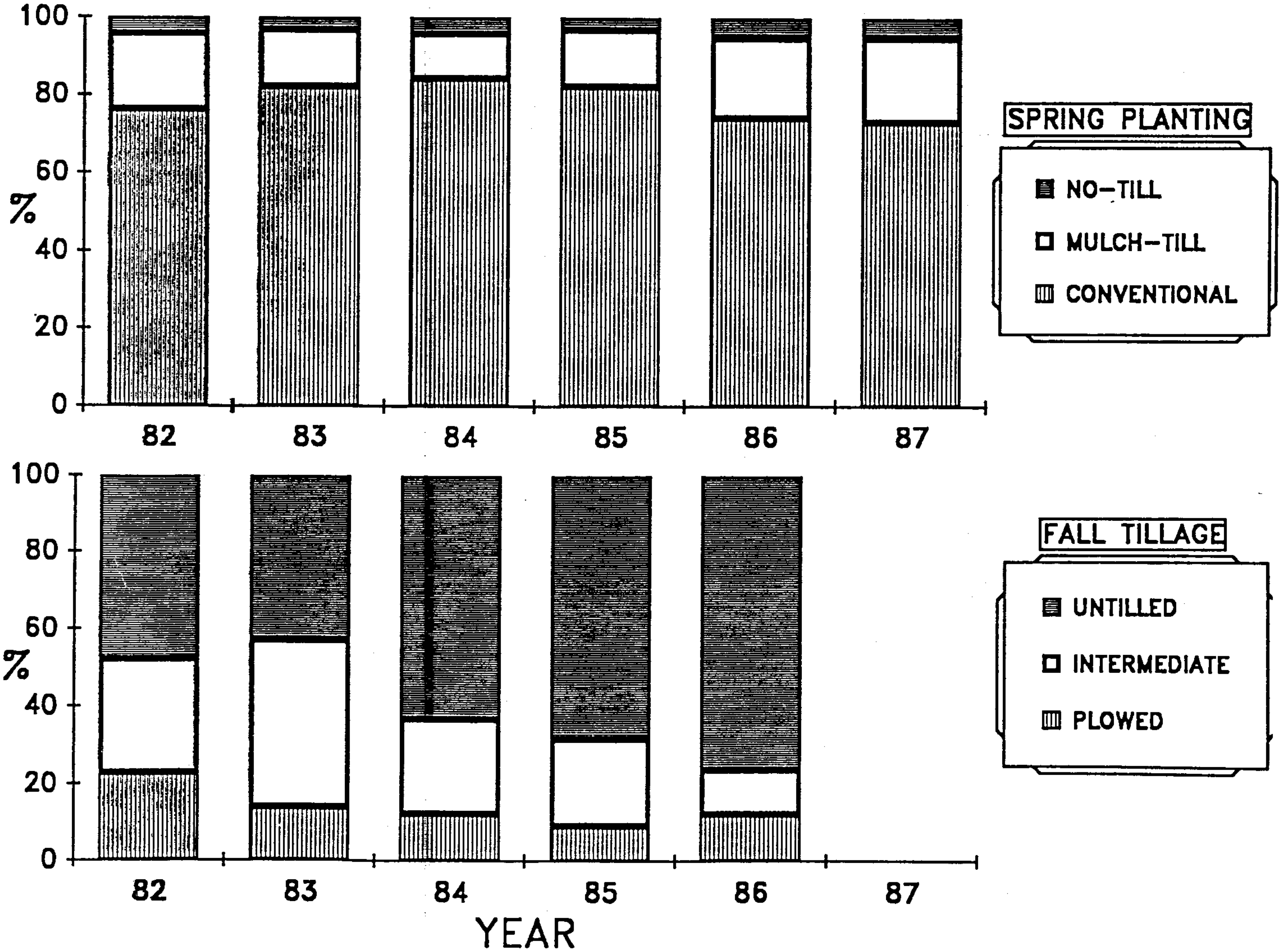

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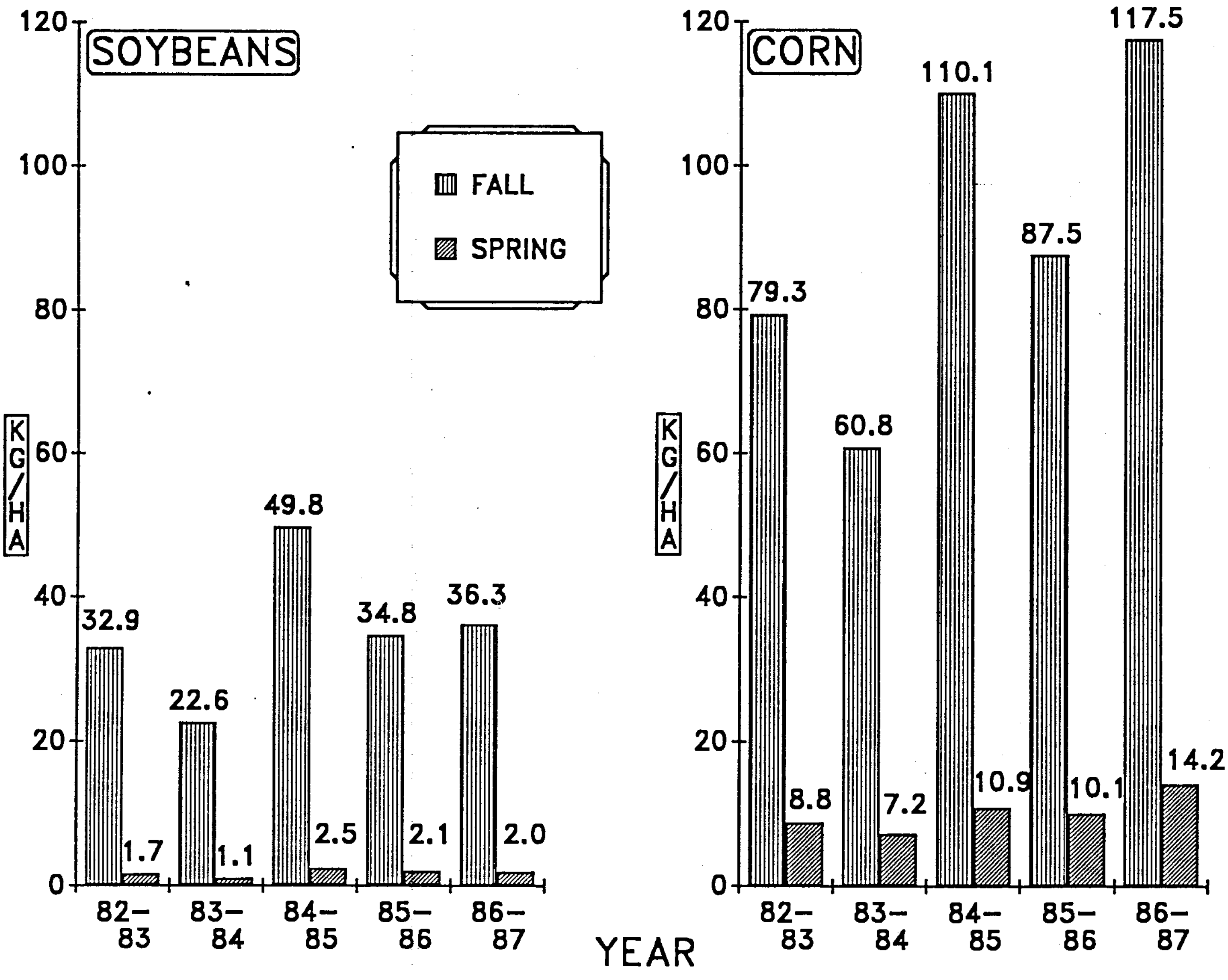
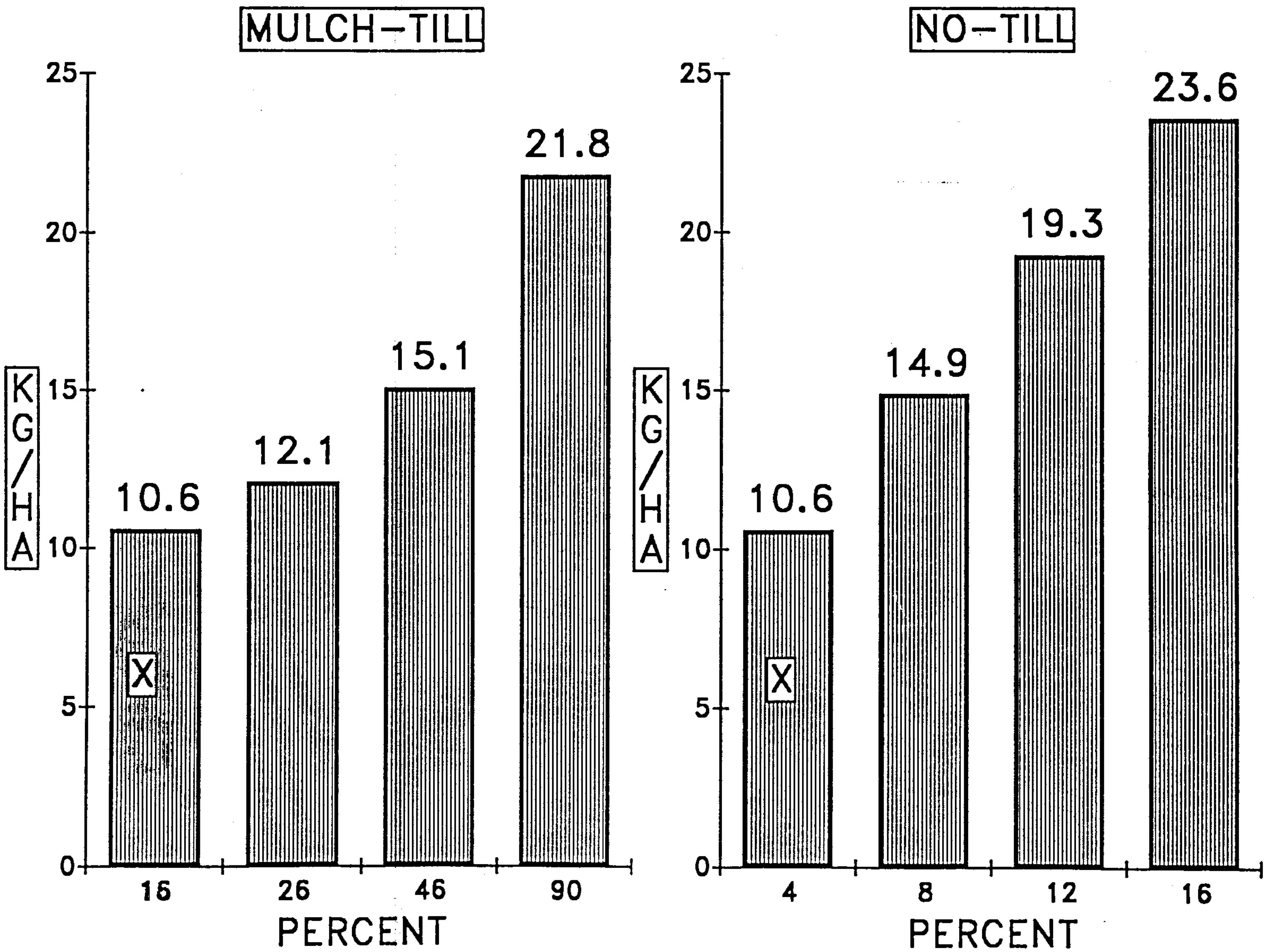


FIG. 4,

INDEX.C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NO-TILL
KG/HA
25
20
15
10
5
0
10.6
12.1
15.1
21.8
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26
46
90
PERCENT
10.6
14.9
19.3
23.6
X
4
8
12
16
PERCENT

FiG. 5

INDEX-SG

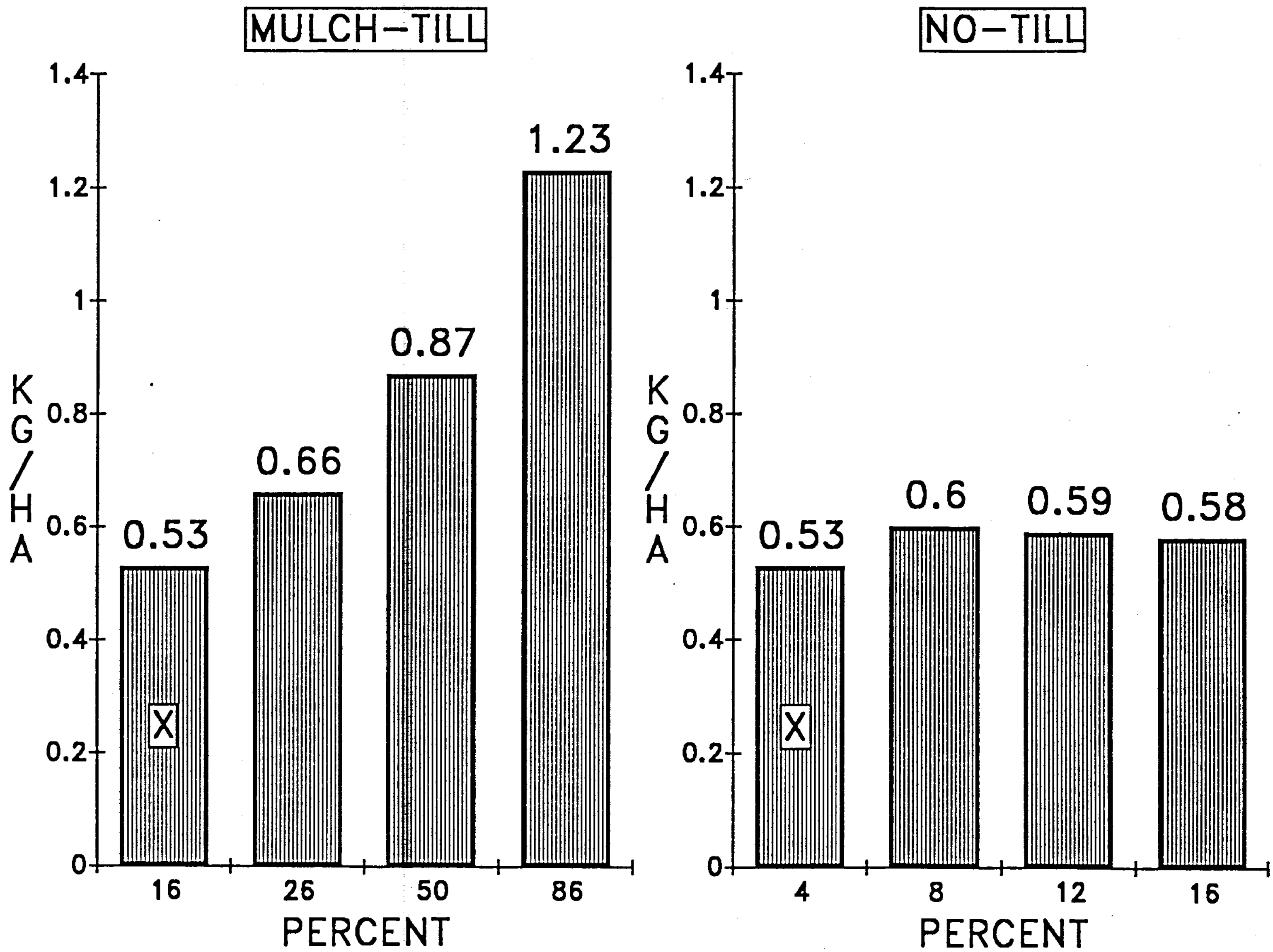
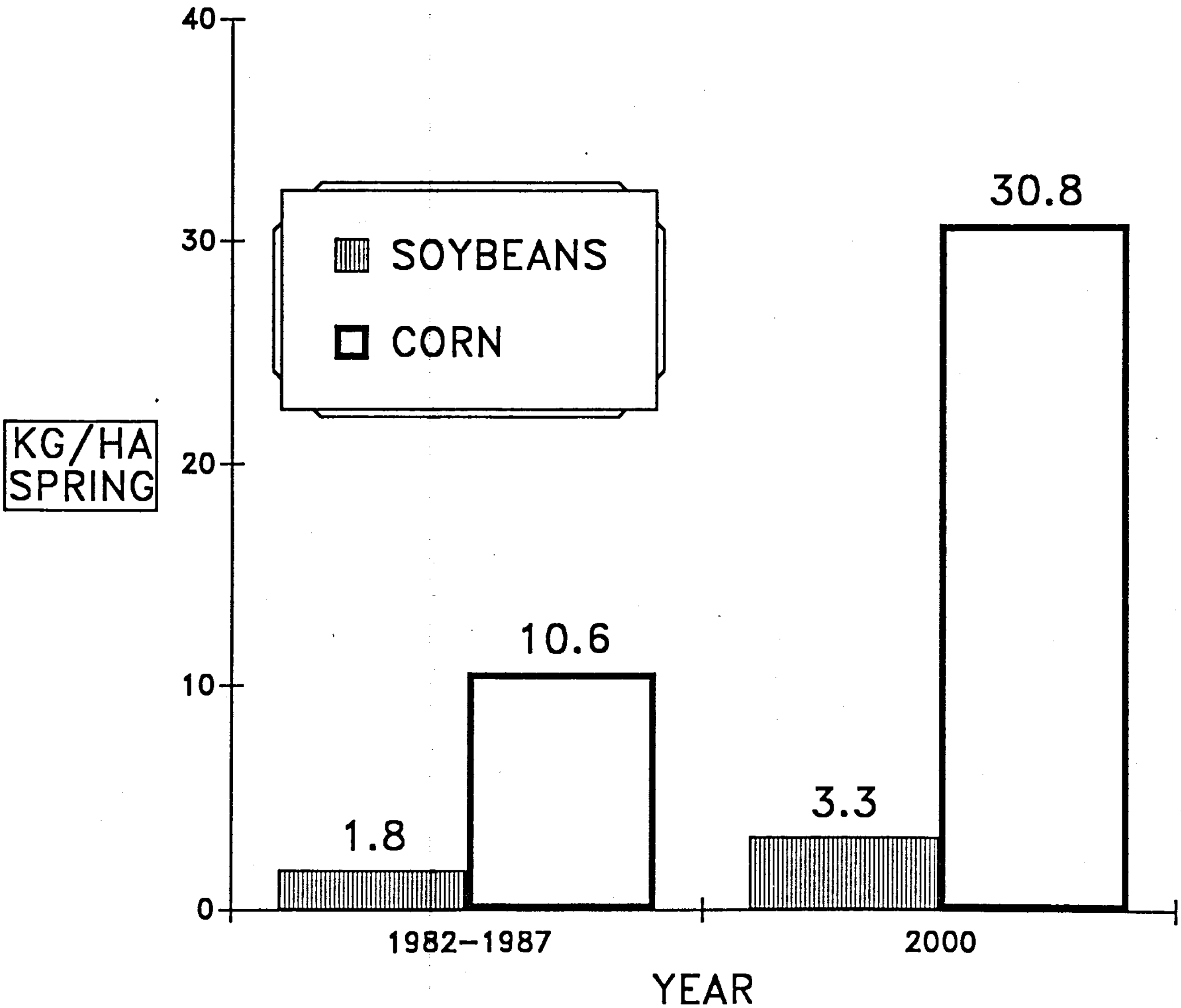


FIG. 6.

INDEX4.CSG



APPENDIX C. The ms. HAY CUTTING AND THE SURVIVAL OF PHEASANTS: A **LONG-TERM** PERSPECTIVE, accepted for publication (April 1989) in **The Journal** of Wildlife Management.

Richard E. Warner
Ill. Natural History Survey
607 East Peabody
Champaign, IL 61820
217-333-5199

HAY CUTTING AND THE SURVIVAL OF PHEASANTS: A LONG-TERM PERSPECTIVE

RICHARD E. WARNER, Illinois Natural History Survey, Champaign, IL 61820

STANLEY L. ETTER[1], Illinois Natural History Survey, Champaign, IL 61820

Abstract: We documented the fates of 1,104 ring-necked pheasant (*Phasianus colchicus*) nests in harvested and unharvested hayfields near Sibley, Illinois, from 1962-72. A mean of 13% and 35% of nests in harvested and unharvested hay, respectively, hatched. Mortality rates of females and embryos were high when cutting of hay coincided with the late stages of incubation. Dates when forage crops in the Midwest are harvested have gradually advanced since World War II, especially in the northern portions of the pheasant range where dairy and livestock production are prevalent. Over the past decade, the mean day of first cutting for alfalfa, the most widely planted hay cultivar in the Midwest, has been 3 June, about 10 days earlier than it was during the 1950's. Mortality rates for pheasant nests found after the first cutting of hay near Sibley, Illinois, were used in conjunction with mean dates of the first hay cutting for Illinois to compute indices of female and nest destruction for 1951-58 and 1977-87. Indices of pheasant destruction were lower ($P < 0.01$) for 1977-87, which suggests that mortality of embryos and females during haying operations is, on average, easing in

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[1] Present address: Illinois Department of Conservation, Gibson City, IL 60936.

the Midwest due to earlier cutting. The presence of small tracts of nest cover near hayfields, if carefully managed, could enhance pheasant reproduction.

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Keywords: farm programs, hay, Illinois, management, Midwest, nest, pheasant, survival.

The ring-necked pheasant range was establishing in North America as agricultural operations were rapidly becoming mechanized (Leopold 1931, Schlebecker 1975). Forage crops, prime nest cover for pheasants (Hamerstrom 1936, McAtee 1945, Baskett 1947), were subjected to increasing mechanical disturbances in the 1920's and 1930's. By the 1930's it was clear that tractor-drawn cutter bars were a major threat to the survival and reproduction of female pheasants.

The interplay between survival of female pheasants and eggs, and the timing of hay harvest (cutting by mowing or chopping), is delicate. Differences of a few days in harvest dates have produced variable effects on local pheasant abundance (Baskett 1947, Allen 1956, Robertson 1958). Weather, forage type, and other factors varying from farm-to-farm contribute to this interplay. Leedy and Hicks (1945) found, for example, that nest destruction rates ranged from 75% in forage legumes and 39-64% in sweet clover and forage mixtures to 10-14% in small grains.

Programs diverting farmland from production have the potential for increasing the quantity and quality of nest cover. "Diverted acres" buoyed numbers of pheasants in the Midwest during the 1930's, 50's, and 60's, when such fields persisted for several years and were free of mechanical disturbances during summer (Joselyn and Warnock 1964, Edwards 1984, Etter et al. 1988). These habitats also benefitted pheasants during fall and winter (Etter et al. 1988). Conversely, when set-aside programs are phased out, nesting pheasants concentrate in the remaining forages, becoming especially vulnerable to destruction during haying or grazing (Warner et al. 1987).

Although the nesting of pheasants in hay has been studied in the United States, recent and long-term perspectives on hay planting and harvest practices and pheasant survival are lacking. Our objectives were to describe long-term trends in the planting of forages in the Midwest, determine post-World War II changes in the chronology of alfalfa cutting, evaluate the survival of females and embryos relative to the timing of forage harvests in Illinois, and to consider the implications of harvest dates for pheasant management and research.

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STUDY AREA AND METHODS

The 9,393-ha Sibley Study Area (SSA) was located in Ford County, east-central Illinois, traditionally the prime pheasant range in Illinois (Robertson 1958, Warner 1981). The deep, dark prairie soils on the area have little relief and were farmed intensively for cash grains (Etter et al. 1988). Annual precipitation averaged 86-90 cm, with approximately 67% occurring as rain from April-September. The SSA was described in detail by Joselyn et al. (1968) and Labisky (1968).

We established an experimental field (EF) 10 km northeast of Sibley in 1965, to study the timing of pheasant nest establishment and hatch in unharvested forage grasses and legumes. This rectangular 9.7-ha tract was subdivided and planted with 4 mixtures of cool-season grasses and/or forage legumes, 10 replications/mixture, in a randomized block. The EF was cut in late summer, 1966-70, with a rotary mower to minimize residual cover.

Fields of primarily rotation harvested hay on the SSA were searched within 1 day of mowing or windrowing after each cutting from 1962-72; 14-25 fields were searched each year, depending upon the amount of hay grown on the area. The EF was searched 2-3 times annually, 1966-70. Fields of unharvested hay were typically searched once in mid July. Because most nests in unharvested fields could not be dated as to the time of establishment or subsequent events, these data were important primarily for comparing rates of nest success (hatch) with harvested hay. Further, success rates of pheasant nests in hay were compared to figures available for the SSA from 1957-61 (Labisky 1968). Nest search techniques are described by Joselyn et al. (1968).

Nests in hayfields were categorized according to their fate including previously abandoned and/or destroyed, hatched, or active nests (embryos and sometimes females) destroyed during cutting. A frequency distribution that combined data for 1962-71 was plotted to estimate the mean rates of hatch and pheasant destruction (females and embryos) according to the week of the first hay cutting. These rates were computed based on the percent of all nests found for a given week of cutting.

Pheasants were captured on the SSA by nightlighting during fall (late Oct and Nov) and winter (Jan-Feb) through 1971. After inspection for mower-related injuries (e.g., loss of a leg), females were weighed, banded and back-tagged, and released (Etter et al. 1988).

The departments of agriculture in midwestern states tabulate information reported by farmers pertaining to the cropping of hay (Ill. Dep. Agric. 1987). We asked 6 state agencies to provide data reliable on a statewide basis; Illinois also provided information by region from 1981 to 1987. Most states record these data according to the percent of first and subsequent cuttings completed at 7- to 10-day intervals. Using the rate of completion (% hay cut/day) between reporting intervals, we estimated the Julian date that represented the mean (approximately 50% completed) day of cutting. Long-term trends in the mean day of cutting were plotted as 3-point moving averages of the year in question and the previous 2 years. Further, for Illinois we analyzed records that described regional trends in the planting and harvesting of various hay cultivars in Illinois since 1900 (Ill. Dep. Agric. 1964, 1987).

Periods selected for consideration of pheasant mortality in Illinois were 1951-58, 1977-87, and a hypothetical future series generated by subtracting 10 days from the mean cutting dates for each year from 1977 to 1987. Mean rates of female and nest destruction were assigned each year for the Illinois pheasant range by associating the mean (statewide) date of the first alfalfa cutting with destruction rates for that week as determined from the frequency distribution of nests in harvested hay on the SSA. Indices of female and nest destruction were computed for each period as the mean, standard deviation, and coefficient of variation.

Although hay mowing was not observed on the SSA earlier than 21-27 May, data from the EF, and unmowed cover not in agricultural production on the SSA (Joselyn et al. 1968), indicated that rates of nest establishment nearly doubled during each week in May. Thus, rates of female and nest destruction on the SSA for 21-27 May were divided by 2 to estimate mortality rates for 14-20 May. Calculations were also made back to 30 April - 6 May by dividing the female and nest mortality rates for the previous week by 2.

Differences in rates of female and nest destruction for 1951-58 and 1977-87 were evaluated using 2-tailed t-tests. Zero-order regression coefficients were computed to test for changes in mean dates of hay cutting over time.

RESULTS

Forage Crops in Illinois

In 1920, 1.25 million ha of forage were harvested for hay in Illinois as compared to only 0.5 million ha in 1985. Only 3% of the hay in 1920 was alfalfa, but by the 1980's alfalfa made up nearly 60% of forage crops. Alfalfa fields have always been among the first forages to be cut in Illinois (Ill. Dep. Agric. 1964).

The trend toward earlier hay harvest in Illinois has been evident since World War II, with the first cutting in the 1980's typically occurring 10 days earlier ($\underline{P} < 0.05$) than during the 1950's (Fig. 1). A 36- to 39-day interval between cuttings has held for the past several decades. All regions of Illinois show the same tendency toward earlier cutting and annual fluctuations in harvest time.

Pheasant Destruction During Hay Harvest Near Sibley

The mean date of the first hay harvest on the SSA tended to be 11 days later than the statewide mean (alfalfa) for 1957-70 (Fig. 2). Annual fluctuations in mean dates of mowing were similar for the SSA and the state ($\underline{r} = 0.64$, $\underline{P} < 0.05$).

From 1962-72 102 (13%) of 797, and 107 (35%) of 307 pheasant nests hatched in harvested and unharvested hay, respectively. From 1957-72, 203 (17%) of 1,231 and 228 (36%) of 631 pheasant nests in harvested and unharvested hay, respectively, were successful. On the EF 120 (32%) of 375 nests hatched from 1966-70. Signs of injured or killed females at destroyed nests in unharvested hay and the EF were rare.

Pheasants began to hatch on the EF after the first week of June, peaking between mid-June and mid-July, and continuing through August (Fig. 3). Due to cutting, the frequency of pheasants hatching in late summer in harvested hay on the SSA was truncated compared to the EF (Figs. 3 and 4) and unharvested hay on the area.

Female pheasants were particularly prone to destruction during cutting of hay in mid-to-late June (Fig. 4). Our data suggest that, on average, females were struck during hay cutting at about 65% of the nests under incubation, with half of the observed destruction between 4 June-1 July (Fig. 4). The week of 11-17 June represented 24% of all nests observed in harvested hay (Fig. 4). During this week, 36% of the nests were destroyed by mowing, accounting for 41% of all hens struck on the area during hay harvest. In addition to first cuttings, the mean rates of nest and female destruction during the second cutting of hay were 26 and 15%, respectively, at 27 nests.

The incidence of female destruction, in conjunction with estimated numbers of pheasants on the area in summer, indicate that up to 25-30% of the females on the area were struck during haying operations. Further, 3.8% of 1,445 adult females captured in fall and winter, 1962-71, had evidence of mower-related injuries (missing toes of feet). However, there were almost no females with more substantial injuries; e.g., legs cut above mid tarsus observed in captured samples. Thus, we estimate that less than 1 out of 7 (3.8/25) of the hens struck during cutting were typically alive at the end of the summer (S.L. Etter and R.E. Warner, unpubl. data).

Indices of Female and Nest Destruction

Indices of nest and female destruction declined 32 and 47%, respectively, from 1951-58 to 1977-87 (Table 1). If future dates of first hay cutting were to become 10 days earlier than they were around 1980, the nest destruction index would decline an additional 31%.

Alfalfa Harvesting Practices in the Midwest

Annual patterns in the chronology of alfalfa harvest have been similar for midwestern states over the past 23 years (Fig. 5). First cutting dates have become earlier over time ($P < 0.05$) for all states except Indiana and Missouri. The slopes of regression lines for Wisconsin, Iowa, and Illinois are greater ($P < 0.05$) than those for Indiana and Missouri. The trend toward earlier harvest is also apparent for cultivars such as red clover and mixtures of forage legumes and grasses.

The shift toward earlier cutting is more pronounced in northern states. If we compare Missouri and Wisconsin, for example, the spread between first cutting dates is now about 20 days compared with about 35 days in 1965 (Fig. 6).

DISCUSSION

Factors Contributing to the Early Cutting of Hay

Farmers in the Midwest recognize that harvesting forage legumes at the first flower rather than at peak bloom approaches an optimal compromise between yield, nutritional quality, and persistence of stands (D.R. Buxton, Iowa State University, pers. commun.). The move toward optimal yields has fostered greater use of alfalfa (Buxton et al. 1985). Northern dairy farmers are especially prone to cut early because they can store succulent early-growth hay as silage, a practice that explains in part the pronounced shift toward earlier harvest in these regions (Fig. 6) (K.D. Johnson, Purdue Univ., pers. commun.). Further, cultivars have been developed that tolerate early and frequent cutting. Most alfalfa in the Midwest is now cut 4-5 times, compared with 2-3 times decades ago (D.W. Graffis, Univ. of Illinois, pers. commun.). However, the speed of cutting and the height of residual stubble have not changed appreciably since World War II (D.R. Buxton, pers. commun.).

Regional Perspectives of Pheasant Mortality

Mortality rates for pheasants on the SSA (Fig. 4) appear to be reasonable, perhaps even conservative, estimates for all of Illinois as documented for earlier decades by Robertson (1958). Further, we recorded numerous pheasants <14 days of age killed during mowing (S.L. Etter and R.E. Warner, unpubl. data), a form of mortality not considered in these estimates. Leedy and Hicks (1945) reported that approximately 30% of the females nesting on study areas in Ohio in the 1930's were destroyed by hay harvesting.

Females are less prone to abandon nests as incubation progresses (Warner and Etter 1983), which is why mowing hay in late May or early June destroys fewer pheasants than disturbances in late June when most embryos are approaching full term. Further, females renesting in hay stubble have little probability of success. Assuming a 36-day interval before hay cutting, a lag of 1-2 weeks before renesting (Dumke and Pils 1979), and time for laying (1.3 days/egg) and incubation (23 days), a female is likely to be well along in incubation, and highly vulnerable, when hay harvesting resumes.

The relationship of changing haying chronologies to pheasant survival warrants further documentation. Even where early hay cutting is becoming less detrimental to nests and females, pheasant demography will not be enhanced unless there is a high probability that renesting females will produce young that are recruited into the fall population. Unfortunately, the effects of regional shifts in the chronology of hay cutting (Fig. 6) on midwestern pheasant abundance are difficult to quantify with available information.

Regional differences in the timing of nesting are subject to varying interpretations, just as techniques for establishing nest phenologies have not been consistent. For example, Gates (1971: 329-330), in comparing several studies that estimated mean dates for earliest clutch establishment, concluded that the onset of nesting for wild pheasants was delayed 2-3 days/degree of latitude going north. With information currently available from radiotelemetry and nest searches, a 6- to 9-day spread in the onset of pheasant nesting between east-central Illinois and central Wisconsin may not be substantiated. The earliest nests are established between the first and second week of April in both regions, with no clear difference in the peak of establishment (Buss 1946, Anderson 1964, Labisky 1968, Gates 1971, Dumke and Pils 1979, Warner and Etter 1983). Furthermore, penned breeders in outdoor environments begin dropping eggs during the first week of April from Illinois north to Ontario (Gates and Woehler 1968, Labisky and Jackson 1969, Barrett and Bailey 1972).

Technological changes in agriculture began to affect hay production over the Midwest 4-5 decades ago. Hay cutting probably first regularly coincided with late stages of incubation in the northern dairy and livestock portions of the pheasant range, resulting in high destruction rates of females and nests. Similarly, rates of pheasant destruction related to haying may first be approaching significant declines in this northern range during the past decade (Fig. 6). In addition, recent patterns in hay cutting over the Midwest (Fig. 5) suggest synchronous, weather-related, annual variations in this important agent of pheasant morbidity.

MANAGEMENT IMPLICATIONS

Pheasants usually do not renest in tracts where their nests were destroyed (Dumke and Pils 1979), which points to the potential importance of establishing unmowed nest cover near forage crops. There is evidence in Illinois, for example, that managed roadsides close to hay and small grains are relatively attractive to nesting pheasants, especially for renesting (Warner and Joselyn 1986, Warner et al. 1987). Thus, tracts of undisturbed nest cover where placed near forage crops do not have to be large to benefit pheasants. For this reason, the Conservation Compliance clause in the 1985 Food Security Act, which requires farmers to meet tolerable soil-loss standards by 1995, may provide opportunities for developing nest habitat near hayfields. Preliminary plans for addressing soil and water quality goals in the Midwest indicate that grass terraces and filter strips along headwater streams will be integral to achieving these goals.

Our findings also have implications for current and future initiatives to divert farmland from the production of key commodities, especially set-aside programs with annual contracts. Whereas diverted cropland has traditionally benefitted pheasants (Joselyn and Warnock 1964, Edwards 1984), guidelines for set-aside programs during the 1970's and 1980's have included several shortcomings from the perspective of pheasant habitat. The existence of diverted acres programs has been uncertain from one year to the next (Berner 1988). Further, contracts for fields enrolled in these programs have encouraged planting of small grains that are unattractive to nesting pheasants until after mid summer; allowed for mowing of seedings during the reproductive season, often during the period when nesting females are most vulnerable (Fig. 4); and frequently encouraged tillage of these fields in early autumn such that they do not persist long enough to develop as habitat.

Diverted farmland that is safe nest cover has been, and probably always will be, an important component of prime pheasant range in the Midwest, although the importance of these fields as habitat during fall and winter cannot be overestimated (Etter et al. 1988). Recent guidelines have encouraged, and in some cases required, field disturbances at the period when nesting females and embryos are most vulnerable to destruction. Ironically, while the cutter bar has historically been a major threat to nesting females, in some portions of pheasant range the detriments of hay harvesting to females and embryos has been declining, while the threat of disturbances in set-aside fields has been increasing.

Eventually, grasses established under the 1985 Food Security Act will diminish. The remaining forages are likely to be disturbed early and frequently. Because the reproductive activities of pheasants will center around such cover (Warner et al. 1987), the configuration of small undisturbed tracts for nesting near forage crops could sustain fall pheasant recruitment when the next phase of expanded row-crop production occurs.

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Table 1. Destruction indices for female ring-necked pheasants and nests in Illinois in relation to median day (Julian date) of first hay cutting.

	Day			% destroyed					
				Nests			Females		
Period	x	SD	CV	x	SD	CV	x	SD	CV
1951-58	163.4	2.8	1.7	34.8	3.5	10.1	20.9	8.6	41.2
1977-1987	153.0	8.3	5.4	23.7	9.1	38.4[a]	11.0	2.0	18.2[a]
Future[b]	143.0	8.3	5.8	16.3	8.2	50.3	11.1	3.8	34.2

[a] Destruction rates lower ($P < 0.01$) than 1951-1958.

[b] Ten days were subtracted from the date of mowing for each year, 1977-1987.

Fig. 1. Median Julian day and a linear regression line (x = year and y = median day) for the first cutting of hay for Illinois, 1951-87.

Fig. 2. Median Julian day for the first cuttings of hay on the Sibley Study Area and statewide in Illinois, 1957-70 (data for 1975-61 from Labisky 1968).

Fig. 3. Percentage of pheasant nests hatched by week (shown as median Julian day of week) for an undisturbed experimental field near Sibley, Illinois, 1966-70 (n = 120).

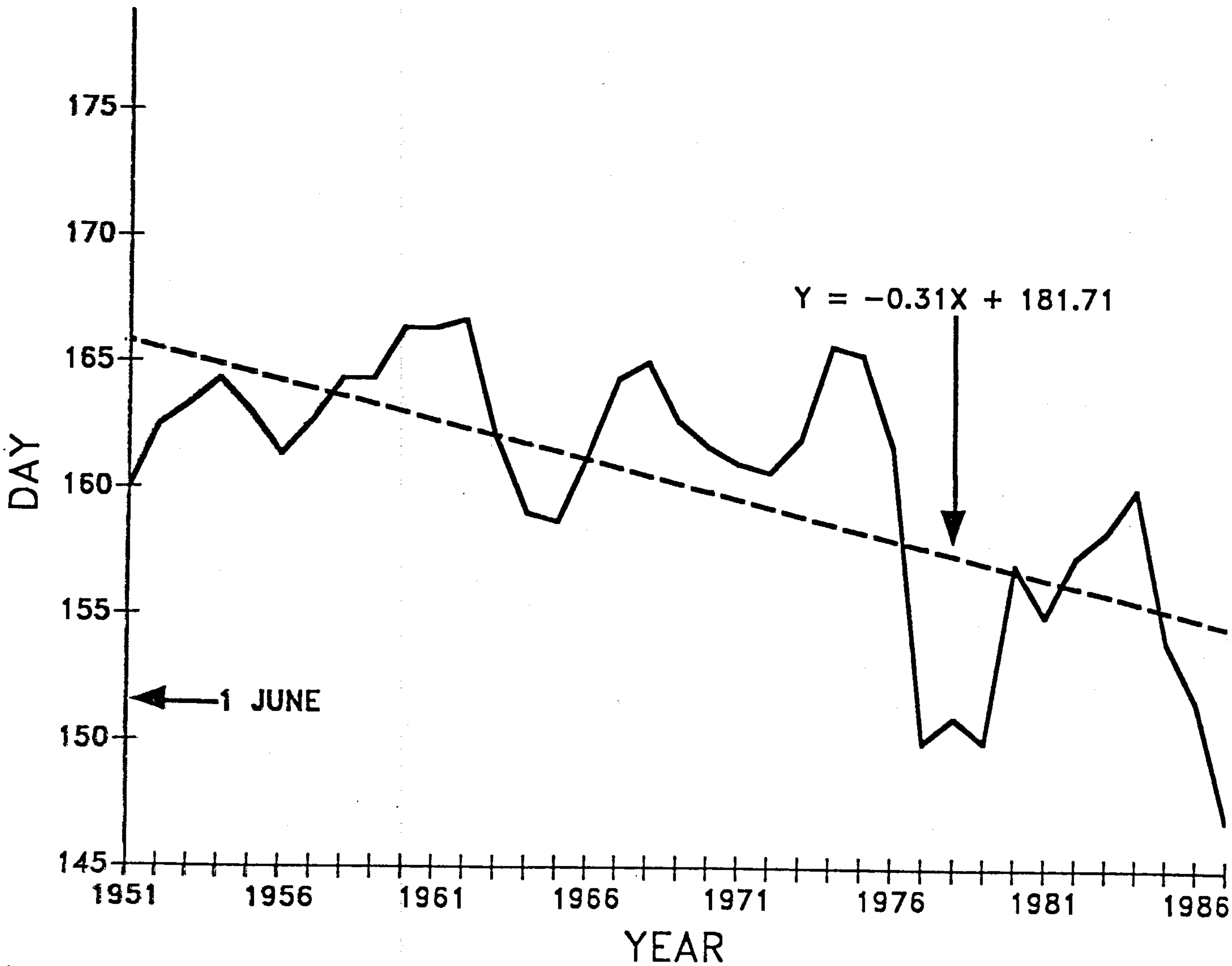
Fig. 4. The fate of pheasant nests, and destruction of females on nests, relative to the week of the first cutting of hay (shown as median Julian day of week or period) on the Sibley study area, Illinois, 1962-71.

Fig. 5. Median dates for the first cuttings of hay in 6 midwestern states, 1965-87.

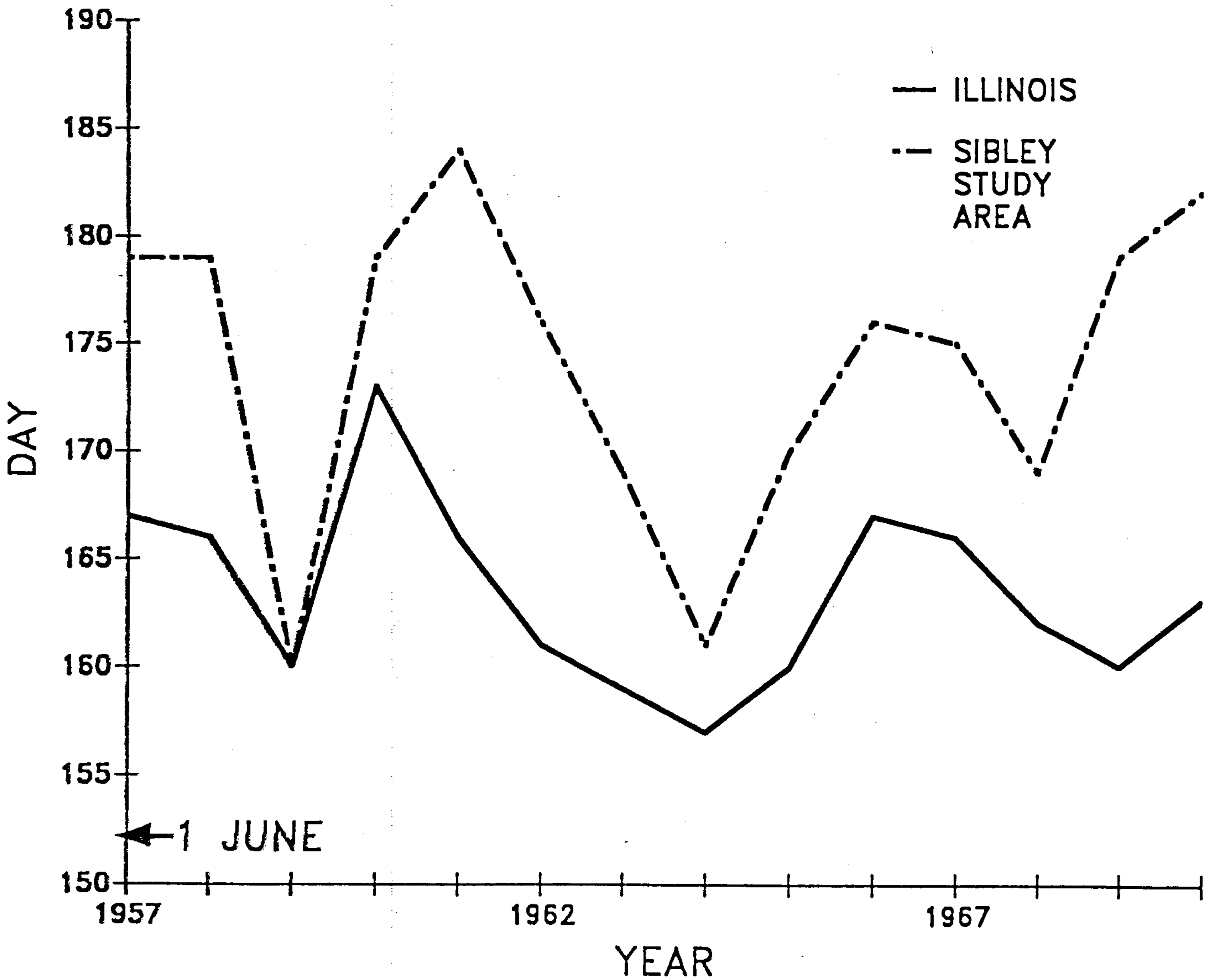
Fig. 6. Linear regression lines for the first cuttings of hay in 5 Midwestern states; $y = ax + b$, where x = year and y = median Julian dates, 1965-1987. Regression coefficients were different between Indiana-Illinois ($P < 0.05$), Indiana-Wisconsin ($P < 0.05$), and Indiana-Iowa ($0.05 < P < 0.10$).

(1)

RICHARD E. WARNER
ILL. NATURAL HISTORY SURVEY
CHAMPAIGN, IL 61820



(2)


ILLINOIS
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DAY
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185
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175
170
165
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155
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1 JUNE
1957
1962
1967
YEAR

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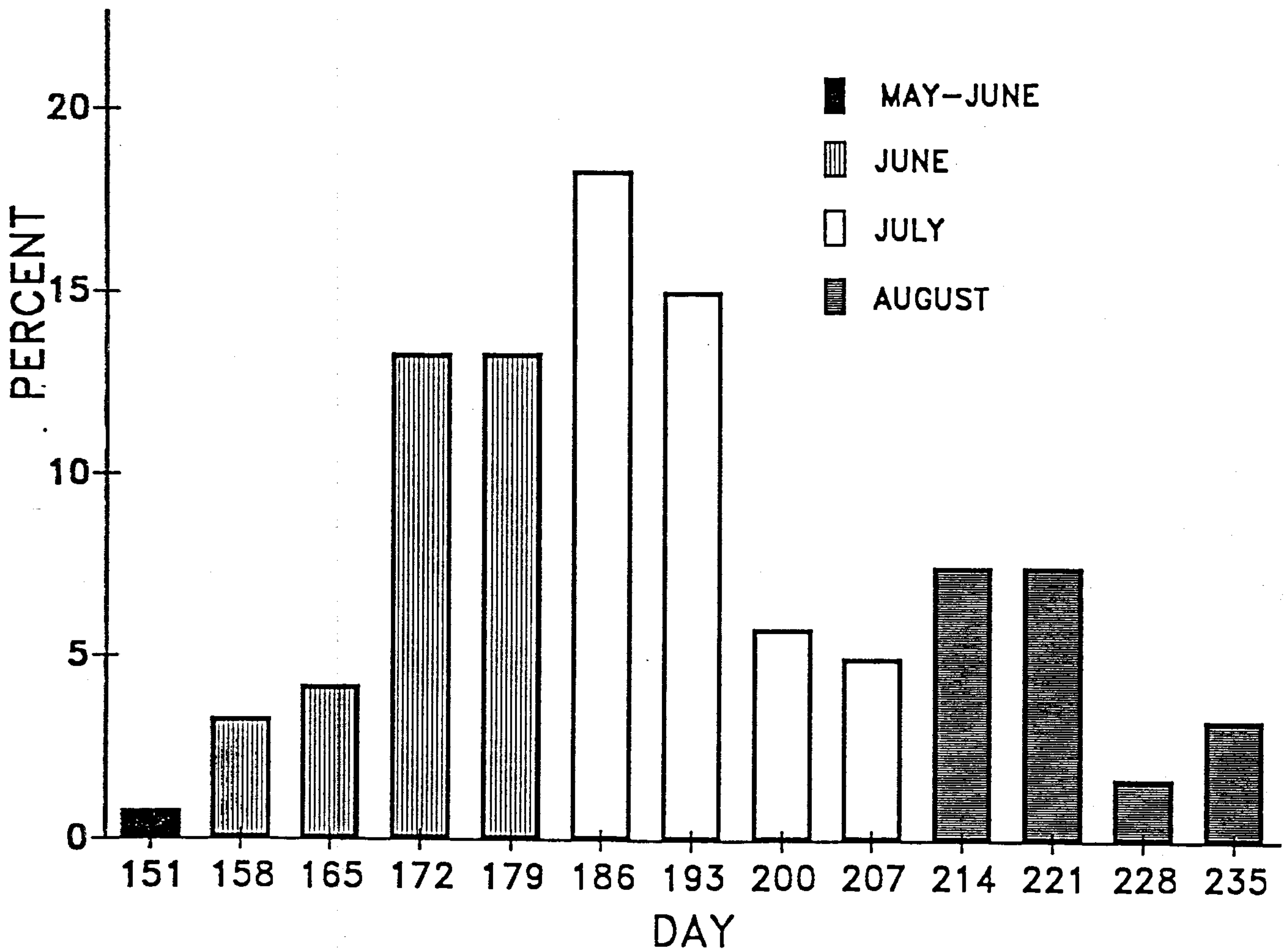
ILL. NATURAL HISTORY SURVEY
CHAMPAIGN, IL. 61820



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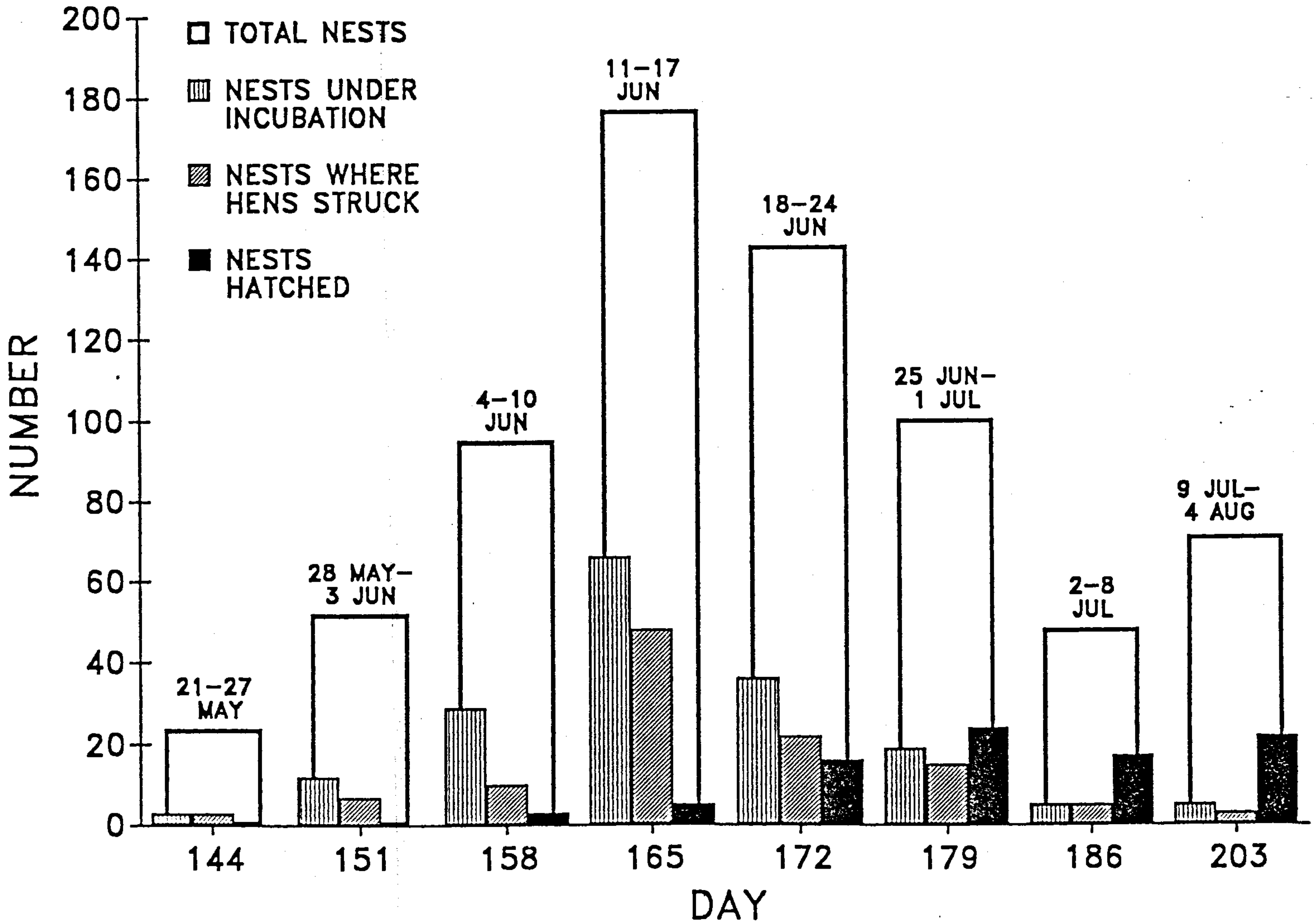
CHAMPAIGN, IL 61820



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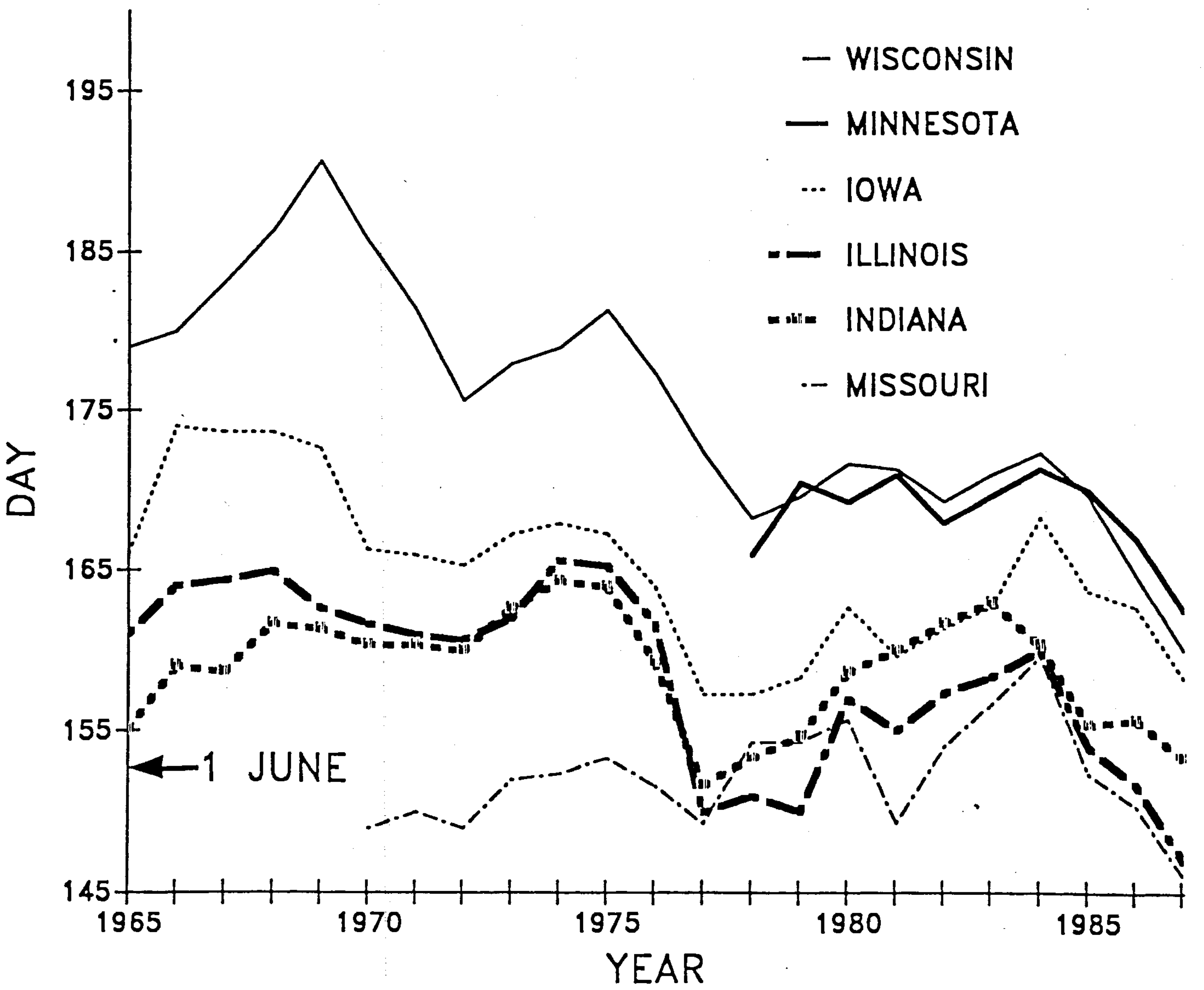
ILL. NATURAL HISTORY SURVEY
CHAMPAIGN, IL 61820



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RICHARD E. WARNER
ILL. NATURAL HISTORY SURVEY
CHAMPAIGN, IL. 61820