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ILLINOIS STATE WATER SURVEY
ATMOSPHERIC SCIENCES SECTION

THE RELATIONSHIP OF ILLINOIS WEATHER AND AGRICULTURE TO THE EASTERN COTTONTAIL RABBIT

by

Stephen P. Havera
Principal Investigator

TECHNICAL REPORT NO. 4
ILLINOIS PRECIPITATION ENHANCEMENT PROGRAM
PHASE 1

June 30, 1973

To

Division of Atmospheric Water Resources Management
Bureau of Reclamation
U. S. Department of Interior

Contract 14-06-D-7197
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ABSTRACT

An investigation was made of the relationships of Illinois weather and crops to cottontail rabbit populations from 1955 through 1971. Such an investigation was desired to ascertain whether precipitation changes produced by weather modification might produce an effect on the ecosystem, as reflected in the rabbit population. Monthly weather parameters, weather factors during critical periods of the cottontail's life cycle, and crop acreages for four Illinois game regions were analyzed with cottontail harvest and census data. Weather factors in general were not highly correlated with cottontail data. Total snowfall for December through March preceding the hunting season appeared to correspond to the success of the cottontail rabbit harvest. The key factor in the decline of cottontail populations in Illinois since 1955 was the changing pattern of land use. Increasing acreages of corn and soybeans were negatively and significantly correlated with the cottontail harvest. Multiple regression equations relating cottontail harvest to land use, the July census, and total snowfall for December through March were developed for each of the four game regions. The direct effect of rainfall enhancement during July and August on cottontails and other wildlife species will probably be less serious than such indirect effects as the planting of more acres of corn and soybeans.

INTRODUCTION

Purpose of Research

The research presented in this report was undertaken to evaluate some of the effects of climate on Illinois cottontail rabbit (*Sylvilagus floridanus*) populations. Studies completed at the Illinois State Water Survey by Changnon and Huff (1971) revealed that in most regions of Illinois, a July-August cloud seeding program would benefit production of corn and soybeans in most growing seasons. In the present study, the relationships of temperature, sunshine, snowfall, and precipitation parameters to cottontail census and harvest statistics were evaluated for the years 1955 through. 1971. Emphasis was placed on the cottontail's relationship to total precipitation in July and August and to the acreages of corn and soybean crops.

The cottontail was selected for the weather analysis because it not only is, the leading small game species hunted in Illinois (Preno and Lahisky, 1971), hut it also is the leading game species on agricultural land throughout most of the United States (Ecke, 1955). Analyses of cottontail, weather, and crop statistics were performed on a contiguous 68-county block that contains most of the state with the highest cottontail harvest from 1956 through 1970 and also most of the state's corn and soybean range. A diversity of land use and forms is represented.

The tasks undertaken in this project were 1) determination of relationships of monthly weather parameters to cottontail census and harvest data, 2) determination of relationships of weather parameters during critical periods of the rabbit's life cycle to rabbit harvest, 3) determination of the effect of total precipitation throughout the year on cottontail harvest, 4) determination of the relationships of crop acreages to cottontail harvest, and 5) the modeling of weather, crop and cottontail harvest data.

Data Used in Research

The data for the cottontail rabbit in Illinois used in the study were taken from Preno and Labisky (1971). Those authors partitioned the state into seven contiguous geographic units, each containing several counties. These units were termed game regions (Fig. 1). Preno and Labisky (1971) based the partitioning of the state into game regions primarily on the relative distribution and abundance of the game species studied. The different game regions represent somewhat different habitats and portray differences in topography, agriculture, forestation, and climate. Within each game region, and on a statewide basis, population and harvest statistics were available for cottontails.

The population indices for the cottontail were collected on 73, 20-mile-long census routes geographically and ecologically distributed in the seven game regions throughout the state. Many of the 73 routes underwent either no changes or only minor changes during the entire study period. Census counts for the rabbit were available for March and July of each year during the study period. The March census counts were taken throughout the month., whereas the July counts were taken between July 1 and July 15.

The estimated numbers of rabbits harvested were based on random samples of resident licensees who completed and returned questionnaires. The number of respondees averaged 3,065 annually from 1956 through 1969. The harvest statistic for rabbits used in the weather analysis was the mean number of cottontails killed per individual hunter trip since more

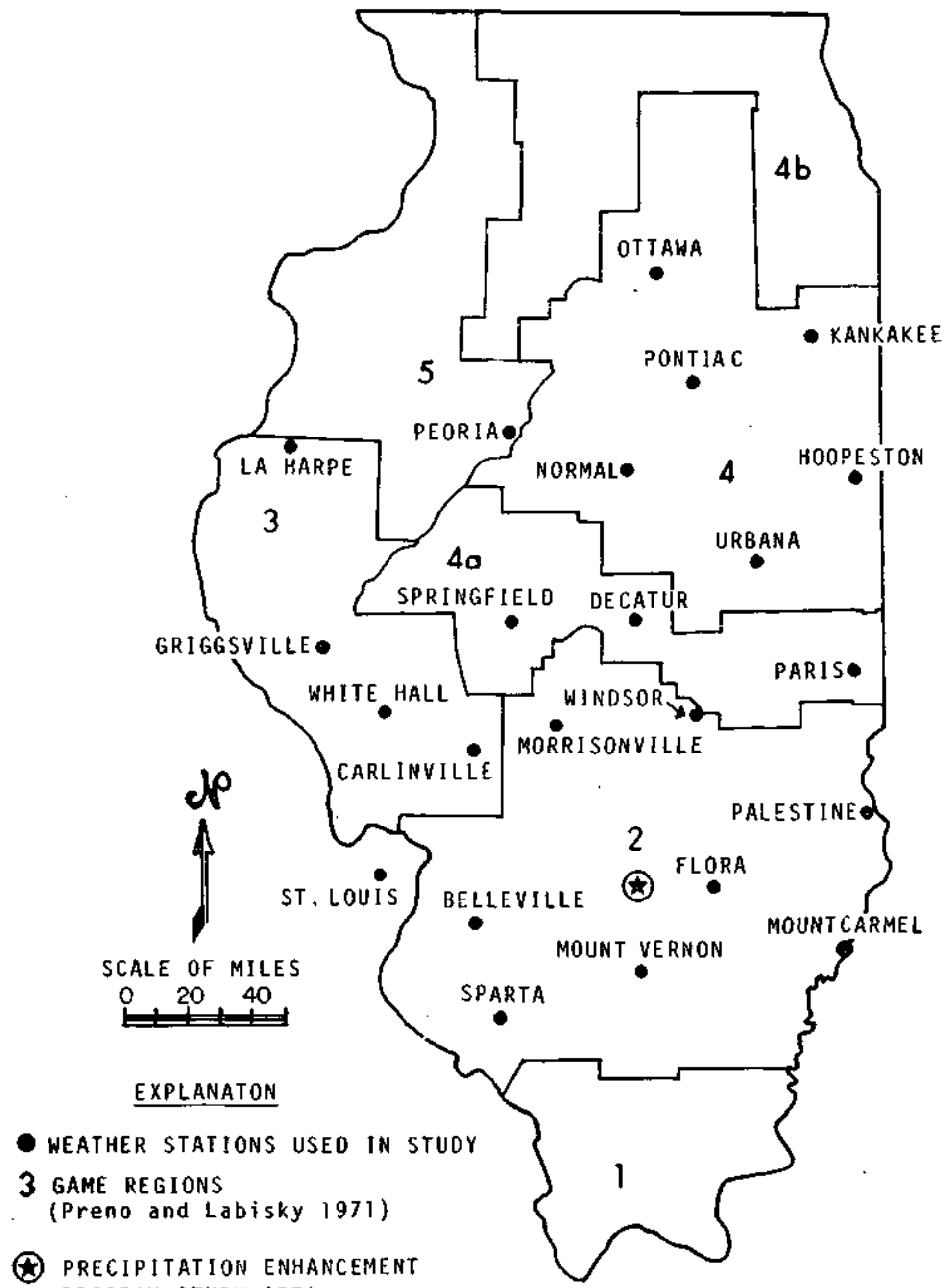


Figure 1. Game regions and selected weather stations for cottontail-weather analysis.

data were available for this parameter than for the other harvest statistics.

Weather data used in the study were taken from 23 stations of the National Weather Service for the period 1955-1971 (Fig. 1). The monthly-weather parameters used are listed in Table 1. Data for the monthly weather variables were obtained from monthly summaries of Illinois Climatological Data, published by the U. S. Department of Commerce. The number of weather stations selected for each game region was based on the land area in each region. In this manner, the game regions have proportionally similar numbers of weather stations contributing climatological data. Eight weather stations were chosen for Game Region 2, four for Region 3, six for Region 4, and three for Region 4a. Stations selected were distributed in a pattern representative of the game regions and provided data on snowfall, precipitation, and temperature. However, because few weather stations record sunshine parameters, St. Louis was used for sunshine information for Region 2, Peoria for Region 4, and Springfield for Regions 3 and 4a. Monthly weather data for weather stations selected in each region were averaged to develop mean weather values for each region.

Crop acreage data for each county of the game regions were taken from annual summaries of Illinois agricultural statistics, published by the Cooperative Crop Reporting Service, Illinois Department of Agriculture.

Table 1. Monthly Weather Variables Used for Analysis with Cottontail Harvest and Census Data

Number	Variable
1	Average maximum temperature
2	Average minimum temperature
3	Average mean temperature
4	Total precipitation
5	Number of days with precipitation ≥0.10 inch
6	Number of days with precipitation ≥1.00 inch
7	Total snowfall
8	Number of days with snow cover ≥1.00 inch
9	Percent of possible sunshine

ANALYTICAL METHODS

Monthly climatological data, agricultural crop data, and cottontail harvest and census data from 1955 through 1971 for the four game regions were placed on computer cards. The IBM 360 Computer at the University of Illinois, Urbana, was used for the analyses of the data.

For the comparison of monthly weather parameters and cottontail statistics, correlation and stepwise multiple regression programs were used. A 14-month time span was used for each cottontail parameter. For example, in the analyses of the July rabbit census, monthly weather factors for the 13 months previous to the census and the month of the census were considered. Over the period 1955 through 1970, 14 individual months with 16 years of data for each month would result. The July census values for 16 years were then compared with the 16 years of weather factors for each of the 14 different months. A stepwise multiple regression program with the F-level to enter and exit set at 0.0 was used for the comparison. The monthly weather parameter that was listed first in the results represented the weather factor from that month that was associated with the most variance in the July census. For a given game region, I then had 14 monthly weather parameters, one for each of the 13 months preceding the census month and one for the census month itself. These 14 monthly weather parameters could then be compared with the July census by a stepwise multiple regression program to determine the order of their accountability of variance in the census data. The same months could then be compared between the different regions to see if the same weather factors had been selected. Analyses of the March census and rabbit harvest were also performed in the same manner. These analyses allowed comparison of monthly weather factors for a given cottontail parameter among regions, comparison of monthly weather factors for different cottontail parameters within the same game region, and comparison of monthly weather factors for different cottontail indices among all the game regions.

For supposed critical periods of the cottontail's life cycle, the monthly weather parameters were averaged over the critical periods. The weather parameters from the critical periods were correlated with the cottontail harvest for the years 1956 through 1970 by stepwise multiple regression programs. The weather parameters from the critical periods that best correlated with cottontail harvest were selected by the programs.

In the formation of the regional models of cottontail harvest from 19.56 through 1970, the acres of favorable habitat (the sum of the acres of total pasture, small grains, hay, and all other land) and the July census, the March census, various combinations of the July and March censuses, and log transformations of the censuses were analyzed using stepwise multiple regression procedures. The July census gave the highest multiple correlation coefficient and t values. The selection of weather parameters for the models was also made by stepwise multiple regression programs. However, favorable habitat and the July census were retained as independent variables when the weather factors were examined. The weather factors selected from individual monthly periods and the critical periods were those that 1) in conjunction with the habitat and July census variables, reacted similarly to the cottontail harvest in all the game regions, 2) increased the multiple regression coefficient of the habitat and July census by an increment of at least 0.01, 3) gave respectable t values, and 4) made sense ecologically. Polynomial expansions and plotting of the crop, census, and weather parameters indicated that the relationship between these variables and the cottontail harvest was linear. Interaction terms and log transformations of independent variables were not used in the models since they did not appreciably increase the sum of squares of the multiple regression. Multiple regression programs were run to obtain predicted values for the dependent variables during the years of the study interval.

RESULTS OF STUDIES

Climate of Illinois

Climate is the interaction of temperature, winds, pressure, and moisture in the atmosphere. Of these elements, temperature and moisture (precipitation) are the most important (Page, 1949). The central continental location and the latitude of Illinois result in generally hot summers, cool to cold winters, and rather abundant precipitation throughout the year with a high degree of reliability from year to year. Cyclonic storms are the dominant control over the Illinois climate for much of the year (Page, 1949).

Temperature. The temperature in Illinois has fluctuated in recent years, but there has been no trend toward a warmer or colder climate. Generally, isotherms have an east-to-west trend. However, in the central and northern parts of the state, the isotherms are somewhat northeast to southwest in December, January, and February. From April through August, in most of the state, the isotherms run slightly northwest to southeast.

Ross and Case (1956) stated that over a long period of years there has been a difference of 10°F in average temperatures from the northern to the southern boundaries of Illinois and a difference of 4 weeks in the length of the growing season. Northern Illinois had winter temperatures considerably lower than those in the south, but the summer average temperatures were almost the same in both areas (Appendix A, Fig. 1). For a 56-year period, the northern part of the state had an average temperature of 22.5°F during the winter months and 72.0°F during the summer months. During the same seasons in the extreme southern part of the state the average temperatures were 38.7°F and 77.7°F. The northern area had an average maximum temperature of 98°F and an average minimum temperature of -14°F, while the corresponding values for the southern area were 99°F and 5°F. Because of the greater difference in average temperature in winter than in summer between northern and southern Illinois, spring temperatures rise faster and autumn temperatures drop more sharply in the north than in the south. The western part of the state had a slightly greater temperature range than the eastern part.

Seasonal changes of temperature follow a similar pattern throughout the state. January and February are both cold months, but the temperature begins to rise from February to March and continues to rise until June. July is usually the warmest month, but during the summer months the changes are slight. From August to September temperatures begin to decrease steadily until they reach the coldest month of the year, which is usually January.

There is more variation in winter temperatures than in summer. Winter temperatures are caused primarily by cyclonic storms and the invasion of warm and cold air masses for relatively short periods of time, but the sun primarily accounts for steady day-to-day differences in the summer (Page, 1949).

Precipitation. Wet and dry years occur in Illinois, but generally the precipitation is quite dependable from year to year. Precipitation, like temperature, does not seem to be increasing or decreasing during recent years, and departures from normal are neither frequent nor large.

The average annual rainfall in Illinois is heaviest in the southern part of the state and lightest in the north, ranging from 47.43 inches at Anna to 30.77 inches at Morris (Appendix A, Fig. 2). The difference is mainly due to the greater winter precipitation in the southern part of the state. In the majority of Illinois, the growing season (April to September) is the period of maximum precipitation (Appendix A, Figs. 3 and 4). Rainfall during the growing season varies over the state from about 19 to 25 inches. May is usually the wettest month of the year, whereas July is the driest month of the growing season.

Winds. The winds of Illinois blow predominantly from the northwest, west, and southwest. Northwest winds seem to be more common in the winter, and southwest in the summer.

Snowfall. Snowfall increases from the southern to the northern part of the state, ranging from less than 10 inches in the south to approximately 35 inches in the northwest (Appendix A, Fig. 2). December, January, and February are the months of heaviest snowfall with January being the month of greatest snowfall in northern and central Illinois and February in the south.

Climate of the Game Regions

Temperature, The annual average maximum, minimum, and mean temperature for the 1956 through 1970 study interval were highest in Game Region 2, the southernmost area, and lowes.t in Game Region 4, the northernmost area (Appendix B, Table 1). Regions. 3 and 4a lie at approximately the same latitude and correspondingly had similar temperature parameters. Region 3 had a higher annual ayerage maximum and mean temperature whereas Region 4a had a higher average annual minimum temperature. In all regions, January had the lowest maximum, minimum, and mean temperature and July had the highest. A wider range of temperature between the game regions occurred in the winter months than in the summer.

For the game regions in general CFig. 2), average maximum, minimum, and mean temperatures began to rise slightly in February, then increased sharply in March, April, and May. The temperatures leveled off in June, July, and August with July being the warmest month. The temperatures then steadily declined from September through January.

Precipitation. Game Region 2 was not only the warmest region but also the wettest. From 1956 through 1970, it had the highest average annual total precipitation and number of days with precipitation ≥0.10 and ≥1.0 inch (Appendix B, Table 2). Game Region 4, the coldest region, had the lowest average annual total precipitation and the number of days with precipitation ≥1.0 inch, but Region 3 had the lowest number of days with precipitation ≥0.10 inch.

In all the regions, there was not a large variation in the precipitation parameters on a yearly basis. The average annual total precipitation, number of days with precipitation £0.10 and £1.0 inch differed by 5.10 inches, 5.2 days, and 2.0 days, respectively, between the regions with the highest and lowest values.

The average monthly precipitation parameters show most of the difference between the wettest and driest regions during the winter months when more rain occurred in the south. Precipitation parameters are fairly similar in all of the regions during the growing season. The months of maximum total precipitation were May for Region 2, July for Regions 3 and 4, and April for Region 4a. Usually July is the driest month of the growing season in Illinois. However, during the study interval, 9 of the 15 Julys in Region 2, and 10 in Regions 3, 4, and 4a were above normal in total precipitation.

April was the month with the highest number of days with precipitation ≥0.10 inch. July had the highest number of days with precipitation ≥1.0 inch in Regions 3, 4, and 4a whereas May was the high month in Region 2. The precipitation parameters reached their lowest levels in all the regions during January and February.

The averages of the monthly precipitation parameter means for Regions 2, 3, 4, and 4a from 1956 through 1970 are shown in Fig. 2. All of the precipitation parameters were at their highest levels from April through July with a secondary peak in September. Total monthly precipitation rose steadily until April and then remained fairly stable

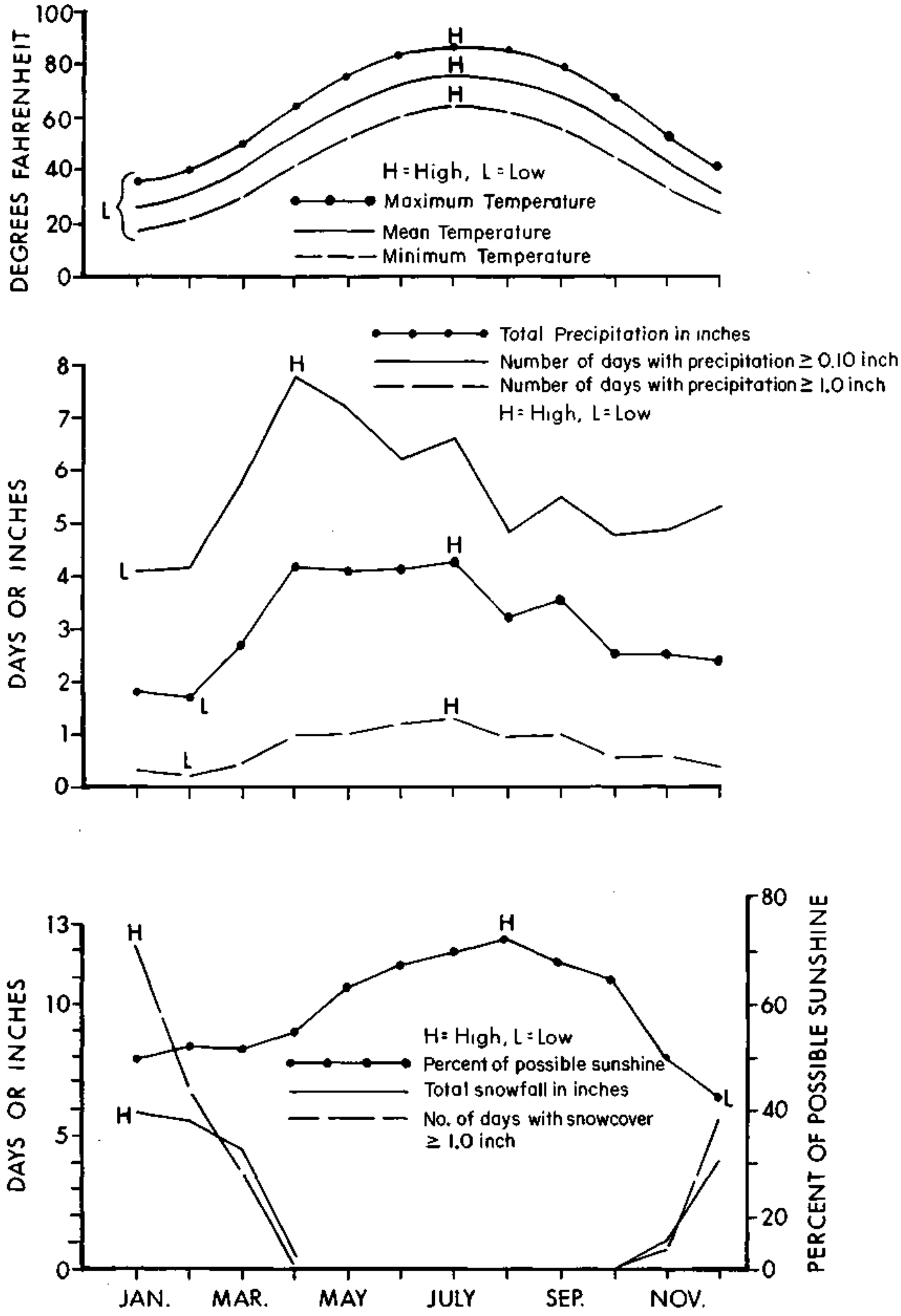


Figure 2. Averages of the monthly weather parameter means from Illinois Game Regions 2, 3, 4, and 4a, 1956-1970.

through July where the peak occurred, decreased noticeably in August, rose somewhat in September, and then decreased during the remaining months. The number of days with precipitation ≥0.10 inch rose sharply to a peak in April, then declined gradually to a lower peak in July, dropped sharply in August, and after an increase in September, remained fairly stable for the remainder of the year. The number of days with precipitation ≥1.0 inch rose gradually to a high in July with secondary peaks in April and September. Although the average monthly precipitation for the game regions was approximately the same from April through July-, the frequency of rainy days with low amounts of precipitation was greater in April and May and days with high amounts of precipitation occurred more frequently in June and July.

Snowfall and Snowcover. Game Region 2 was the warmest and wettest area, and it had the lowest annual average total snowfall (17.2 inches) and average number of days with snowcover ≥1.0 inch (19.3 days) from 1956 through 1970 (Appendix B, Table 3). Region 4, the coldest and driest region, had the highest average snowfall (25.1 inches) and number of days with snowcover ≥1.0 inch (39.0 days). January was the month of greatest total snowfall in Regions 3, 4, and 4a and February was the highest month in Region 2. January had the highest number of days with snowcover ≥1.0 inch in all the regions.

For the game regions in general (Fig. 2), December, January, February, and March were the primary snow months with January having the highest value for total snowfall and snowcover.

Sunshine. In all the game regions, the percentage of possible sunshine was lowest in December and reached its highest value in August (Appendix B, Table 3). The graph of the average of the four regional mean monthly values (Fig. 2) shows a slight increase in the percentage of possible sunshine from January to April, a sharper rise from May to August, a slight decline to October, and a steep decline in November and December.

Land Characteristics of Illinois

Illinois is 385 miles long, covers an area of 55, 947 square miles, and lies in the corn belt. Most of the land is gently rolling or level with approximately 88% between 400 and 800 feet in altitude. Illinoian age glaciers covered all of the state except Calhoun County in the west-central part, Jo Daviess County in the northwest corner, and the seven most southern counties (Fig. 3). Wisconsin age glaciers covered the northeastern one-third of the state, and the soil weathering in this area is fairly weak because the time since the Wisconsin glaciers has been comparatively short.

The average productivity of Illinois soils is high. Corn, soybeans, wheat, oats, and hay are the principal crops. Corn and soybeans are grown in every county, and they comprise about 85% of the harvested farmland.

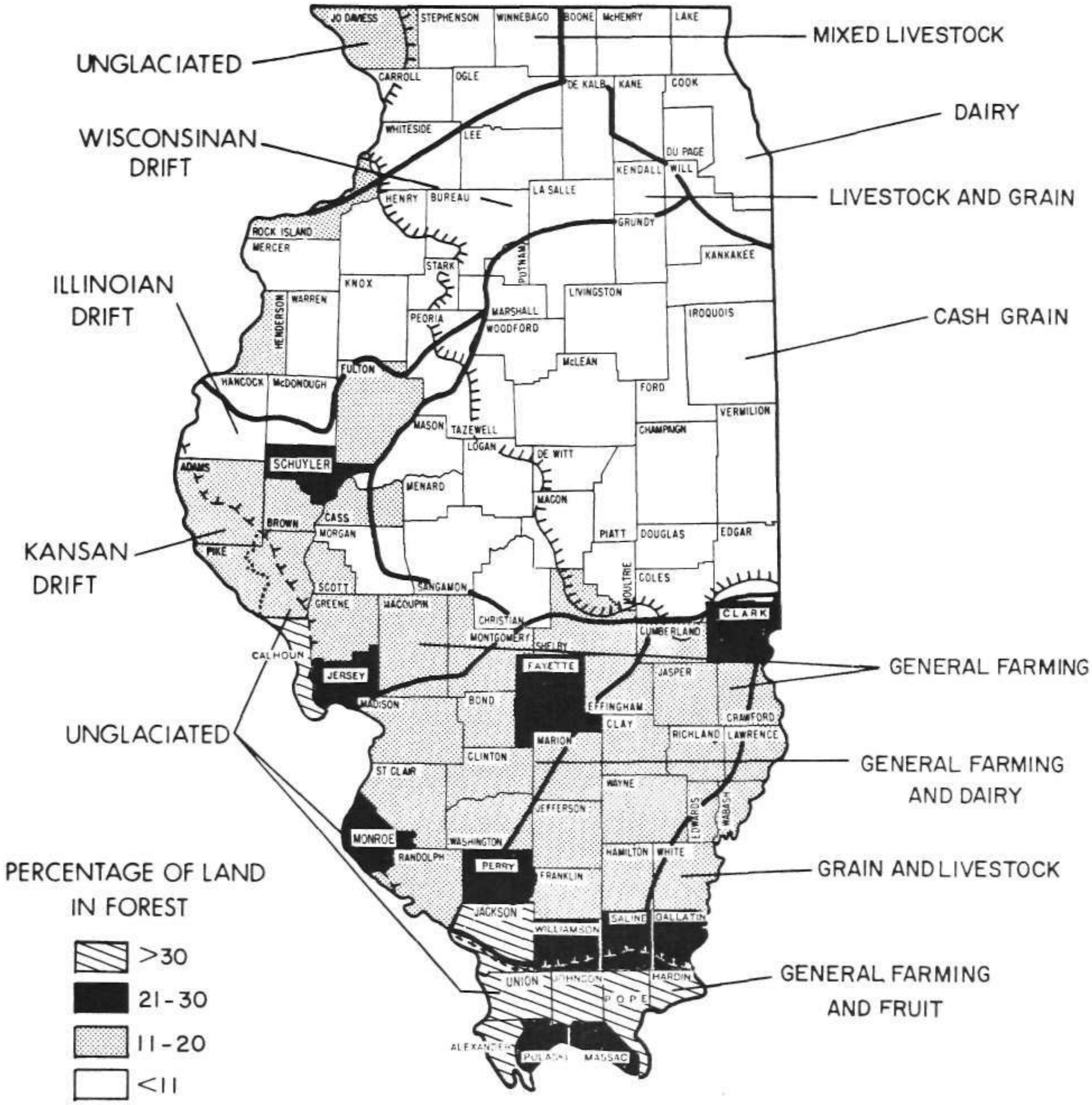


Figure 3. Farming types, forested areas, and glacial drifts in Illinois. The nine farming regions, separated by solid lines, are distinguished by the kinds and proportions of farm products (after Ross & Case, 1956), The terminal boundaries of the Wisconsinan (most recent) and. Illinoian ice sheets are designated, respectively, by solid and broken lines with projections; a small region of Kansan drift (oldest in state) is found in southwestern Illinois. The forest statistics are for 1962 (Essex & Gansner, 1964), [Map and legend Preno and Labisky, 1971].

Illinois is the leading producer of soybeans in the United States , and is second only to Iowa in corn production. In 197Q, Illinois corn and soybeans: represented one-sixth of the Nation's harvested acreage for each of these two crops. Corn production is the heaviest in the northern half of the srtate (Appendix A, Fig. 5). The greatest concentration of soybeans is found in central and south-central Illinois, but in recent years soybeans have increased in importance in the northern counties. Soybean acreage has increased from a few thousand acres before 1920 to over 7 million acres in 1971. Wheat is grown mostly in lower central and southern Illinois, and oats are grown primarily in the northern third of the state.

In 1970, crops were harvested from 68% of Illinois farmland. Corn accounted for 34% of the farmland acreage, soybeans 23%, wheat and oats 5%, and hay 4%. Unharvested farmland consisted of pasture (14% of the total acreage of farmland), and all other land (timber, wasteland, farmsteads, and government program land), which comprised 18% of the total acreage of farmland. The acreage of farmland is slowly declining in Illinois with a 4% decrease in farmland acreage in the last 10 years.

Land Characteristics of the Game Regions

Game Region 2. Game Region 2 consists of 28 counties and approximately 25% of the state's area (Table 2). The study area for the precipitation enhancement program lies in the center of this game region. Approximately 16% of Region 2 is forested, and it was not covered by the Wisconsin glaciers. Loess is the main kind of soil parent material in Region 2. Ross and Case (1956) described three farming types for this general area of the state (Fig. 3).

Table 2. Information on Illinois Game Regions 2, 3, 4, and 4a*

Game Region	Number of Counties in Region	Square Miles in Region	Percentage of State in Region	Percentage of Region Forested	Number of Rabbits Killed per 1,000 acres, 1956-70
2	28	14,328	25.6	15.6	149
3	12	6,679	10.2	14.4	103
4	18	12,048	21.5	3.0	79
4a	10	5,202	9.3	5.4	96
Entire State	102	55,947	100.0	10.8	103

*Information taken from Preno and Labisky, 1971.

The western part of Region 2 is. a general farming and dairy area. Wheat and soyheans are the crops heat adapted to this area. Much of the land cannot be cultivated, and the tillable land is poor in quality with, lights to medium-colored soils.

The central part of Region2 is a general farming area consisting of nearly equal numbers of cash-grain, livestock , and general farms. Corn and soybeans are the most important crops in this area. The land surface is level to gently rolling. The soils are generally fine-textured and light-colored or light- to medium-colored with relatively low natural productivity and high acidity.

The eastern part of Region 2 is a cash-grain and livestock area. Corn is the leading grain crop. Farms consist of grasslands on the upland areas and grain crops in the bottomlands.

For Game Region 2 as a whole, corn and soybeans occupied the highest percentage of farmland from 1956 through 1970 (Appendix B, Table 4). They were followed by all other land and total pasture. Harvested wheat, harvested small grains, and all other land expressed as a percent of operated farm acreage were higher in this region than in any other from 1956 through 1970. Region 2 ranked second to Region 3 in the percentage of favorable cottontail habitat. Region 2 had a higher density of cottontails killed per 1,000 acres from 1956 through 1970 than any other region.

Game Region 3. Game Region 3 is a 12-county area in the west-central part of the state (Table 2). It accounts for approximately 10% of the state's area, and about 14% of the region is forested. Except for Calhoun County, Region 3 was covered by the Illinoian glaciers; the Wisconsin glaciers did not enter this region (Fig. 3). The soil parent material in this area is mainly loess with some alluvium. Ross and Case (1956) classify this part of the state as a general farming area.

Less than three-fourths of the farmland in Region 3 is tillable. Because of the roughness of the surface and the light-colored and somewhat poor condition of the soil, farming is less intensive than in some of the other areas of the state. Hay and pasture are more abundant here than in any other game region with pasture consisting of a third to a half of the total acreage in some counties. Most of the farmland not in grain crops is used for pasture, but much of the pastured area is woodland. The crops accounting for the most farmland from 1956 through 1970 in order of their importance are total pasture, corn, soybeans, and all other land (Appendix B, Table 4). Of the game regions analyzed in this study, Region 3 had the highest percentage of favorable cottontail habitat. It had the highest average number of cottontails killed per hunter trip and the second highest number killed per 1,000 acres from 1956 through 1970.

Garoe Region 4. Game Region 4 is, an 18-county area in east-central Illinois (Table 2). It extends farther north than the other game regions analyzed. Region 4 represents about 21% of the state's area and only 3% of the region is forested. Ross and Case (1956) classify this part of the state as a cash-grain area and consider it the most important cash-region region in the corn belt (Fig. 3). Livestock and general farms are of secondary importance. Both the Illinoian and Wisconsin glaciers covered this area. The soils are dark-colored and productive, and the soil parent material is mainly glacial till and outwash with some loess. The land is level to gently rolling with a high proportion that is tillable.

Corn is the major crop in this region with 43.8% of the farm acreage planted to corn in 1970 (Appendix B, Table 4). Soybeans is the second leading crop. From 1956 to 1970, Region 4 had more of its farmland in total row crops (corn and soybeans) and oats than any other game region, but it had the lowest amount of farmland in wheat and total pasture. Region 4 had the least amount of favorable cottontail habitat, and it had the lowest average number of cottontails killed per hunter trip and per 1,000 acres during the study period.

Game Region 4a. Game Region 4a is a 10-county area that occupies approximately 9% of the central part of the state between Regions 2 and 4 (Table 2). It is a cash-grain area that is similar to Region 4 in farming practices, soil, and topographical features (Fig. 3). The Illinoian glaciers covered the entire region, but the more recent Wisconsin glaciers reached only the eastern half. Loess is the primary soil parent material. As in Region 4, corn and soybeans are the major crops, but Region 4a has relatively more farmland in wheat and less in oats. The amount of favorable cottontail habitat is low, and the average rabbit harvest in Region 4a from 1956 through 1970 was higher than in Region 4 but lower than in Regions 2 and 3.

Life Cycle of the Eastern Cottontail

The abundance of cottontails in a given area typically fluctuates from year to year. Population fluctuations are a result of variations in weather, changes in the habitat, changing densities of predators, outbreaks of diseases, and, perhaps, changes within the cottontail itself. Bailey (1968) reported evidence of geographically widespread and synchronous fluctuations in cottontail abundance throughout the north-central and northeastern United States with peaks of abundance occurring at 8- or 9-year intervals.

Cottontails are prolific animals whose change in annual abundance is due to fecundity during the breeding season and mortality during the remainder of the year. The average life expectancy at birth of a cottontail is only 6.4 months and 75% of the rabbits born do not live to attain the age of 4 months (lord, 196Q). Although the potential life span of the cottontail is 10 years, very few live to be 3 years old (Lord, 1961h). The mortality rate of adult Illinois cottontails is about 83% annually (Edwards, 1964b).

The breeding season of Illinois cottontails extends over several months. Lord (1963) states that the first copulations occur in February, the first births occur in March., and breeding continues into August, with the last births occurring near the middle of September. Similar breeding seasons in other states have been noted by Hamilton (1940), Evans et al. (1965), and Wight and Conaway (1961). Since the gestation period of the cottontail is approximately 28 days and copulation is postpartum, a single female could have as many as seven litters during a breeding season with an average of four to seven individuals per litter (Lord, 1963). Individual cottontails in a given area have a marked synchrony in conception dates of their first pregnancy (Schwartz, 1942; Conaway and Wight, 1962) and this synchrony of conception remains until near the end of the breeding season. The breeding season of Illinois cottontails begins and ends a week earlier in the southern part of the state than in central and northern Illinois (Lord, 1963).

Lord (1961a) found that the percentage of female cottontails pregnant was highest in March, with the percentage in April and May also very high. Litter sizes are largest in May (Dalke, 1937; Schwartz, 1942; Barkalow, 1962; Lord, 1961a). In cottontails sampled mainly from central Illinois and some from southern Illinois in 1957 through 1959, most of the year's production of cottontails occurred in the 4-month period from March through June (Lord, 1961a). Beule and Studholme (1942) found that May was the most important month for nesting in Pennsylvania during 1939 and 1940, although April, June, and July were also important. In Missouri from 1958 through 1960, Wight and Conaway (1962) found almost all adult females collected were pregnant from April through June. Conaway et al. (1963) reported almost 98% pregnancy in female cottontails from the middle of March to the middle of August.

Lord (1961a) reported a 5-fold increase in the number of rabbits during the March to July segment of the breeding season with the peak abundance of cottontails occurring in east-central Illinois during May and June. Rose (1972) found an August peak in the annual cycle of the cottontail in east-central Illinois. Lord (1961b) found that rabbits born later in the breeding season had a better chance to live to be 12 months of age than cottontails born in the early part of the season. July was found to be the peak month of birth of rabbits killed during the hunting season and three-fourths of the hunters' kill was born in May, June, July, and August (Lord ,1961b).

Cottontails often nest in a variety of cover, but Beule and Studholme (.1942) found a greater number of nests in fallow fields and hayfields. Pasture had a high density of nests. Cottontails are born blind, helpless, and almost naked state, but they have a rapid growth rate (Dell, 1951). The eyes, of young cottontails open in about 7 days. Juveniles leave the nest at ahout 14 days of age, and reach adult size in approximately 22 weeks.

Cottontails born in April and May frequently breed their first summer at about 90 days of age (Casteel and Edwards, 19.64). Wainwright (.1969) stated in has literature review of cottontail reproduction that pregnant juvenile females have been collected during the period from June 25 to October 2 and than an estimated 12-23% of the yearly cottontail production may be provided by juvenile breeding. Casteel and Edwards (1964) in Illinois, Schierbaum (1965) in New York, and Evans et al. (1965) in Missouri reported juvenile females that had two litters. In these cases, most of the conception dates for first litters for the juvenile rabbits were near the end of June and the conception dates for second litters occurred in July. Negus (1959) concluded that the success of the early-season adult breeding determined the amount of juvenile breeding during the same year.

Cottontail abundance decreases rapidly in fall and winter. Lord (1961b) stated that two-thirds of the midsummer's Illinois rabbit population died by the beginning of the hunting season with a rapid decline in numbers beginning in September. Beule (1946) reported that in Pennsylvania during 1939, only 20 juvenile cottontails remained on November 1 from a summer juvenile population of 65. Kline and Hendrickson (1954) reported that an estimated population of 284 Mearns cottontails on September 1 in Iowa was reduced to 41 by January 1. Rose (1972) in Illinois found that a large proportion of the annual mortality of an unhunted cottontail population occurred during the fall, primarily in November. Perhaps disease may be a factor, but most authors attribute the fall decrease to predation. The fall period of peak mortality of cottontails coincides with peak numbers and activity of predators and the loss of cover as a result of crop harvest and the end of the growing season. Dalke and Sime (1938), however, noted that predation could not account for the disappearance of much of the juvenile rabbit population in Connecticut.

Hunting success in the fall is directly related to the size of the population of rabbits (Andersen, 1952; Kriz, 1971). A large fall population usually means good hunter success, given normal cover and weather conditions during the hunting season.

Effect of Monthly Weather Parameters on Cottontail Populations

The effects of weather on wild animals are exceedingly difficult to evaluate. Animals are faced with the coordinated interaction of a great variety of weather parameters—not all of which are measured or are measurable. The factors measured and investigated are considered largely on an individual basis. Frequently, too few years of population data in relation to the number of possible weather factors are available for analyses. Often, because of these limitations, the true picture of weather:animal relationships are not revealed. Both weather conditions and cottontail populations are variables. They do not remain constant from year to year. Cottontail populations apparently undergo cyclic fluctuations (Bailey, 19.68). Variations in weather conditions and cottontail populations: add difficulty not only in identifying clear-cut weather:animal relationships, but in identifying the effects of weather modification on animal populations as well.

The three indices of cottontail abundance used for weather analysis were the March and July censuses and the mean number of cottontails killed per hunter trip. Data on cottontail abundance and harvest from 1955 through 1969 were published in Preno and Labisky (1971); data for 1970 and 1971 were obtained from Preno (Personal Communication). The rabbit data used in the study are given in Table 3, and Figs. 4, 5, and 6 display these data for the March census, the July census, and the number of cottontails killed per hunter trip, respectively.

There has been only a slight decrease in the number of cottontails censused during March and July from 1955 through 1970. However, the cottontail harvest in Illinois has declined severely during the same period In 1956, almost 6.5 million cottontails were harvested, but in 1970 only a little over 2 million were bagged by hunters. These figures represent a decrease of approximately 68% for the 15-year period. Preno and Labisky (1971) found that both the total number of hunter trips per season for cottontails and the mean number of cottontails bagged per hunter trip decreased. The total number of hunter trips per season for cottontails was 2.7 million in 1956 but declined to 1.6 million in 1970. The number of cottontail hunters also declined, and Preno and Labisky (1971) attribute the decline to a waning interest in rabbit hunting undoubtedly due to the decrease in cottontail abundance.

With the exception of Region 4, cottontail indices within the same region are usually not significantly correlated (Table 4). A high number of rabbits in March apparently did not mean that there would be a high population in July or a large kill during the hunting season. Dell (1958) and Rose (1972) found that a low spring broodstock did not mean a low fall population because other factors such as a higher production or survival of the young often compensated for the deficit of spring breeders. There was, however, a significant relationship ($P \leq 0.05$, 13df) between the population in July and the rabbit harvest in Regions 2 and 4 and the entire state.

There is a significant correlation ($P \leq 0.05$, 13df) of cottontail harvests between game regions (Table 5). The March censuses were significantly correlated between most regions ($P \leq 0.05$, 14df) but the July censuses appear almost completely unrelated.

Table 3. The mean number of cottontails sighted per 20-mile route during the March and July census periods (1955-70) and the mean number of cottontails killed per individual hunter trip (1356-70) in Illinois Game Regions 2, 3, 4, 4a and the entire state.[a]

Year	March Census					July Census					Cottontails per Trip				
	2	3	4	4a	Entire State[b]	2	3	4	4a	Entire State[b]	2	3	4	4a	Entire State
1955	10	3	7	7	3.85	6	0	10	6	9.34					
1956	6	4	4	5	5.12	17	12	3	4	11.36	2.4	2.4	1.9	2.0	2.35
1 957	13	4	8	4	7.10	35	10	7	5	16.06	2.J	2.4	1.8	2.1	2.28
1958	17	9	8	11	12.64	18	13	10	8	11.52	2.8	2.3	1.8	2.6	2.38
1959	16	8	7	16	10.43	26	10	3	3	14.22	2.7	2.6	1.8	1.8	2.19
1960	29	9	10	13	13.56	17	19	7	6	11.82	2.2	2.2	1.6	2.1	1.73
1961	14	8	3	10	3.23	15	13	6	3	10.51	2.3	2.4	1.5	1.8	1.91
1962	8	3	6	3	6.64	13	15	5	6	8.28	2.2	2.6	1.4	1.3	1.76
1963	7	13	6	6	6.24	17	11	7	6	9.82	2.4	2.3	1.4	1.6	1.89
1964	9	8	7	11	7.22	14	11	5	6	9.07	1.8	2.1	1.3	1.6	1.53
1965	8	5	4	5	5.37	14	4	3	6	8.01	1.8	1.6	1.0	0.3	1.38
1966	3	3	5	4	5.47	13	13	3	5	3.97	1.9	1.8	1.3	1.4	1.57
1967	11	6	5	7	6.40	20	18	4	6	10.51	1.9	1.9	0.7	1.4	1.33
1363	12	5	2	2	5.51	17	15	5	4	9.77	2.2	2.4	1.0	1.4	1.69
1969	10	4	3	1	4.86	18	14	4	4	9.83	1.9	2.4	0.9	1 .5	1.53
1970	10	3	3	1	4.61	14	7	4	2	7.31	1.5	1.9	0.9	1.3	1.24
Average	11.8	6.3	5.8	6.3	7.39	17.1	12.3	6.1	9.0	10.40	2.23	2.26	1.35	1.69	1.79

[a]Data taken from Preno and Labisky, 1971.

[b]The value given is the sum of the products of the percentages of the state contained within each game region multiplied by the mean number of rabbits observed per route in each region.

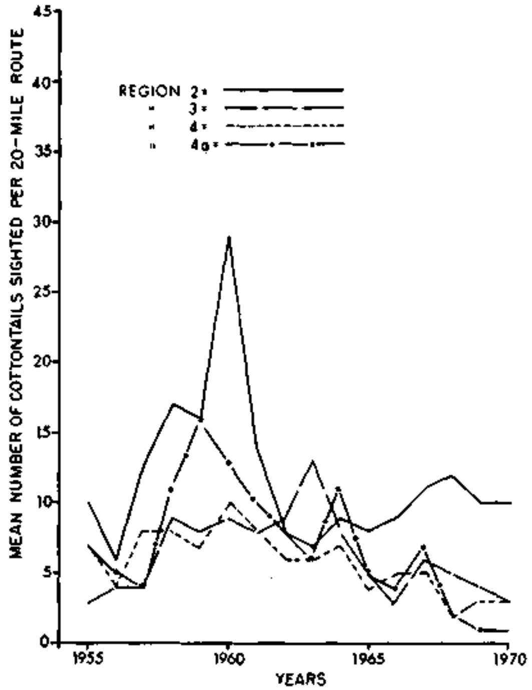


Figure 4. The mean number of cottontails sighted per 20-mile route during March in Illinois Game Regions 2,3,4, and 4a; 1955-70 [Data—Preno and Labisky 1971]

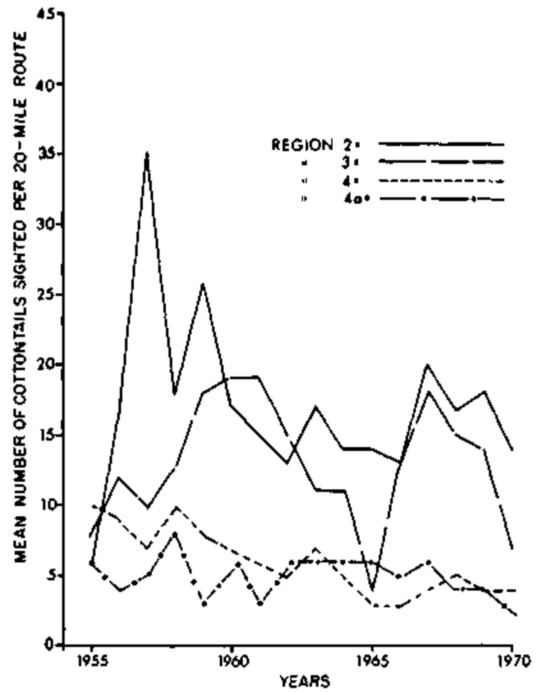


Figure 5. The mean number of cottontails sighted per 20-mile route during July in Illinois Game Regions 2,3,4, and 4a; 1955-70 [Data—Preno and Labisky 1971]

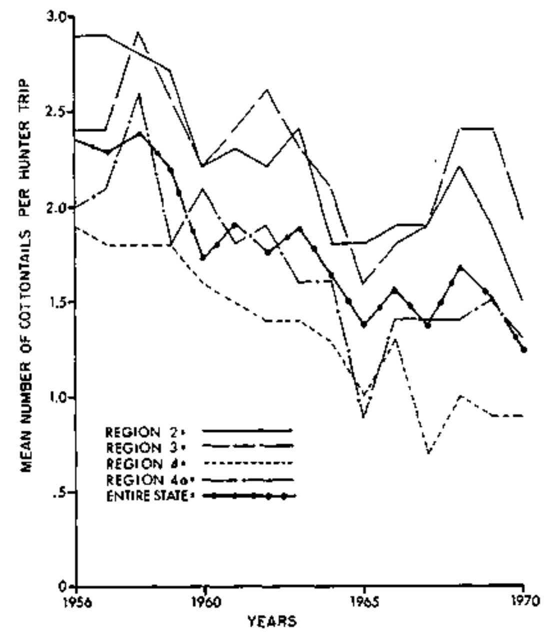


Figure 6. The mean number of cottontails killed per hunter trip in Illinois Game Regions 2,3,4,4a and the entire state; 1956-70 [Data—Preno and Labisky, 1971]

Table 4. Correlation coefficients of cottontail indices within Illinois Game Regions 2, 3, 4, 4a, and the entire state.

Game Region	March and July Censuses (1955-70)	March Census and Rabbits per Trip (1956-70)	July Census and Rabbits per Trip (1956-70)
2	+0.24	+0.13	+0.61*
3	+0.39	+0.42	+0.44
4	+0.52*	+0.64**	+0.84**
4a	+0.27	+0.49	+0.33
Entire State	+0.45	+0.46	+0.73**

* $\underline{P} \leq 0.05$.

** $\underline{P} \leq 0.01$.

Table 5. Correlation coefficients of cottontail indices between Illinois Game Regions 2, 3, 4, 4a, and the entire state.

Game Regions	March Census (1955-70)	July Census (1955-70)	Rabbits per Trip (1956-70)
2 and 3	+0.27	+0.22	+0.73**
2 and 4	+0.64**	+0.10	+0.36**
2 and 4a	+0.56*	-0.14	+0.76**
2 and Entire State	+0.84**	+0.87**	+0.38**
3 and 4	+0.49	+0.09	+0.62*
3 and 4a	+0.60*	-0.11	+0.31**
3 and Entire State	+0.46	+0.35	+0.77**
4 and 4a	+0.77**	+0.24	+0.80**
4 and Entire State	+0.83**	+0.50*	+0.91**
4a and Entire State	+0.31**	-0.05	+0.82**

* $\underline{P} \leq 0.05$.

** $\underline{P} \leq 0.01$.

The four game regions were analyzed for relationships between monthly-weather parameters and rabbit census and harvest data. Nine weather parameters (Table 1) from each month of a 14-month interval were compared with March and July census data from 1955 through 1970 and with harvest data from 1956 through 1970. For the censuses, 13 months of the interval preceded the census month, and the 14th month was the month of the census. For the harvest data, 11 months of the interval preceded the hunting season and the remaining 3 months were the months of the hunting season. The hunting season usually began in the second half of November and extended through December and January.

In each region a stepwise multiple regression analysis was performed on each set of individual months. (All the Januarys from 1956-70 were analyzed with the number of rabbits killed per hunter trip from 1956-70). The weather parameter that was associated with the most variance in the cottontail indices was selected from each set of months. These weather parameters were then compared within each region and among the four game regions to determine if common parameters had been selected. It was hoped that the analysis would reveal those weather parameters consistently associated with fluctuations in the abundance of rabbits in all the regions. It is recognized that in a given year, one parameter may be more important than another and that cottontails may be more susceptible to the same weather parameter during different times of the year.

The environment affects an organism in a complex fashion. The weather parameters selected by the regression programs may be only a few of several that affected the cottontail populations during the study interval. Perhaps it is not the weather parameters themselves that are important, but other factors with which the selected parameters are correlated or interact. The observed correlations of weather parameters with rabbit abundance does not imply a cause and effect relationship, but only that the selected parameters are the ones examined that are most closely associated with fluctuations in rabbit numbers.

The weather parameters from the same month that account for most of the variance in at least two of the three cottontail indices within a game region are given in Table 6. Most of the weather parameters selected for each region are different. The only one that occurs in two regions is the number of days with precipitation $\geq$0.10 inch in October in Regions 2 and 4a.

Weather variables from the same month of the 14-month intervals that account for the most variance in a specific rabbit index and occur in at least two game regions are given in Table 7. This method of examination may remove some of the extraneous weather parameters that are uniquely related to cottontail indices within a given region. It appears that total snowfall may have an adverse effect on rabbit populations. Total snowfall in February was negatively correlated with the rabbit harvest the following fall in Regions 2, 3, and 4a. Also, the number of rabbits counted in July was negatively correlated with December snowfall in Regions 2, 3, and 4a and March snowfall in Regions 2 and 4. Another

Table 6. Correlation Coefficients of Weather Parameters from the Same Month that Account for the Most variance in Both the Cottontail Haryest and Census Data within Game Regions. 2, 3, 4, and 4a

Game Region, Month, and Monthly Weather Variables	Correlation Coefficient		
	March Census[a] (1955-70)	July Census[b] (1955-70)	Cottontails[c] per Trip (1956-70)
GAME REGION 2			
January			
% of possible sunshine		-0.33	-0.35, -0.36d
February			
Total snowfall	-0.30d		-0.48
May			
No. days with precipitation ≥1.0 inch		+0.62e	+0.64e
July			
% of possible sunshine	-0.29	-0.59[d,e]	-0.47
October			
No. days with precipitation ≥0.10 inch		-0.47	-0.37
December			
Total snowfall		-0.28	-0.48
GAME REGION 3			
January			
No. days with precipitation ≥ 1.0 inch	-0.38	-0.38	
June			
No. days with precipitation ≥0.10 inch	-0.22		-0.26
November			
No. days with precipitation ≥ 0.10 inch	+0.18	+0.36	

Table 6, continued.

Game Region, Month, and Monthly Weather Variables	Correlation Coefficient: March Census[a] (1955-70)	July Census[b] (1955-70)	Cottontails[c] per Trip (1956-70)
GAME REGION 4			
January			
Minimum temperature	+0.24		+0.21
Total precipitation		-0.28	-0.30[d]
March			
% of possible sunshine	-0.21, -0.44		-0.14
April			
Minimum temperature	-0.21		-0.38
June			
% of possible sunshine	+0.35		+0.29
July			
No. days with precipitation ≥1.0 inch	+0.22	+0.43[d]	
Total precipitation		+0.41	+0.33
August			
Minimum temperature	+0.54[e]	+0.47	
September			
No. days with precipitation ≥ 0.10 inch		-0.61[e]	-0.47
December			
No. days with precipitation £1.0 inch	-0.26	-0.43	-0.44[d], -0.33
GAME REGION 4a			
March			
No. days with precipitation £1.0 inch	+0.38	+0.41	
% of possible sunshine		-0.56[d,e]	-0.25
June			
No days with precipitation £1.0 inch	+0.43	+0.44	+0.57[e]
October			
No. days with precipitation ≥ 0.10 inch	-0.21	-0.22	

Table 6, continued,

[a]Cottontail variable was compared with the 13 individual months (February-February) preceding the census and with the month of census.

[b]Cottontail variable was compared with the 13 individual months (June-June) preceding the census and with the month of the census.

[c]Cottontail variable was compared with the 11 individual months (December-October) preceding the hunting season and the 3 months (November-January) during the hunting season.

[d]Correlation is with the cottontail variable 1 year later.

[e]$P \leq 0.05$.

Table 7. Monthly Weather Variables that Account for the Most Variance in the Same Cottontail Index in Two or More Game Regions

Index, Month, and Monthly Weather Variables	Game Region			
	2	3	4	4a
MARCH CENSUS, 1955-70[a]				
March				
% of possible sunshine[b]		-0.56£	-0.21	-0.56£
June				
No. days with precipitation ≥0.10 inch	-0.16	-0.22		
July				
No. days with precipitation ≥1.0 inch			+0.22	+0.34
August				
Minimum temperature	+0.54c			+0.35
January				
Minimum temperature	+0.47		+0.24	
JULY CENSUS, 1955-70d				
September				
No. days with precipitation ≥0.10 inch		-0.6lc		-0.43
October				
No. days with precipitation £0.10 inch	-0.47			-0.22

Table 7, continued.

Index, Month, and Monthly Weather Variables	Game Region			
	2	3	4	4a
December				
Total snowfall	-0.28	-0.36		-0.43
March				
Total snowfall	-0.19		-0.23	
July				
Total precipitation			+0.40	+0.31
COTTONTAILS PER HUNTER TRIP, 1956-70[e]	Correlation Coefficients			
February				
Total snowfall	-0.48	-0.29		-0.22
March				
% of possible sunshine			-0.14	-0.25
April				
Minimum temperature			-0.38	-0.21
July				
% of possible sunshine	-0.47	-0.56[c]		
September				
No. days with precipitation ≥0.10 inch	-0.45		-0.47	
October				
No. days with precipitation ≥0.10 inch	-0.37		-0.47	
January				
% of possible sunshine	-0.35	-0.47		-0.22

[a]Cottontail variable was compared with the 13 individual months (February-February) preceding the census and with the month of census.

[b]Correlation is with the cottontail variable 1 year later.

[c]$P \leq 0.05$.

[d]Cottontail variable was compared with the 13 individual months (June-June) preceding the census and with the month of the census.

[e]Cottontail variable was compared with the 11 individual months (December-October) preceding the hunting season and the 3 months (November-January) during the hunting season.

trend that appears, in the harvest data and in the July census data is, the adverse effect of the number of rainy days in September and October. Other monthly parameters in Table 7 that have appeared previously are the negative effect of the percentage of possible sunshine in March on the harvest and on the March census data and the positive effect of precipitation in July on the March and July census data.

The selected monthly weather factors Cone from each month) from the 14—month intervals were ranked according to the amount of variance they accounted for in each rabbit index by a stepwise multiple regression program. Examination of the top five weather parameters were made for the March census, the July census, and the rabbits killed per hunter trip within each game region; for the same cottontail index in different regions; and for cottontail indices in general in the different regions. This cross analysis revealed monthly weather factors from Tables 6 and 7 that were consistent in the reduction of variance in the rabbit parameters.

Examination of the top five weather parameters for the rabbit indices within each game region disclosed that the weather factors from Table 6 that were the most important parameters in Region 2 were the percentage of possible sunshine in January and July and the number of days with precipitation ≥1.0 inch in May. In Region 4, the major parameters were March sunshine, the number of days with precipitation 51.0 inch in July, August minimum temperature, and the number of days with precipitation ≥0.10 inch in September. However, in Regions 3 and 4a there were no weather parameters in common among the first five variables for each index.

Ranking the best monthly weather variables also revealed the parameters from Table 7 that accounted for the most variance in the harvest and census data for all four game regions. For the harvest data, these were the percentage of possible sunshine , and the number of days with precipitation ≥0.10 inch in September. The number of days with precipitation ≥0.10 inch in June, the number of days with precipitation ≥1.0 inch in July, and August minimum temperature were the most important variables for the March censuses , whereas the July censuses for all the regions did not have a weather variable that consistently accounted for a large amount of variance.

The weather factors among the best five weather parameters for each rabbit index that were important in more than one region without regard to a specific rabbit index are given in Table 8. It was anticipated that this procedure would provide a general picture of the weather factors that influenced the cottontail populations during the study period. The parameters that occur in Table 8 and have also appeared in other analyses are the negative effects of the number of days with precipitation ≥1.0 inch in January, the percentage of possible sunshine in March and July, total precipitation in April, and the number of days with precipitation ≥0.10 inch in September. Favorable factors were precipitation in July and minimum temperature in August.

Table 8 . Correlation coefficients of weather parameters occurring in two or more game regions among the five monthly weather variables that account for the most variance in the cottontail indices.

Month and Weather Variables	March Census[a]				July Census[b]				Rabbits per Trip[c]			
	Game Region				Game Region				Game Region			
	2	3	4	4a	2	3	4	4a	2	3	4	4a
January												
Number of days with precipitation ≥1.0 inch						-0.38						-0.44
March												
Percent of possible sunshine			-0.44	-0.56[d,e]							-0.14	
April												
Total precipitation							-0.40			-0.58[d]		
May												
Number of days with precipitation ≥0.10 inch	+0.50[d]											+0.50
July												
Number of days with precipitation ≥0.10 inch						+0.47						+0.56[d]
Number of days with precipitation ≥ 1.0 inch			+0.22	+0.34			+0.43[e]					
Percent of possible sunshine	-0.29				-0.59[d,e]				-0.47	-0.56[d]		
August												
Minimum temperature			+0.54[d]	+0.35			+0.47					
September												
Number of days with precipitation ≥0.10 inch							-0.61[d]		-0.45		-0.47	

[a] Cottontail variable was compared with the 13 individual months (February-February) preceding the census and with the month of census.

[b] Cottontail variable was compared with the 13 individual months (June-June) preceding the census and with the month of the census.

[c] Cottontail variable was compared with the 11 individual months (December-October) preceding the hunting season and the 3 months (November-January) during the hunting season.

[d] $P \leq 0.05$.

Correlation is with the cottontail variable 1 year later.

In general terms, the monthly weather parameters and their effects on the cottontail indices for the four game regions are giyen in Table 9. These are the weather variables that were usually stable in correlation signs and were frequent in occurrence in variance analyses for the rabbit indices within each game region, for the same rabbit index in different game regions, and for all rabbit indices in different game regions (Tables 6, 7, and 81. Snowfall during the winter months was adversely related to the censuses and harvest. There were indications that precipitation parameters in January were detrimental to the cottontail indices, whereas warm temperatures in January showed some favorable relationships to the rabbit data. Sunshine in March and warm temperatures in April appeared to be unfavorable to the cottontail indices. The unfavorable effect of temperature in April may result because in approximately 10 of 15 years of the study interval for all the regions, April temperatures were above normal. Total precipitation in April was generally negatively correlated with the rabbit indices.

Table 9. General Monthly Weather Parameters that were Consistent in Variance and Correlation Analyses of Illinois Cottontail Census (1955-70) and Harvest (1956-70) Data

Weather Parameters	Effect
Total snowfall in December, February, and March	Strongly unfavorable
Precipitation parameters in January	Somewhat unfavorable
Warm temperature in January	Somewhat favorable
Sunshine in March	Unfavorable
Total precipitation in April	Unfavorable
Warm temperature in April	Unfavorable
Precipitation parameters in July	Strongly favorable
Sunshine in July	Strongly unfavorable
Minimum temperature in August	Favorable
No. days with precipitation in September	Strongly unfavorable
No. days with precipitation in October	Unfavorable

In July, precipitation parameters were strongly favorahle and the percentage of possible sunshine was strongly unfavorable to cottontail indices. Sunshine and precipitation parameters in July, however, were generally negatively correlated ($P \leq 0.05$) in all regions. Minimum temperature in August was favorably related to cottontail populations. However, in an average of 12 of. the 15 years of the study Interval, temperatures in August were below normal for all game regions. The number of days with precipitation ≥0.10 inch during the fall months of September and October was strongly unfavorable.

Based on the analyses of monthly weather variables, the parameters that seem to have had the most influence on cottontail populations in Illinois from 1955 through. 1970 were 1) unfavorable—total snowfall during the winter months of December, February, and March; total precipitation in April; and the number of days of precipitation ≥0.10 inch during the fall months of September and October—and, 2) favorable—total precipitation and days with precipitation Cor reduced sunshine) in July.

Effect of Monthly and Critical Period Weather Factors on Cottontail Harvest

Since hunting results are more meaningful to sportsmen than census data, the cottontail harvests in the four game regions were investigated to determine if the above mentioned weather:cottontail relationships were also associated with harvest. The harvest data were significantly correlated among the different regions (Table 5), and this relationship may have allowed the general weather effects on cottontails to be apparent. In addition to examining weather from individual months, the same weather parameters (Table 1) were examined over 12 different time intervals (Table 10) that were considered to be critical periods in the life cycle of the cottontail. Weather over a period of months may affect cottontails more than weather during a single month, primarily because of the long breeding season of the cottontail, which extends from about the beginning of March through September.

Table 10. Critical Periods of the Cottontail's Life Cycle

Number	Time Interval
1	December - March
2	January - July
3	March - May
4	March - June
5	March - September
6	April - July
7	May - August
8	June - September
9	July - August
10	July - January
11	September - November
12	November - January

The weather parameters for individual months and for interyals of months that had the same linear correlation coefficient sign with the number of cottontails killed per hunter trip in all of the four game regions from 1956 through 1970 are given in Fig. 7. The weather parameters are not significantly correlated (P≥0.05) with the other weather parameters of the same month or of the same interyal of months. The correlation coefficients listed are the averages of the four independent correlation coefficients from the different game regions. If two or more significantly related weather parameters occurred during the same time interval, the one with the highest average correlation coefficient was chosen. The purpose of such a diagram was to see which weather parameters similarly affected the cottontail harvest in all of the game regions and during what time of the year the weather parameters had their effect. Weather parameters should have a similar effect on cottontails in all of the game regions since the cottontail evolved under the climate prevailing in Illinois. However, major abnormal weather differences that occurred in one region and not another would have a differential effect on the populations, but no isolated weather phenomena were noted in the weather

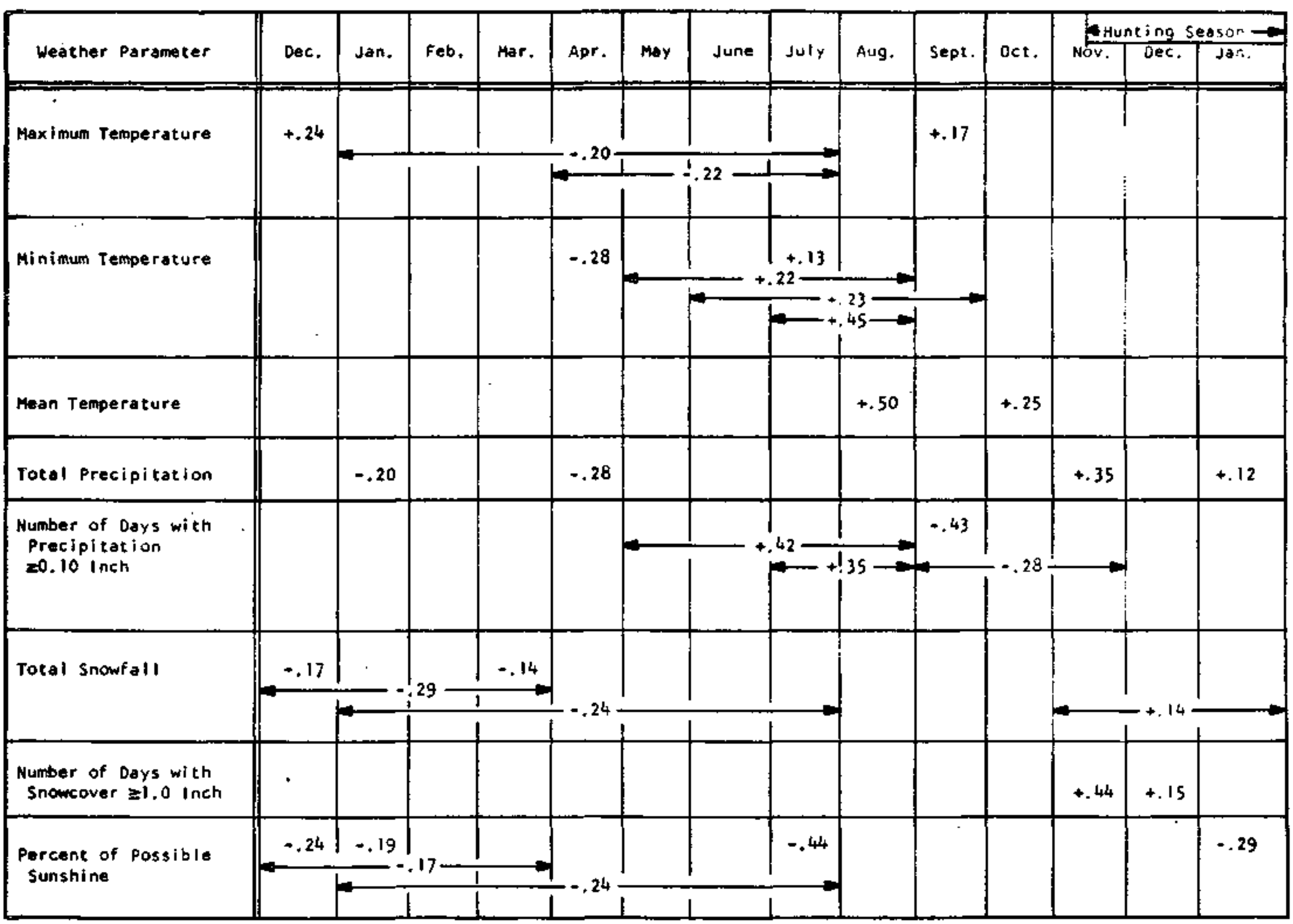


Figure 7 . Weather parameters having the same linear correlation coefficient sign with the mean number of cottontail? killed **per** hunter trip in Illinois Game Regions 2, 3, 4, and 4*a*, 1956-70. The correlation coefficient is the average of the four independent correlation coefficients from each Game Region. The weather parameters are not significantly correlated (P>0.05) with other weather parameters of the same month or the same interval of months.

data for the different regions. The magnitude of the correlation signs in Fig. 7 indicates that these weather parameters generally did not have a great influence on cottontail populations in the game regions considered.

Temperature. In general, temperature was negatively correlated with the cottontail harvest during the first half of the year when there was a steady increase in the temperature over the game regions (Fig. 2). During summer and fall, temperature was positively related to the rabbit harvest.

Maximum temperature for January through July was negatively correlated with the cottontail kill in all of the regions. It is commonly believed that warm temperatures in winter are beneficial to cottontails. Hill (1972) attributes an earlier general commencement of the cottontail breeding season in Alabama to warmer than normal temperatures. However, Edwards (1964a) found generally higher spring densities of cottontails following winters of higher precipitation or lower temperature, or both. Andersen (1952) found that mild mean monthly temperatures in February, March, April, and May were favorable to hare populations in Denmark.

Warm temperature may affect cottontail behavior and, therefore, their survival. Allen (1939) and Linduska (1917) both noted that cottontails use dens and burrows during periods of low temperatures in winter. If temperatures are above normal in winter, cottontails may seldom use burrows and thus may become subject to greater predation and hunting pressure. Bailey (1969) noted that from September to March, trap success of cottontails tended to be greater during cooler days than during warmer days.

Maximum temperature for April through July was negatively correlated with the cottontail kill in all the regions. Sittman et al. (1964) showed that in caged domestic New Zealand rabbits, the conception rate and the percentage mortality at birth varied inversely with maximum temperature. Edwards (1964a) found that fall populations tended to be higher in years following above normal precipitation or below normal temperature in late spring, or both. High maximum temperatures in late spring and early summer may be detrimental to immature cottontails (Hickie, 1940; Beule, 1946). High maximum temperatures may be detrimental to vegetative growth or to the nutritional content of the vegetation. Succulent vegetation is not only an important food source, but its nutrition is necessary for juvenile and adult reproduction (Hill, 1972).

Minimum temperature was positively correlated with the rabbit harvest during the late spring, summer, and early fall months. Warm nights may have favored immature survival or vegetative growth. Mean monthly temperature in August and October was favorably related to the cottontail kill. The majority of the Augusts were below normal during the study interval and these below normal temperatures may explain the positive relation with August temperature. Kline and Hendrickson (1954) noted that early killing frosts in October greatly reduced green vegetation and, therefore, enhanced predation on cottontails. A warm October would favor vegetative growth and provide food and protection for cottontails while row crops are being harvested.

In general, temperature seems to he negatively correlated with rabhit harvest when the temperature curyes. are increasing (Jig. 1) and positively-related when the curyes are stahle (during the summer months.) and when they are decreasing Cduring the fall). Perhaps cottontails are acclimated to colder temperatures in the winter and spring months and high temperatures at these times may present them with a greater period of adjustment. In the fall, cottontails may be acclimated to warm temperatures from the summer months, so warm fall temperatures may present less of an environmental change for cottontails and, thus, be favorable. The same may hold true for the positive relationships with minimum temperatures in the summer. Page (1949) stated that the difference between the average maximum temperature and the average minimum temperature is greater in summer than in winter in Illinois. Perhaps less difference between daytime maximum temperature and nighttime minimum temperature presents less variation or environmental stress to which cottontails, especially the young, have to adjust.

Precipitation. There were few correlations with precipitation parameters and the rabbit harvest in the game regions. The most important precipitation parameter appeared to be the number of days with precipitation ≥0.10 inch. Total precipitation was related to the rabbit harvest in four different months, but two of these occurred during the hunting season. There were no similar correlations with the number of days with precipitation ≥1.0 inch in all four game regions.

Total precipitation in January and April was negatively correlated with cottontail abundance. Precipitation in January, which includes snowfall, may interact with cold temperatures to present an unfavorable combination of weather conditions to the cottontail. High total precipitation in April may be unfavorable to survival of nestlings (Hickie, 1940; Beule and Studholme, 1942; Atzenhoefer, 1953; Linder and Hendrickson, 1956; Redd, 1956; Carson and Cantner, 1963) or may interact with cool temperatures to adversely affect the survival of the young. Total precipitation increased sharply in the game regions in April (Fig. 2).

Total precipitation during the hunting season in November and January undoubtedly exerts its effects through the favorable influence of snow and snowcover on the cottontail harvest. A wet November may also delay fall plowing, thereby providing more cover and enhancing rabbit survival into the hunting season months of December and January.

The number of days with precipitation ≥0.10 inch was positively correlated with the cottontail harvest for the periods of May through August and July through August. The same weather parameter for September and for September through November was negatively correlated with the haryest.

Rainy days during the late spring and summer months are important to rabbits. Leopold and Anderson (.1938) noted that numerous young were seen in the spring of 1936 in Wisconsin, but not after the intense heat and drought of midsummer. Carson and Cantner C1963) stated that from 1951 to 1956 in West Virginia, 1956 not only had more precipitation from April through August, but also had the greatest autumn population of cottontails. Rainy days have a favorable effect on vegetation that provides cottontails with both food and protection from predators and environmental factors. Hill (1972) stated that green succulent vegetation appears; to be a limiting factor during the cottontail breeding season. Myers and Poole (.1961) found that the European rabbit (Oryctolagus cunniculus) in Australia can enter a non-reproductive state during periods of drought and its resulting effect on vegetation. Ingles (.1941) stated that the year-round supply of green vegetation in the irrigated valleys of California may explain the year-round breeding of the Audubon cottontail (Sylvilagus audubonii). In other areas of California, Fitch (1947) found that the breeding season of the Audubon cottontail was restricted to the growing season when green vegetation is plentiful. The dry season and the infertility period in the brushrabbit (Sylvilagus bachmani) coincide in west-central California (Mossman, 1955). Sheffer (1957) found that drought caused an early termination of cottontail reproduction in Maryland, possibly because of the drought's effect on the vegetation. Trethewey and Verts (1971) found that drought may have been responsible for an early cessation of breeding in Oregon cottontails during 1967. Hill (1965) attributed the lack of adequate rainfall and the corresponding wilted conditions of vegetation for the decreases in pregnancy rates in Alabama cottontails during May of 1963, May and June of 1964, and May of 1965. Pelton (1969) stated that hot or dry summer weather, or both, and their resulting effects on vegetation might determine the success of juvenile breeding in cottontails. Hill (1972) suggested that lack of adequate, well-distributed rainfall and the subsequent reduction of the quality of vegetation may not only curtail adult cottontail reproduction, but may also slow the growth and development of juveniles and prevent their breeding. Juvenile breeding is important because it may contribute an estimated 12-23% to cottontail populations (Wainwright, 1969). Lactating females also need nutritional food sources to sufficiently feed nestlings.

The above reasons may explain the positive correlations of the rabbit indices in all the game regions with the number of days with precipitation >0.10 inch for May through August and July through August. Rainy days may be important during these months since Lord (1961) found that three-fourths of the cottontails harvested were born in the months May through August. However, Hill (1972) stated that the effects of drought on vegetation, and, therefore, on cottontail reproduction, may be diminished in the mid-western states because of the lower rates of soil moisture evaporation due to the greater water holding capacity of the soil and milder surface temperatures.

Rain days in the fall, and primarily September, had an adverse effect on the cottontail harvest. Dampness combined with decreasing temperatures during this time of year may adversely affect rabbit survival. Cottontail populations decline sharply in the fall (Dalke and Sime, 1938; Beule, 1946; Kline and Hendrickson, 1954; Lord, 1961; Rose, 1972). A rainy fall would hinder crop harvesting and fall plowing. Additional cover for cottontails may make them less concentrated and harder for rabbit hunters to find, thus accounting for a lower kill. However, more cover should allow for better winter surviyal for the cottontails and proyide a larger breeding stock for the spring. Rut rainy days in September and October are negatively correlated with the March census in Regions. 3, 4, and 4a and are negatively correlated with the July census in Regions 2, 4, and 4a. Perhaps the main effect of the frequency of days with light precipitation in the fall, therefore, is a biological one on the cottontails themselves (for example, susceptibility to disease).

Snowfall. Total snowfall during the winter and spring months preceding the hunting season is negatively correlated to the rabbit harvest. This relationship may be due to several reasons. Snow may force rabbits to switch from a preferred herbaceous diet to a less nutritious woody diet (Beule, 1946; Dusi, 1952; Sweetman, 1949). A direct result of this switch may be a decrease in body weight (Allen, 1939; Haugen, 1942) and perhaps a corresponding physiological stress on the breeding stock. Snow during February and March may delay the onset of the breeding season (Wight and Conaway, 1961; Trethewey and Verts, 1971) may cause litter reabsorption (Kline, 1942), and may increase natural predation and mortality (Besadny, 1963).

Total snowfall and the number of days with snowcover ≥1.0 inch during the hunting season were favorably correlated with hunter success. In 1949-50 in Missouri, lack of snow during the hunting season resulted in a kill of a million fewer rabbits (Wight, 1959).

Sunshine. The percentage of possible sunshine throughout the first half of the year was negatively correlated with the cottontail harvest. This negative relationship is somewhat difficult to understand unless sunshine interacted with other parameters that were not considered in the investigation. It is possible that ultraviolet light associated with more sunshine may be detrimental to the physiology of the cottontail. However, Shelford (1951) concluded that rabbit populations are favorably related to February ultraviolet light through its influence as a reproductive stimulus. Meslow and Keith (1971) found that brighter days and warmer temperatures were favorable to survival of the first litter of snowshoe hares. Lord (1961a) suggested a relationship between the hours of sunshine in March, April, May, and June and the prevalence of pregnancy in cottontails. Perhaps sunny days favor the spread of disease or parasites or they may affect rabbit behavior in such a manner as to make them more vulnerable to predation. Ingles (1941) in his observations of the Audubon cottontail found that they preferred clear nights and days , and they were less active during windy rainy weather. Bailey (1969) concluded that rabbits become more trappable during weather conditions that prevail near the centers of high barometric pressure and such generally associated factors as clear skies , calm winds , and cool temperatures. Sunshine in July may exert its effect through ultraviolet light, through its high positive corelation with maximum temperature, through its high negative correlation with total precipitation, or through both of the latter factors. As previously discussed, succulent vegetation appears to be important to cottontail reproduction, and sunshine in July may be detrimental because of its drying effect on yegetation. Direct sunshine may he disagreeable to cottontails since during warm weather they avoid sunlit forms (Beule, 19461. The. negative correlation of sunshine in January during the hunting season is: likely due to its inverse relationship with snowfall and snow-cover, which increase hunter succes.s.

Table 11. Change in the Number of Cottontails Killed Per Hunter Trip from the Preceding Year for Illinois Game Regions 2, 3, 4, and 4a, 1957-70.

Year	Game Region			
	2	3	4	4a
1957	—	—	0.1-	0.1+
1958	0.1-	0.5+	—	0.5+
1959	0.1-	0.3-	--	0.8-
1960	0.5-	0.4-	0.2-	0.3+
1961	0.1+	0.2+	0.1-	0.3-
1962	0.1-	0.2+	0.1-	0.1+
1963	0.2+	0.3-	--	0.3-
1964	0.6-	0.2-	0.1-	--
1965	—	0.5-	0.3-	0.7-
1966	0.1+	0.2+	0.3+	0.5+
1967	—	0.1+	0.6-	--
1968	0.3+	0.5+	0.3+	--
1969	0.3-	--	0.1-	0.1+
1970	0.4-	0.5-	--	0.2-

Hunter Success. From Table 11, high and low years in the number of cottontails killed per hunter trip during the study interval can be noted. The high years in which the rabbit kill generally increased in the game regions were 1958 and primarily 19.66 and 1968. The low years in which the kill generally decreased were 1959, 1960, 1963, 1964, 1965, and 1970. To determine if weather had any influence on the increases or decreases in the cottontail harvest, the weather parameters during the critical periods in Fig. 7 were examined to see if unusual years (one or two standard deviations about the 19 56 through 1970 mean) corresponded with high and low cottontail years.

In 1958, there were sharp increases in the rabbit harvest in Regions 3 and 4a (Table 11). Maximum temperature was one standard deviation above the mean in all the regions in December, preceding the hunting season, one standard deviation below the mean during January through July in all the regions , and one standard deviation below the mean for April through July in Regions 3, 4, and 4a. Total snowfall from December through March was one standard deviation below the mean in Regions 4 and 4a, and below normal in the other regions. The number of days with precipitation ≥0.10 inch from May through August was one standard deviation above the mean in Regions 3, 4, and 4a and the percentage of possible sunshine in July was two standard deviations below the means in all the regions. The number of days with snowcover ≥1.0 during the hunting season month of November, which should have facilitated hunter success, was two standard deviations above the mean in Regions 2, 3, and 4a.

The cottontails per hunter trip increased in all of the game regions in 1966, but few weather parameters from Fig. 7 were abnormal. The maximum temperature in December preceding the hunting season was one standard deviation below normal in Regions 3, 4, and 4a.

The rabbit harvest in 1968 increased in Regions 2, 3, and 4. However, the only above or below normal weather parameters occurred during the hunting season. Total precipitation for November of the hunting season was one standard deviation above normal in Regions 2, 4, and 4a, and two standard deviations above normal in Region 3. Total precipitation during January of the hunting season was one standard deviation above normal in Regions 3 and 4a, and two standard deviations above normal in Region 2. The percentage of possible sunshine was one standard deviation below normal in all of the regions during January of the hunting season.

The first poor hunting season of the study interval was 1959 when the cottontail harvest decreased in Regions 2, 3, and 4a. Maximum temperature for January through July was one standard deviation above normal in Regions 2 and 4a, and maximum temperature for April through July was one standard deviation above normal for Regions 4 and 4a. No other weather parameters listed in Fig. 7 were unusual.

In 1960, the cottontail kill decreased in Regions 2, 3, and 4 (Table 11). Total snowfall for December through March was one standard deviation above normal in Regions 2, 4, and 4a and two standard deviations above normal in Region 3. Total snowfall from January through July was one standard deviation above normal in Regions 4 and 4a, and two standard deviations above normal in Regions 2 and 3. March total snowfall was two standard deviations above normal in all the game regions. The other abnormal weather parameters from Fig. 7 occurred during the hunting season. November had little snowcover. Total precipitation in January was one standard deviation below normal in all of the regions while the percentage of possible sunshine in January was one standard deviation above normal in Regions 3, 4, and 4a.

The rabbit harvest decreased in Regions 3 and 4a in 1963. Maximum temperature from April through July was one standard deviation above normal in Regions 3, 4, and 4a. The percentage of possible sunshine in July was one standard deviation above normal in Regions 3 and 4a, and sunshine during January of the hunting season was one standard deviation above normal in all of the regions.

Cottontail harvest declined in Regions 2, 3, and 4 in 1964. It was an unusual year for maximum temperature, total snowfall, the percentage of possible sunshine, and the number of days with precipitation ≥0.10 inch. Maximum temperature for December preceding the hunting season was one standard deviation below normal in all the regions. Maximum temperature for January through July was one standard deviation above normal in Regions 2, 3, and 4a and two standard deviations above normal in Region 4. During April through July, maximum temperature was one standard deviation above normal in Regions 2 and 4, and two standard deviations above normal in Regions 3 and 4a. Sunshine was one standard deviation above normal in all the regions for January and January through July. Total snowfall for December through March was one standard deviation above normal in Regions 3 and 4a. The number of days with precipitation ≥0.10 inch for May through August was one standard deviation below the mean in Regions 2, 4, and 4a, and two standard deviations below the mean in Region 3. The number of rainy days for July through August was one standard deviation below the mean in Regions 2 and 3.

In 1965, the rabbit harvest declined severely in Regions 3, 4, and 4a. Total precipitation in January was one standard deviation above normal in Region 4a, and two standard deviations above normal in Regions 3 and 4. Total snowfall was one standard deviation above normal in all the regions for December through March and one standard deviation above normal for Regions 3 and 4 during March. Maximum temperature for April through July was above normal in all the regions. In September, the number of days with precipitation ≥0.10 inch was one standard deviation above normal in Regions 2, 3, and 4. In November of the season, there were no days with snowcover ≥1.0 inch and snowcover was below normal in all regions in December. Total precipitation in November was one standard deviation below normal in all the regions. Total snowfall during the hunting season, November through January, was one standard deviation below normal in Regions 2, 3, and 4a and two standard deviations below normal in Region 4.

In 1970, the cottontail harvest decreased in Regions 2, 3, and 4a. Total snowfall for December was one standard deviation above normal in Region 4 and two standard deviations above normal in Regions 2, 3, and 4a. December through March snowfall was one standard deviation above normal in Region 2. Total snowfall in April was higher than in any other year of the study interval with Regions 4 and 4a one standard deviation above normal and Region 3 two standard deviations above normal. Total precipitation in April was one standard deviation above normal in Regions 3, 4, and 4a. The number of days with precipitation ≥0.10 inch was one standard deviation above the mean in Region 2 and two standard deviations above the mean in Regions 3, 4, and 4a in September and one standard deviation above the mean in Regions 2, 3, and 4a and two standard deviations above the mean in Region 4 for September through November. During the hunting season, total precipitation in November was one standard deviation below normal in Regions 2, 3, and 4a. There were no days with snowcover ≥1.0 inch in November and snowcover was one standard deviation below normal in all of the regions in December.

These results show that more than one weather parameter may vary beyond its normal range in a given year, and, in turn, may affect cottontail populations. However, the weather conditions affecting cottontail abundance one year may or may not be the same conditions that influence the population in following years. Any weather parameter can influence a population if it becomes extremely abnormal.

The weather parameters that were most frequently one or two standard deviations above or below normal in high and low cottontail years from 19 56 through 1970 were total snowfall for December through March and maximum temperature from April through July. Both of these parameters are negatively correlated with the cottontail harvest in all of the game regions. Abnormal deviations in total snowfall for December through March corresponded to fluctuations in cottontail harvest in 1958, 1960, 1964, 1965, 1966, and 1970. Fluctuation in rabbit harvest and deviations in maximum temperature for April through July corresponded in 1958, 1959, 1963, 1964, and 1965.

Snowfall. Analysis of cottontail harvest with weather parameters disclosed that deviations in total snowfall for December through March preceding the hunting season paralleled some of the cottontail trends in all game regions.

The patterns of the number of cottontails killed per hunter trip and the total snowfall for December through March preceding the hunting season for Regions 2, 3, 4, and 4a, respectively, are given in Figs. 8, 9, 10, and 11. These parameters are negatively but not significantly correlated in all of the regions ($P \geq 0.05$, 13 df). However, Region 2, which had the lowest annual snowfall, had the highest correlation coefficient ($r = -0.49$), and Region 4, which had the highest annual snowfall, had the lowest correlation coefficient ($r = -0.07$). The cottontails in the warmer areas of the state may be more sensitive to snowfall, especially in the late winter and spring months, than in the more northern areas where winters of heavy snowfall are more common.

In Fig. 8, an apparent relationship exists between the rabbit harvest and December-March total snowfall in Region 2. The peak snow years of 1960, 1964, and 1970 corresponded to sharp decreases in the rabbit harvest. The years of decreasing snowfall (1961, 1963, and 1966) corresponded to slight increases in the cottontail harvest. Apparently years of heavy amounts of snowfall were more important in this region than are years of normal or light amounts.

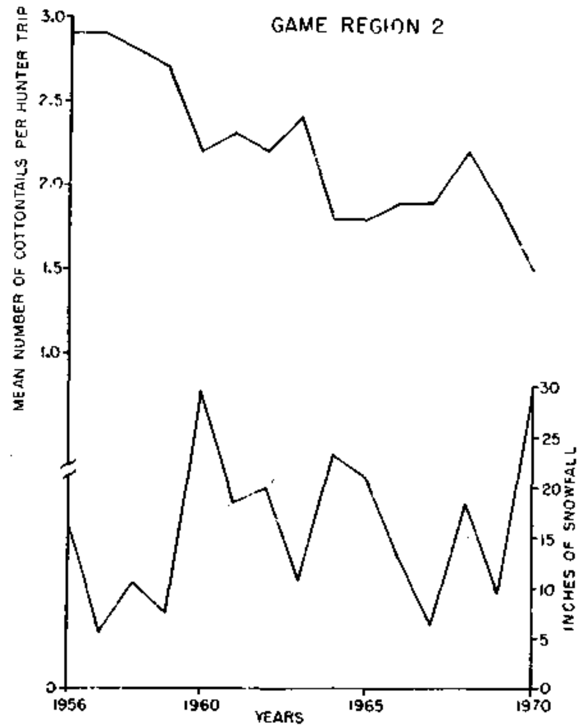


Figure 8. Patterns of the number of cottontails killed per hunter trip and the total snowfall for December-March preceding the hunting season for Illinois Game Region 2 (P ≥ 0.05, 13df)

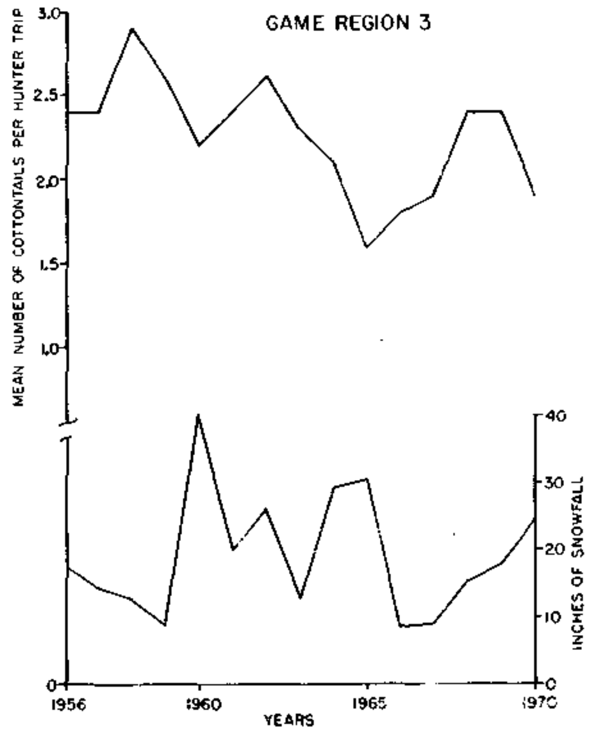


Figure 9. Patterns of the number of cottontails killed per hunter trip and the total snowfall for December-March preceding the hunting season for Illinois Game Region 3 (P≥ 0.05 13 df)

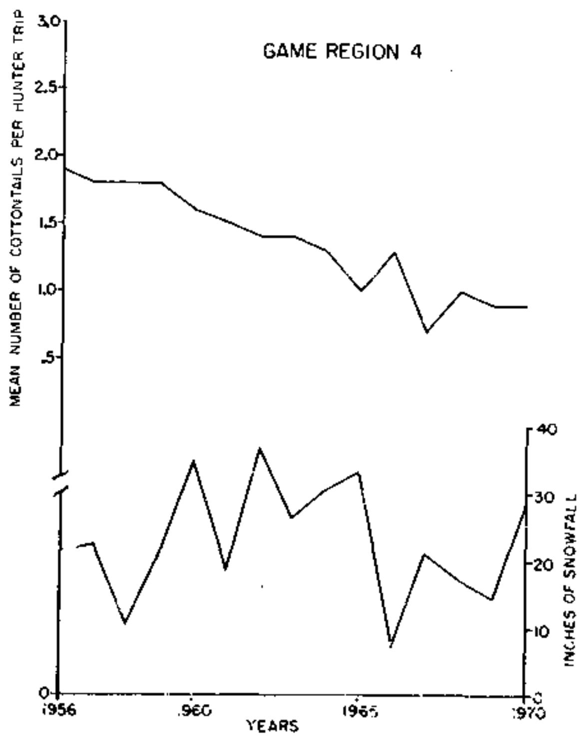


Figure 10. Patterns of the number of cottontails killed per hunter trip and the total snowfall for December-March preceding the hunting season for Illinois Game Region 4 (P≥ 0.05, 13df)

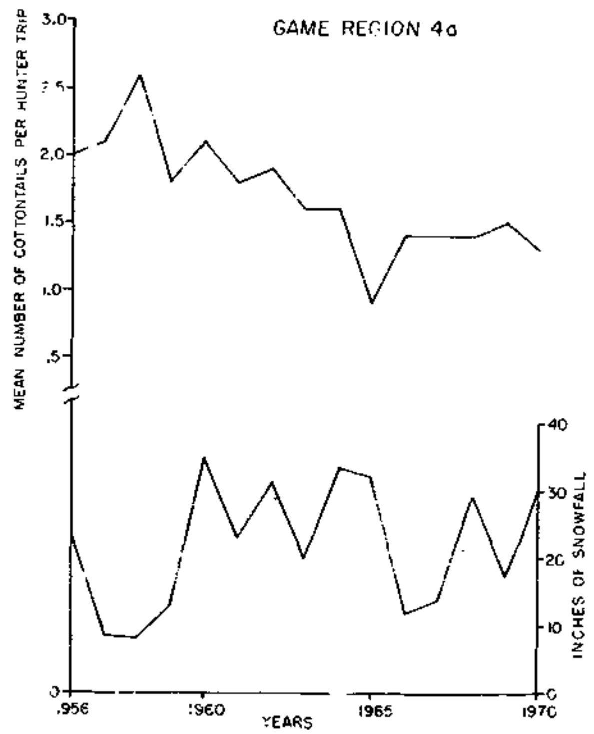


Figure 11. Patterns of the number of cottontails killed per hunter trip and the total snowfall for December-March preceding the hunting season fro Illinois Game Region 4a (P≥ 0.05, 13 df)

Game Region 3 shows a similar pattern in Fig. 9. The years of the heavy December-March snowfall (1960, 1964, 1965, and 1970) corresponded to noticeable decreases in the cottontail harvest. Years of decreasing snowfall (1958, 1961, 1966, and 1967) showed a slight increase in the cottontail kill.

The 3 years of the heaviest snowfall for December-March (1960, 1962, and 1965) in Region 4 also corresponded to a decreased cottontail harvest (Fig. 10). In 1964 and 1967, snowfall increased over the previous year's total, and the rabbit curves decreased. Heavy snowfall in this northern area also appeared to have a negative relationship with the cottontail harvest. The year with the lowest snowfall in Region 4 was 1966, and there was a noticeable increase in the cottontail harvest.

Heavy snowfall in Region 4a (Fig. 11) did not show as clear a relationship with the rabbit harvest. Only in the high snow years of 1965 and 1970 did the rabbit kill decline. However, the 3 lowest snowfall years (1957, 1958, and 1966) all corresponded to an increased rabbit harvest. In 1969, a noticeable decrease in total snowfall and a slight increase in the rabbit harvest occurred.

Table 12. Total Snowfall (in inches) for December-March in Illinois Game Regions 2, 3, 4, and 4a, 1955-56 to 1969-70

Year	Game Region				Sum of Game Regions
	2	3	4	4a	
1955-56	16.7	17.5	21.5	23.6	79.3
1956-57	5.4[a]	14.3	22.4	8.6[a]	50.7
1957-58	10.5	12.6	10.6[a]	8.2[a]	41.9
1958-59	7.8[a]	8.8[a]	21.0	13.2	50.8
1959-60	29.5[a]	40.0[b]	34.7[a]	35.0[a]	139.2
1960-61	18.3	19.9	18.7	23.0	79.9
1961-62	19.8	26.2	36.7[a]	31.5	114.2
1962-63	10.7	13.2	26.4	19.9	70.2
1963-64	23.2	29.3[a]	30.4	33.5[a]	116.4
1964-65	20.8	30.4[a]	33.3[a]	32.0[a]	116.5
1965-66	13.0	8.6[a]	7.4[a]	11.9[a]	40.9
1966-67	6.2[a]	9.2[a]	21.4	14.0	50.8
1967-68	18.5	15.5	17.2	29.6	80.8
1968-69	9.5	18.2	14.6	17.5	59.8
1969-70	29.8[a]	24.7	28.4	30.5	113.4
Mean	16.0	19.2	23.0	22.1	
Standard Deviation	±7.8	±9.2	±8.7	±9.5	

[a]Values are 1 standard deviation above mean. Two standard deviations above mean

The sum of the total snowfall for December through March in the four game regions is of interest (Table 12). The 3 years with the highest snowfall for the game regions were, in descending order, 1960, 1965, and 1964. The fifth highest total was in 1970. In all of these years the cottontails killed per hunter trip decreased in most of the game regions (Table 11). The years with lowest snowfall for the four game regions were 1966 and 1958. These were years in which the cottontail harvest increased in most of the game regions. There were two exceptions to the December-March snowfall and rabbit harvest trend. The rabbit harvest was low in 1959, and snowfall was also low in all of the game regions. 1968 was a good year for cottontail hunters, and the December-March snowfall was normal. Other factors may have favored cottontail populations in this year.

Table 13. Total Snowfall (in inches) During February for Illinois Game Regions 2, 3, 4, and 4a, 1956-70

Year	Game Region				Sum of Game Regions
	2	3	4	4a	
1956	5.0	6.3	8.8	8.4	28.5
1957	0.1[a]	0.0[a]	0.7[a]	0.0[a]	0.8
1958	2.6	0.8[a]	0.9[a]	1.3[a]	5.6
1959	0.2[a]	1.8	2.8	2.6	7.4
1960	10.0[a]	11.8[a]	12.4[a]	13.3[a]	47.5
1961	9.2[a]	8.4	6.0	7.4	31.0
1962	4.8	7.9	11.5[a]	9.7	33.9
1963	3.0	3.6	12.4[a]	8.8	27.8
1964	6.1	9.3[a]	9.9	11.9[a]	37.2
1965	7.9	9.3[a]	8.7	11.6[a]	37.5
1966	11.0[a]	5.2	2.6	7.2	26.0
1967	2.2	0.9[a]	4.3	4.1	11.5
1968	0.9[a]	1.0[a]	2.9	1.7[a]	6.5
1969	3.4	6.9	1.3[a]	3.8	15.4
1970	6.6	3.8	5.2	5.1	20.7
Mean	4.9	5.1	6.0	6.5	
Standard Deviation	± 3.5	± 3.8	± 4.3	± 4.2	

[a]Values are one standard deviation above the mean.

Further examination of the snowfall for December-March revealed the importance of the total snowfall for February and March. The 3 years of the greatest total snowfall for December through March (1960, 1965, and

1964 were not only 3 years of low cottontail populations, hut were also during February (Table 13) and March (Table 14). In these 3 years, more than half of the total snowfall from December through March occurred during February and March. In 1960 in all of the regions, total snowfall was one standard deviation above the mean in February and two standard deviations above the mean in March. In 1964 and 1965, total snowfall one standard deviation above the mean occurred in Regions 3 and 4a during February, and the other regions were also above normal. In March of 1965, total snowfall one standard deviation above the mean occurred in Regions 3 and 4, and the other regions were also above normal. Total snowfall in March was above normal in all regions except 2 in 1964. The cottontail harvest was low in 1970, and snow in March was above normal in most regions but the winter of 1969-70 had more snow in December and April than in any other year of the study.

Table 14. Total Snowfall (in inches) During March for Illinois Game Regions 2, 3, 4, and 4a, 1956-70

Year	Game Region				Sum of Game Regions
	2	3	4	4a	
1956	3.4	2.6	4.5	5.3	15.8
1957	0.8	2.9	4.1	2.3	10.1
1958	3.5	3.8	1.0	1.8	10.1
1959	1.8	0.2	4.0	4.2	10.2
1960	18.1[a]	23.3[a]	15.6[a]	18.1[a]	75.1
1961	0.1	0.1	1.1	0.7	2.0
1962	2.1	0.4	3.1	2.1	7.7
1963	3.6	0.4	0.9	0.4	5.3
1964	3.4	5.5	8.3	5.3	22.5
1965	7.0	10.3[b]	12.0[b]	8.4	37.7
1966	1.2	1.9	2.7	3.0	8.8
1967	2.9	0.5	3.8	3.2	10.4
1968	4.0	2.3	2.7	4.8	13.8
1969	2.2	4.7	4.0	5.8	16.7
1970	5.3	4.6	6.9	3.6	20.4
Mean Standard Deviation	4.0 ±4.3	4.2 ±5.9	5.0 ±4.2	4.6 ±4.3	

[a]Values are two standard deviations above the mean.

Values are one standard deviation above the mean.

The effect of snowfall in February and March can also be seen in the high years of cottontail harvest (1958, 1966, and 1968). The total snowfall for all of the game regions in February was at its second and third lowest values of the study in 1958 and 1968, with total snowfall one standard deviation below normal in three of four regions for each year. March snowfall was below normal in all of the regions in 1958 and 1966 and was normal or below in 1968.

Effect of Snow on Cottontails

It appeared that total snowfall in the months of December through March, the months of the heaviest snowfall in the four game regions and in the state, had some influence on high and low rabbit harvest in the subsequent hunting season. A majority of the effect of snowfall on the cottontail harvest may have occurred in February and March.

Winter is a critical time for game populations in the northern states (Allen, 1954). Blizzards are well known for their devastating effects on rabbits and other game species (Schultz, 1951; Steel, 1957). In the southern regions of European Russia, the number of hares depends upon the maximum depth of snow the previous year (Dinesman, 1960). Besadny (1963) reported that rabbits and other farm game populations decreased noticeably after sever winters in Wisconsin. Meslow and Keith (1971) found that colder temperatures and deeper snow from January to April 25 were correlated with poor adult survival of snowshoe hares in Alberta.

Large amounts of snowfall can affect cottontails in several ways. Besadny (1963) noted that natural mortality and predation of cottontails increased during severe winters. Increased mortality and predation may partially result from changes in rabbit behavior caused by snowfall. If deep enough, snow may force rabbits to switch from a preferred herbaceous diet to a woody diet that has less nutritional value (Beule, 1946; Dusi, 1952; Sweetman, 1949). Beule (1947) states that a rabbit probably needs twice as much bark, by volume, to maintain its weight as it does green summer foods. Allen (1938) and Haugen (1942) reported that deep snow and cold weather caused weight loss in cottontails. Siivonen (1956) found that deep and long lasting snow in winter caused death by starvation in European hares. A less nutritious diet adds greater physiological stress on the breeding stock and makes the individuals more susceptible to diseases, parasites, and predation. A longer feeding time may be required during periods of deep snow because of the decreased nourishment of a woody diet. A longer feeding time means more opportunity for increased predation, especially with a white blanket of snow on which cottontails are easily visible. Snowfall may affect the movements of cottontails. Hanson et al. (1969) found that on nights with snow on the ground, cottontails moved less and remained in dense woody cover. Beule (1946) stated that the use of burrows by rabbits was correlated with snow depth. Allen (1939), Haugen (1942), and Johnson and Hendrickson (1958) found that cottontails increased their use of heavy *covev* during periods of deep snow. Heavy cover affords cottontails with a food source and protection from the winter elements. If no areas of heavy cover are available to cottontails, the effect of snowfall and other climatic factors are much greater. However, the concentrations of cottontail populations caused by snowfall may not only induce physiological stresses, but may facilitate the transfer of disease and parasites and increase predation.

Perhaps the greatest effect of snowfall is on the reproduction of cottontails. Heavy snowfall during the winter may not only decrease the breeding population, which does not seem to be significantly correlated with the fall populations (Table 4) (Dell, 1958; Rose, 1972), but it may delay the onset of breeding and even reduce the physical condition of the females enough to interfere with birth and care of the early litters of the breeding season. Snow may thus exert its effects by controlling the number of litters per female per year and the number of juveniles that are born early in the breeding season and bear litters during the same year. It seems that a large effect on the number of cottontails in the fall would be the length of the breeding season. If environmental factors shortened either or both ends of the breeding season, a low rabbit harvest would probably result. The necessity for succulent vegetation for continued reproduction in the last part of the breeding season has been previously discussed. However, examination of high and low years of cottontail harvest did not show a relationship with a lack of July or August total precipitation, but positive correlations were found between cottontail harvest and the number of days with precipitation $\geq$0.10 inch for May through August and July through August. The relationships of high and low years of cottontail harvest with total snowfall from December through March, and also in February and March, may have resulted from the effects of late winter snowfall on the early stages of the cottontail breeding season. The differences between high and low cottontail years may depend substantially on the success of breeding by subadults born during March, April, and early May. Lord (1958) stated that juvenile breeding accounted for 24 to 27% of the annual cottontail crop available to hunters in November. Lord (1958) also noted that in 1957, 55% of the breeding females in August and 76% in September were juveniles. Wainwright (1969) stated that about 10-23% of the annual cottontail population may be attributed to juvenile breeding. The young contributed by juvenile breeding during July, August, and September may be especially important to hunter success. Lord (1961b) found that rabbits born late in the breeding season had a better chance to live to be 12 months of age and three-fourths of the hunters' kill was born from May through August.

Negus (1959) and Conaway and Wight (1962) suggested that the amount of juvenile breeding would be influenced by the amount of adult breeding early in the season. Negus (1959) believed that rabbits born later than April would not be expected to breed during their first summer. Although snowfall may cause resorption of litters (Kline, 1962), snowfall, primarily in February and March, probably exerts its greatest effect by delaying the onset of breeding. Wight and Conaway (1961) reported that severe cold and snowfall delayed the onset of the 1960 cottontail breeding season from the last of February to the last of March. Trethewey and Verts (1971) stated that the onset of the 1969 cottontail breeding season in Oregon was retarded by below-average daily temperatures and above normal snowfall and the first litters were not conceived until 3 days after the ground was clear of snow. Inclement weather may delay the onset of the cottontail breeding season to late March in New York (Hamilton, 1910). Conaway and Wight (1962) found a relationship between severe weather and delays in the onset of the breeding season. Marsden and Conaway (1963) reported that brief periods of bad weather may delay reproductive behavior. If the breeding season is delayed long enough by severe weather, juvenile breeding is greatly reduced or eliminated (Dudley, 1963). With a delay in the onset of the breeding season the sexual maturity of juveniles may be delayed a month or more (Conaway and Wight, 1962).

Thus , it can be concluded that poor years of cottontail hunter success in Illinois probably resulted from heavy winter and spring snowfall. Heavy snowfall can be expected to decrease the number of breeding females, reduce the physical condition of adult females sufficiently to impair their reproductive capabilities, and reduce the amount of juvenile breeding either by decreasing the survival of early season litters or by delaying the initiation of the breeding season and thereby decreasing the number of juvenile females of breeding age in July and August.

Total Precipitation and Cottontail Populations

Changnon and Huff (1971) concluded that in most regions of Illinois, corn and soybean crops would be benefited economically in the majority of the growing seasons by a July-August cloud seeding program. Therefore, for this study the relationship of July and August total precipitation to cottontail harvest is especially important.

The correlation coefficients of total precipitation in July and August and July plus August with the number of cottontails killed per hunter trip in Regions 2, 3, 4, and 4a are given in Table 15. The study area for the Precipitation Enhancement Project lies within Region 2. In all regions, total precipitation in July and July plus August was positively correlated with the number of cottontails killed per trip from 1956 through 1971. Total precipitation in August, however, was positively correlated with the rabbit harvest in Regions 2 and 4 but was negatively correlated in Regions 3 and 4a. Total precipitation in August and July plus August had the highest correlation values with the cottontail harvest in Region 2, the warmest region.

Except for Region 2, total precipitation in July had a higher correlation coefficient with rabbit harvest than total precipitation in August. Perhaps for rabbits, July would be a better month for precipitation enhancement than August. However, August had an average of 10.0 below

Table 15. Correlation Coefficients of Total Precipitation for July and August and July plus August with the Number of Cottontails Killed Per Hunter Trip in Game Regions 2, 3, 4, and 4a, 1956-71

Game Region and Month	Sixteen Year Mean of Total Precipitation in Inches	Correlation Coefficient of Total Precipitation
Game Region 2		
July	4.39	+0.28
August	3.18	+0.44
July £ August	7.57	+0.50*
Game Region 3		
July	4.35	+0.46
August	3.59	-0.08
July £ August	7.96	+0.31
Game Region 4		
July	4.50	+0.17
August	2.78	+0.02
July £ August	7.28	+0.17
Game Region 4a		
July	4.27	+0.37
August	2.93	-0.27
July £ August	7.20	+0.14

*$P \leq 0.05$.

normal years of total precipitation for all four game regions from 1956 through 1971 whereas July only had an average of 5.25 below normal years. If precipitation enhancement of moderate amounts during August would prevent below normal precipitation, the correlation of cottontail harvest with total precipitation in August might increase. Generally, the more that a given environmental factor departs from, either above or below, its long-term average under which a species evolved, the more intolerable that factor becomes to the animal. Precipitation enhancement that would normalize precipitation, such as more rainfall during summers of drought, should benefit cottontail populations. However, if precipitation enhancement increases total precipitation appreciably above the long-term average, the direct effects of precipitation enhancement on cottontail populations may be adverse.

In general, the magnitudes of the correlation coefficients in Table 15 indicate that precipitation in July and August and July plus August had a favorable but not a critical effect on cottontail harvest. Therefore, precipitation enhancement that would not result in large departures from the long-term average of precipitation in July and August would not be expected to have a direct adverse effect on rabbit populations.

A comparison of monthly total precipitation for 11 individual months was made with the cottontail parameters in the four game regions. The March and July censuses were compared with the 11 individual months of total precipitation preceding the month of each census (April-February and August-June, respectively), for the period 1955 through 1970. The number of cottontails killed per hunter trip was compared with the 11 individual months of total precipitation (January-November) preceding the hunting season from 1956 through 1970. The months of total precipitation were ranked in the order of their accountability for the variance in the cottontail data by a stepwise multiple regression program. The best 5 months of the 11 months for each cottontail index are listed in Table 16.

Within Region 2, May and November appear to have been the most influential months of total precipitation. Total precipitation in May was positively related to both the rabbit harvest and the July census, and total precipitation in November was positively related to all three cottontail indices. In Region 3, April appeared to have been the most important month of total precipitation with a negative relationship to all three cottontail indices. Total precipitation in January was negatively correlated to the rabbit harvest and the July census, and total precipitation in October was negatively related to both of the censuses. In Region 4, total precipitation in January, February, and April was related to all of the rabbit indices. February was positively related but January and April were negatively related. Within Region 4a, total precipitation in June and November was positively correlated with the censuses in March and July.

Comparison of monthly total precipitation with a specific cottontail index in all four regions is possible with the information presented in Table 16. Cottontail harvest was positively correlated with total precipitation in July in all four regions. However, total precipitation in January (Regions 3, 4, and 4a), April (Regions 2, 3, and 4), and September (Regions 3 and 4a) was unfavorable to rabbit harvest, possibly because excess moisture during these times of the year may be detrimental to cottontail survival.

Table 16. Individual Months of Total Precipitation in the Order of Their Accountability for the Variance in the Number of Cottontails Killed Per Hunter Trip (1956-70) £ Census Values (1955-70) in Game Regions 2, 3, 4, and 4a

Rabbits per Trip[a]		March Census[b]		July Census[c]	
Game Region and Month	Correlation Coefficient	Month	Correlation Coefficient	Month	Correlation Coefficient
GAME REGION 2					
1. May	+0.56*	August	+0.53	May	+0.47
2. July	+0.38	November	+0.22	October	-0.37
3. February	+0.29	January	+0.04	June	+0.42
4. November	+0.55*	December	+0.33	November	+0.37
5. April	-0.10	October	+0.09	September	-0.13
GAME REGION 3					
1. April	-0.58*	May	+0.67**	April	-0.42
2. September	-0.39	April	-0.37	January	-0.25
3. July	+0.47	December	-0.27	October	-0.08
4. January	-0.21	February	-0.50*	September	+0.19
5. June	-0.15	October	-0.11	December	+0.14
GAME REGION 4					
1. February	+0.45	February	+0.33	September	-0.48
2. July	+0.33	October	-0.13	April	-0.40
3. January	-0.30	January	-0.10	February	+0.35
4. May	-0.13	August	+0.04	January	-0.28
5. April	-0.25	April	-0.14	December	-0.26
GAME REGION 4a					
1. September	-0.54*	June	+0.35	August	+0.38
2. July	+0.51*	February	+0.32	April	-0.23
3. August	-0.38	December	-0.29	June	+0.37
4. January	-0.26	November	+0.23	May	-0.06
5. February	-0.03	August	-0.01	November	+0.05

*$P \leq 0.05$.

[a]Cottontail index was compared with the 11 individual months (January-November) of total precipitation preceding the hunting season.

[b]Cottontails index was compared with the 11 individual months (April-February) of total precipitation preceding the census.

[c]Cottontail index was compared with the 11 individual months (August-June) of total precipitation preceding the census.

The number of cottontails sighted in March was negatively correlated with total precipitation in April (Regions 3 and 4) but was favored by a wet November (Regions 2 and 4a). The July counts were positively correlated with total precipitation in June and November (Regions 2 and 4a) but negatively correlated with total precipitation in January (Regions 3 and 4), April (Regions 3, 4, and 4a), and October (Regions 2 and 3).

A rearrangement of Table 16 is given in Table 17. It shows the correlation coefficients of the 5 months of total precipitation during the year that accounted for the most variance in the three rabbit indices in all the regions. Total precipitation in 3 months had the same correlation sign for all the cottontail indices. Total precipitation in April appeared to be the most important month of precipitation since it was negatively correlated with at least one rabbit index in every game region. Total precipitation in July and November was favorably correlated with the rabbit indices. Total precipitation in July appeared to be especially important to rabbit harvest.

In general, total precipitation in January, September, and October was negatively correlated with the cottontail variables, and total precipitation in February and June was positively correlated.

Based on similarities in the signs of the correlation coefficients of the months of total precipitation that were most strongly associated with the variance in the cottontail indices (Table 17) and on similarities in the signs of the correlation coefficients of all the months of total precipitation (Table 18), there appeared to be fluctuations in the effect of total precipitation on rabbit populations during the year. Total precipitation was generally negatively correlated in January but became favorable in February. With the approach of spring, total precipitation became unfavorable, especially in the month of April. During the warm months of late spring and early summer, increased rainfall became beneficial since positive correlations appeared in May and June and became numerous in July. As fall approached, total precipitation again became unfavorable since negative correlations appeared in August and became consistent in September and October. Moisture in November, however, was beneficial.

The favorable peaks of total precipitation occurred in February, May-June-July, and November. Total precipitation in May, June, and July probably exerted its favorable effect by enhancing vegetative growth for food and protection of young cottontails (Hickie, 1940) and by favoring the reproduction of juvenile (Pelton, 1969) and adult cottontails (Sheffer, 1957; Trethewey and Verts, 1971). Moisture in November and February may have delayed fall and spring plowing and thus provided protective cover for cottontails. Rose (1972) stated that a large proportion of the annual mortality of cottontails in central Illinois occurred during November.

Total precipitation in January, April, and September-October was negatively correlated with cottontail populations. January is the coldest month of the year in Illinois, and above normal precipitation (which includes snowfall) combined with cold temperatures is probably detrimental to cottontail

Table 17. Correlation coefficients of the 5 months of total precipitation that accounted for most of the variance in the number of cottontails killed per hunter trip (1956-70), and the March and July censuses (1955-70) for Game Regions 2, 3, 4, and 4a.

Season and Month	Rabbits per Trip[a]				March Census[b]				July Census[c]			
	2	3	4	4a	2	3	4	4a	2	3	4	4a
WINTER												
December	—	Hunting Season		—	+0.33	-0.27	—	-0.29	—	+0.14	-0.26	—
January	—	-0.21	-0.30	-0.26	+0.04	—	-0.10	—	—	-0.25	-0.28	—
February	+0.29	—	+0.45	-0.03	—	-0.50*	+0.33	+0.32	—	—	+0.35	—
SPRING												
March	—	—	—	—	—	Month of Census		—	—	—	—	—
April	-0.10	-0.58*	-0.25	—	—	-0.37	-0.14	—	—	-0.42	-0.40	-0.23
May	+0.56*	—	-0.13	—	—	+0.67*	—	—	+0.47	—	—	-0.06
SUMMER												
June	—	-0.15	—	—	—	—	—	+0.35	+0.42	—	—	+0.37
July	+0.38	+0.47	+0.33	+0.51*	—	—	—	—	—	Month of Census		—
August	—	—	—	-0.38	+0.53*	—	+0.04	-0.01	—	—	—	+0.38
FALL												
September	—	-0.39	—	-0.54*	—	—	—	—	-0.13	+0.19	-0.48	—
October	—	—	—	—	+0.09	-0.11	-0.13	—	-0.37	-0.08	—	—
November	+0.55*	—	—	—	+0.22	—	—	+0.23	+0.37	—	—	+0.05

*$P \leq 0.05$.

[a] Cottontail index was compared with the 11 individual months (January-November) of total precipitation preceding the hunting season.

Cottontail index was compared with the 11 individual months (Apri1-February) of total precipitation preceding the census.

Cottontail index was compared with the 11 individual months (August-June) of total precipitation preceding the census.

Table 18. Correlation coefficients between total precipitation and cottontail statistics for Illinois Game Regions 2, 3, 4, and 4a.

Season and Month	Rabbits per Trip (1956-70)[a]				March Census (1955-70)[b]				July Census (1955-70)[c]			
	2	3	4	4a	2	3	4	4a	2	3	4	4a
<u>WINTER</u>												
December	Hunting Season				+0.33	-0.27	-0.23	-0.29	+0.02	+0.14	-0.26	+0.22
January	-0.02	-0.21	-0.30	-0.26	+0.04	-0.20	-0.10	0.00	+0.17	-0.25	-0.28	+0.20
February	+0.29	+0.02	+0.45	-0.03	-0.17	-0.50*	+0.33	+0.32	+0.04	+0.07	+0.35	-0.14
<u>SPRING</u>												
March	-0.08	-0.10	+0.01	-0.09	Month of Census				-0.17	+0.10	-0.15	+0.13
April	-0.10	-0.58*	-0.25	-0.19	+0.03	-0.37	-0.14	-0.05	+0.36	-0.42	-0.40	-0.23
May	+0.56*	-0.04	-0.13	+0.24	+0.25	+0.67*	+0.09	-0.09	+0.47	+0.10	-0.28	-0.06
<u>SUMMER</u>												
June	+0.04	-0.15	+0.14	+0.43	-0.05	-0.03	-0.03	+0.35	+0.42	-0.29	+0.22	+0.37
July	+0.38	+0.47	+0.33	+0.51*	-0.01	+0.22	+0.19	+0.27	Month of Census			
August	+0.29	-0.17	-0.11	-0.38	+0.53*	-0.22	+0.04	-0.01	-0.05	+0.03	-0.04	+0.38
<u>FALL</u>												
September	-0.36	-0.39	-0.31	-0.54*	+0.05	-0.07	-0.08	-0.21	-0.13	+0.19	-0.48	-0.19
October	-0.21	+0.18	-0.29	-0.09	+0.09	-0.11	-0.13	-0.15	-0.37	-0.08	+0.42	-0.12
November	+0.55*	+0.30	+0.11	+0.43	+0.22	+0.15	-0.15	+0.23	+0.37	+0.07	-0.22	+0.05

*$P \leq 0.05$.

[a] Cottontail index was compared with the 11 individual months (January-November) of total precipitation preceding the hunting season.

[b] Cottontails index was compared with the 11 individual months (April-February) of total precipitation preceding the census.

[c] Cottontail index was compared with the 11 individual months (August-June) of total precipitation preceding the census.

survival. During April, the first and the second litters of young are present (Lord, 1963). Young females born in early spring are important because they can bear offspring in late July, August, and September (Lord, 1958). The greatest change in monthly precipitation parameters during the study interval occurred in April when total precipitation and the number of days with precipitation ≥0.10 and ≥1.0 inch increased sharply (Fig. 2). Heavy precipitation during this time of the year in conjunction with cool temperatures may have been harmful to survival of nestlings. Heavy rainfall can drown nestlings (Atzenhoefer, 1953; Carson and Cantner, 1963; Hickie, 1940; Redd, 1956). Total precipitation in September and October may have exerted its detrimental effects on cottontails by interacting with decreasing fall temperatures.

When total precipitation was examined over the critical periods of the cottontail life cycle (Table 10), total precipitation in three of the periods had the same relationship to the number of cottontails killed per hunter trip in all of the game regions. These periods and their relationships were 1) May through August, positive, 2) July through August, positive, and 3) September through November, negative. These relationships were similar to those found for total precipitation in individual months during the same time of the year (Tables 16 and 17). Total precipitation in May through August accounted for more of the variance in the cottontail harvest than in any other critical period. Lord (1961b) stated that the months of May, June, July, and August produced three-fourths of the hunter's bag in central Illinois. Lord (1961b) also noted that in east central Illinois the peak of cottontail abundance occurs in May and June, and that July is the peak month for birth of rabbits killed during the hunting season. However, the number of days with precipitation ≥0.10 inch during these same three periods had the same relationship as total precipitation but were better correlated with cottontail harvest. Apparently the number of days with precipitation ≥0.10 inch during these periods was more important to cottontail harvest than total precipitation.

Based on linear correlation and variance analyses (Fig. 7 and Tables 8, 16, 17, and 18), total precipitation in January, April, July, and November had the best relationships with cottontail populations from 1955 through 1970. Total precipitation in January and April was negatively correlated with the rabbit populations, but total precipitation in July and November was positively correlated to the rabbit indices. The most important months appeared to be April and July, respectively. April was the only month in which total precipitation was always more important to the cottontail indices than the number of days with precipitation. Generally, the number of days with precipitation was better correlated with cottontail abundance than total precipitation in the analyses of monthly and combined months of weather data. It appears that the frequency of precipitation and its interaction with other climatic factors, habitat, disease, and predation may have been more influential to cottontail behavior, reproduction, survival, and overall fitness than total precipitation.

Changnon and Huff (.1971) found that there is not a lack of days with light rainfall during July-August in dry areas, but there is a lack of days with moderate to heavy rainfall. The authors stated that seeding operations can be successful if existing rainfall can be enhanced, rather than attempting to produce rain on days with no naturally-occurring rainfall. Since cottontails appeared to react more to the frequency of precipitation than to the total amount, cloud seeding procedures during July and August that only increase total precipitation during days with naturally-occurring rain may have little effect on cottontail populations if extremely heavy rainfalls of great accumulations do not occur. It would be more beneficial for cottontails to increase the number of days with light rainfall in July and August than to increase the total precipitation for these months.

Another factor that may be important, especially during the spring and summer months when nestlings and juvenile cottontails are abundant, is the intensity of precipitation. An inch of rain that is accompanied by strongly blowing winds and falls in a short period of time would undoubtedly be more detrimental to cottontail populations than a gently falling inch of rain. Grinnel (1939) observed that downpours of heavy intensity during the winter resulted in fewer cottontails and jackrabbits in June in parts of California. In many cases, the frequency and intensity of precipitation may affect wildlife populations more than the total amount of rainfall.

Relationship of Cottontail Harvest to Crop Acreages

Cottontails, like other wildlife species, require suitable habitat in order to maintain their populations at respectable levels. No matter how favorable weather conditions are, rabbit populations will fail to maintain themselves without adequate food, water, and cover. Ideal cottontail habitat consists of about equally represented and we11-distributed cropland, grassland, woodland, and brushland on somewhat fertile agricultural lands (Crawford, 19 52).

Adequate cover is necessary throughout the year for cottontails. In the spring, the females need good nest sites. These sites can be provided in fallow fields, hayfields, and pasture (Beule and Studholme, 1942). Juveniles, and adults as well, need a food source and protection from rain, sun, heat, and predators during the spring and summer months. In the fall, cottontails become more vulnerable to predation after the crops are harvested and the frost reduces the green ground cover (Kline and Hendrickson, 1954). Allen (1939) stated that winter cover is more important to cottontails than at any other time of the year. Brush and heavy grasses are preferred winter cover (Hickie, 1940; Beule, 1946).

To determine the relationship of cottontail populations to land use, the acreages of crops obtained from annual summaries of Illinois agricultural statistics were correlated with cottontail harvest and census data. The linear correlation coefficients between crop acreages and the harvest statistic of the number of cottontails killed per hunter trip for the four game regions and for the entire state from 1956 through 1970 are shown in Table 19. Almost all of the correlation coefficients in Table 19 are significant ($P \leq 0.05$, 13 df) and are generally much higher than the correlation coefficients between weather parameters and rabbit harvest (Fig. 7 and Tables 6, 7, and 8). The cottontail harvest in Illinois from 1956 through 1970 appears to have been influenced more by the acreages of crops than by the weather parameters examined. Correlation values between cottontail census data and crop acreages were not as high as the cottontail harvest:crop acreage relationships.

Table 19. Correlation Coefficients Between Land Use (acres) and the Mean Number of Cottontails Killed Per Hunter Trip in Illinois Game Regions 2, 3, 4, 4a, and the Entire State, 1956-70

Land Use	Game Region				Entire State
	2	3	4	4a	
Harvested Corn	-0.51*	-0.54*	-0.67**	-0.66**	-0.71**
Harvested Soybeans	-0.84**	-0.42	-0.90**	-0.30	-0.82**
Total Row Crops Harvested	-0.80**	-0.56*	-0.90**	-0.70**	-0.86**
Harvested Oats	+0.76**	+0.64*	+0.94**	+0.80**	+0.93**
Harvested Wheat	+0.28	+0.24	+0.45	+0.58*	+0.49
Total Small Grains Harvested	+0.74**	+0.53*	+0.95**	+0.80**	+0.92**
Harvested Hay	+0.82**	+0.51*	+0.94**	+0.75**	+0.87**
Harvested Hay & Harvested Seed Crops	+0.75**	+0.55*	+0.94**	+0.75**	+0.87**
Plowland Pasture	+0.91**	+0.60*	+0.94**	+0.75**	+0.92**
Other Pasture	+0.80**	+0.64**	+0.95**	+0.83**	+0.91**
Total Pasture	+0.89**	+0.65**	+0.95**	+0.82**	+0.92**
All Other Land[a]	+0.09	-0.48	-0.70**	-0.55*	-0.63*
Harvested Small Grains, Harvested Hay & Seed Crops, Total Pasture, & All Other Land (Favorable Habitat)	+0.84**	+0.62*	+0.92**	+0.74**	+0.89**

*P≤0.05.

**P≤0.01.

[a]Consists mainly of farmsteads, land in federal farm programs, idle cropland, wasteland, and timber.

The relationship between the acreages of corn and soybeans and cottontail harvest is of particular interest since the primary reason for increasing summer rainfall is for the benefit of these two crops. The category of total row crops consists almost exclusively of the sum of the acreages of corn and soybeans. In all regions and for the entire state, the acreages of corn, soybeans, and total row crops were negatively correlated with the cottontail harvest (Table 19). In most cases, these relationships were significant ($P \leq 0.05$, 13 df). All the acreages of the other crops were positively correlated to the rabbit harvest with the exception of the All Other Land category.

The acreages of corn and soybeans during the study interval increased in every game region at the expense of such favorable cottontail crops as hay, pasture, and small grains (Fig. 12; Appendix A, Fig. 5; Table 20; Appendix B, Table 4). The most rapidly increasing crop was soybeans. Soybean acreage increased by 45% in Region 2, 33% in Region 3, 59% in Region 4, 14% in Region 4a, and 48% in the entire state from 1956 through 1970 (Table 20). The increase in corn acreage was not as great with increases of 6, 16, 20, 32, and 16% in Regions 2, 3, 4, 4a, and the entire state, respectively. The acreage of oats decreased more than any other crop with losses of 87, 83, 87, 85, and 79% in Regions 2, 3, 4, 4a, and the entire state, respectively. Small grains (wheat, oats, barley, and rye), hay, and total pasture have declined the greatest in both acreage (Table 20) and as a percentage of operated farm acreage (Appendix B, Table 4) in cash-grain Region 4.

An index to the total amount of favorable cottontail habitat in each game region during the study interval was needed in order to determine how much of the declining cottontail harvest was attributable to changes in land use and how much was attributable to weather influences. The index to the amount of favorable cottontail habitat selected in this study was the sum of the acreages of harvested small grains, harvested hay and seed crops, total pasture, and all other land. The category of all other land consists mainly of farmsteads, land in federal farm programs, idle cropland, wasteland, and timber. The components of the favorable habitat classification were all positively and significantly ($P \leq 0.05$, 13 df) correlated with the cottontail harvest with the exception of all other land (Table 19). All other land was negatively related to the rabbit kill in Regions 3, 4, 4a, and the entire state because its acreages rose during the study interval due to the increased land in the federal farm programs. The ecological status of land included in the all other land category, however, should be favorable to cottontails. Favorable habitat essentially includes the acreages of all crops except row crops, which consists primarily of corn and soybeans. Pasture, weeds, brush, legume crops, small grains, and grassy cover, which consist of the majority of the favorable habitat acreage, have been cited as vital for cottontail populations (Allen, 1939; Beule, 1946; Ecke, 1948; Crawford, 1952; Lord, 1963; Rose, 1972).

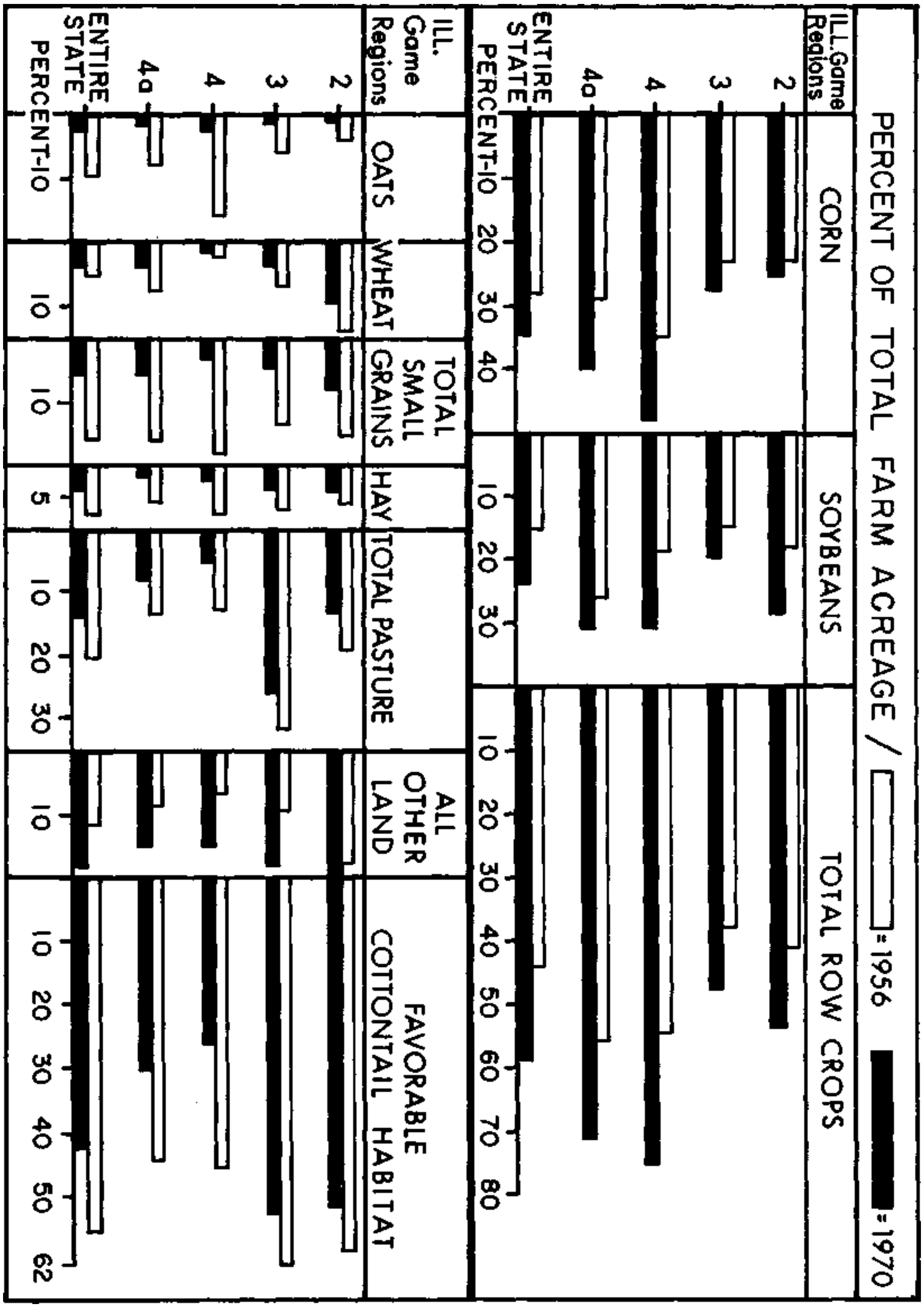
Favorable habitat was significantly related to cottontail harvest in Regions 2, 4, 4a and in the entire state ($P \leq 0.01$) and in Region 3 ($P \leq 0.05$) (Table 19). Favorable habitat accounted for 71, 38, 85, 55, and 79% of the variance (r^2) in the cottontail harvest for Regions 2, 3, 4, and 4a, and the entire state from 1956 through 1970. The linear regression equation for favorable habitat and cottontail harvest in Game Regions 2, 3, 4, 4a, and the entire state are presented in Appendix A, Figs. 6, 7, 8, 9, and 10, respectively. The acreages of favorable habitat in the game regions and in the entire state from 1956 through 1970 are provided in Appendix B, Table 5.

Table 20. Changes in land use between 1956 and 1970 for Illinois Game Regions 2, 3, 4, 4a, and the entire state.

Land Use	Game Regions: 2		3		4		4a		Entire State	
	Thousands of Acres	Percent Change	Thousands of Acres	Percent Change	Thousands of Acres	Percent Change	Thousands of Acres	Percent Change	Thousands of Acres	Percent Change
Harvested Corn	+103.7	+5.94	+138.1	+15.55	+501.2	+20.00	+281.5	+31.73	+1384.3	+15.90
Harvested Soybeans	+653.0	+45.48	+180.7	+32.63	+772.1	+59.35	+108.1	+13.67	+2229.8	+47.89
Total Row Crops Harvested	+746.9	+23.21	+314.2	+21.59	+1267.8	+32.63	+396.5	+23.53	+3557.1	+26.12
Harvested Oats	-248.9	-86.60	-182.3	-82.53	-980.0	-87.05	-192.2	-84.78	-2411.2	-70.22
Harvested Wheat	-234.8	-28.91	-121.3	-46.24	-67.1	-43.66	-126.0	-53.21	-586.8	-36.5[illegible]
Total Small Grains Harvested	-585.7	-48.34	-333.2	-64.67	-1053.6	-81.72	-330.4	-67.14	-3171.9	-65.29
Harvested Hay	-172.5	-36.95	-122.5	-44.35	-392.5	-71.64	-123.1	-70.46	-1255.6	-50.69
Harvested Hay and Harvested Seed Crops	-164.7	-32.87	-120.6	-45.30	-400.0	-71.76	-129.4	-71.06	-1338.6	-51.12
Plowland Pasture	-312.5	-56.53	-51.0	-25.31	-382.1	-86.31	-79.4	-68.10	-1195.5	-59.46
Other Pasture	-181.4	-18.92	-223.6	-22.17	-154.5	-32.75	-97.4	-32.55	-1140.6	-26.20
Total Pasture	-494.0	-33.09	-275.1	-22.70	-536.6	-58.68	-176.8	-42.09	-2336.1	-36.71
All Other Land[a]	+187.3	+13.47	+295.0	+77.10	+568.3	+122.06	+184.3	+71.13	+1315.6	+54.05
Harvested Small Grains, Harvested Hay and Seed Crops, Total Pasture, and All Other Land **(Favorable Habitat)**	-1057.1	-23.00	-442.9	-18.48	-1421.8	-44.06	-636.7	-58.92	-4031.0	-28.36
Operated Farm Acreage	-433.7	-5.94	-161.2	-4.17	-248.7	-3.30	-107.2	-3.54	-172.1	-5.55

[a] Consists mainly of farmsteads, land in federal farm programs, idle cropland, wasteland and timber.

Figure 12. Crops expressed as a percentage of total operated farm acreage in 1956 and 1970 for Illinois Game Regions 2, 3, 4, 4a, and the entire state. Favorable cottontail habitat is the sum of the acres of total small grains, hay, total pasture, and all other land.



In all regions and in the entire state, both the acreages and the percentage of operated farm acres of favorable habitat decreased and total row crops increased CTable 20; Appendix B, Table 4). Corn and soybeans do not adequately provide the food, nest cover, and protection from environmental factors and predation that cottontails require. Lord (1963) found that cottontails frequented hayfields more than corn and soybean fields during midsummer. The fall is a time of rapid decrease of cottontail populations probably due to predation (Beule, 1946; Kline and Hendrickson, 1954; Lord, 1961; Rose, 1972). It is interesting that the linear correlation coefficients of favorable habitat were higher with the rabbit harvest than with the July census (Appendix B, Table 6). This result infers that much of the effect of land use on cottontail populations occurred after July, probably during the fall and early winter months before the hunting season. After soybean fields are harvested, little protective cover is left. Cottontails then become concentrated in areas of favorable cover and this increased rabbit density could lead to greater predation rates and the spread of disease and parasites. Corn and soybeans also are of little value for nest sites during spring and summer.

Besadny (1963) noted that changes in agricultural practices (debrushing of fence rows, indiscriminate use of herbicides to control brush and weeds, and more intensive and efficient farming practices) adversely affected the cottontail harvest, which had steadily decreased in Wisconsin. Similar changes in farming practices in Illinois, in addition to the decline in the acreages of favorable habitat, would seemingly make habitat even more important to cottontail populations.

There was a decline of almost 5 million acres in the favorable habitat index in Illinois from 1956 through 1970 (Table 20). At the same time, total row crops in the state increased by 3.5 million acres. In 1956, 43.9% of the total operated farm acreage was planted to total row crops while 56.0% was occupied by favorable habitat (Appendix B, Table 4). In 1970, however, 58.6% of the farm acreage was accounted for by total row crops and favorable habitat was responsible for only 42.5%. Row crops now occupy more of Illinois' total farm acreage than all the other crops, wasteland, and timber combined. Region 4 underwent the greatest change in land use during the study interval. It lost over 1.4 million acres of favorable habitat that was replaced by almost 1.3 million acres of row crops.

A comparison of the acres of favorable habitat (Fig. 13) and the number of cottontails killed per hunter trip (Fig. 6) during the study interval show the high degree of correlation between these two parameters. All four game regions and the entire state had the highest number of cottontails killed per hunter trip in the first 3 years of the study interval (1956-58) when the amount of favorable habitat level was the highest. Regions 2, 3, and 4 had their highest years of cottontails killed per hunter trip in 1957, 1958, and 1956, respectively, when the number of acres of favorable habitat was at its highest level in each of these regions. The lowest number of cottontails killed per hunter trip in Region 4 occurred in 1967 when the acres of favorable habitat also reached their lowest level. The increase in

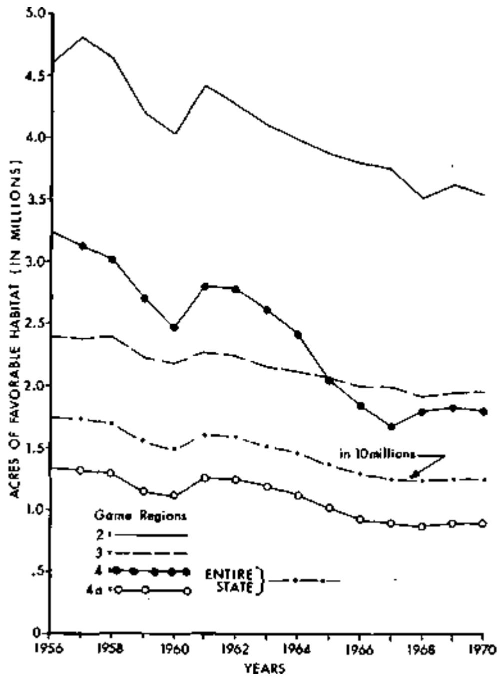


Figure 13. Acres of favorable cottontail habitat in Illinois Game Regions 2, 3, 4, 4a, and the entire state, 1956-70.

favorable habitat in 1961 (Fig. 13) was caused by the beginning of the Federal Feed Grain Program. Regions 2, 3, and the entire state responded with an increase in rabbit harvest (Fig. 6) over the 1960 level.

A comparison of the changes in favorable cottontail habitat, total row crops, and the number of cottontails killed per hunter trip in the four regions and the entire state between 1956 and 1970 are shown in Table 21.

Table 21. A Comparison of the Mean Number of Cottontails Killed Per Hunter Trip, Favorable Cottontail Habitat, and Total Row Crops From 1956 Through 1970 for Illinois Game Regions 2, 3, 4, 4a, and the Entire State

Game Region	Grand Mean Number of Rabbits Per Trip	Mean Percent[a] of Favorable Habitat	Mean Percent[a] of Total Row Crops	Change between 1956 & 1970		
				Mean Number of Rabbits Per Trip	% of[a] Favorable Habitat	% of[a] Total Row Crops
2	2.23	53.51	46.49	-1.40	-10.85	+12.50
3	2.26	56.96	43.04	-0.50	- 9.26	+10.12
4	1.35	34.41	65.59	-1.00	-19.07	+20.44
4a	1.69	37.06	62.94	-0.70	-13.87	+15.63
Entire State	1.79	48.77	51.23	-1.11	-13.53	+14.72

[a]Expressed as a percentage of operated farm acreage.

The region with the highest average of the number of cottontails killed per hunter trip from 1956 through 1970 was Region 3. This region also had the highest percentage of total farm acres in favorable habitat and the lowest percentage in total row crops. This trend is evident in the other game regions. The higher the percentage of the total farm acreage in favorable habitat, the higher the average number of cottontails killed per hunter trip from 1956 through 1970. Region 4 had the lowest average rabbit harvest, and, correspondingly, it had the lowest percentage of favorable habitat.

There are also some similarities in the changes in the number of cottontails killed per hunter trip and the changes in the percentage of favorable habitat and row crops between 1956 and 1970 (Table 21). The greatest decrease in the value of rabbits per trip occurred in Region 2 (-1.40 per trip). There was a substantial decrease in favorable habitat (-10.9%) and an increase in total row crops (+12.5%). The greatest change in the habitat occurred in Region 4 where the favorable habitat de creased 19.1% and total row crops increased 20.4%. The decrease in rabbits per trip in Region 4 was not quite as great as in Region 2. The smaller decrease in Region 4 may have resulted because there was less opportunity for a large decrease in the kill in Region 4 since the 1956 value was 1.9 rabbits per trip as compared with 2.9 for Region 2. Region 3 had the lowest decrease in the cottontail harvest and the smallest change in land use. It appears that the higher the index of favorable habitat for an area, the more likely the area is to have a higher number of cottontails killed per hunter trip. This trend was also reflected in the statewide data by a noticeable decrease in rabbits per trip and a corresponding substantial decrease in the favorable habitat index.

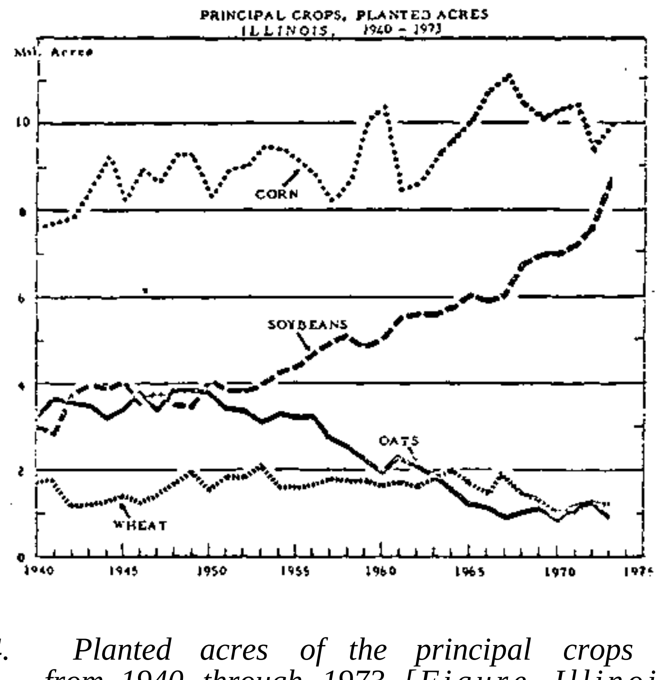


Figure 14. Planted acres of the principal crops in Illinois from 1940 through 1973 [Figure—Illinois Cooperative Crop Reporting Service, Illinois Agricultural Statistics, Crops, March, 1973].

The changes in the principal crops in Illinois (corn, soybeans, oats, and wheat) from 1940 through 1973 are given in Fig. 14. The acreages of soybeans are rapidly increasing with intentions of a 15% increase in 1973 over the 1972 level. Probably the major effect of a July-August cloud seeding program on Illinois cottontail populations, as well as other wildlife species, would not be the direct effect of increased rainfall on the animals, but the indirect effect of increased precipitation encouraging farmers to plant more acres of corn and soybeans, thereby further reducing what favorable wildlife habitat remains in Illinois. If corn and soybean acreages continue to increase because of precipitation enhancement or any other reason, we can expect a further decline in rabbit abundance and harvest, and, therefore, a reduction in the recreation which this species provides for sportsmen in Illinois.

Model for Illinois Cottontail Harvest

To better understand the decreasing success of cottontail hunters in Illinois and the factors influencing the decline, multiple regression equations were constructed for the four game regions based on data from 1956 through 1970. The dependent variable used was the number of cottontails killed per hunter trip. Equations with good predictability outside of the 1956 to 1970 interval were desired, but good predictability was difficult to achieve because of the limited years of rabbit data.

A good model should account for a significant proportion of the variance in the dependent variable. Because of the significant relationship of favorable habitat to cottontail harvest, it was included as an independent variable in the multiple regression equations involving weather parameters. A useful model should also contain an independent variable from the rabbit population because not all of the changes in rabbit numbers can be explained by habitat and weather. Innate properties of the rabbit that are numerically difficult to identify greatly influence population numbers. Wight (1959) tried to explain cottontail hunting success in Missouri on the basis of weather and cover conditions and concluded that the altered hunting success may be primarily determined by the reproductive physiology of rabbits themselves. The July census was used as a second independent variable. The July census was, perhaps, not as suitable for a population or reproductive indicator as desired, but it may be correlated to such immeasurable variables. The July census also gives an indication of the reproductive success during the spring and early summer. The July census combined with favorable habitat contributed more to the sum of squares of the multiple regression equations than favorable habitat combined with the March census, combinations of the March and July censuses, or log transformations of the censuses. The linear relationships between the July census and the rabbit harvest for Game Regions 2, 3, 4, and 4a from 1956 through 1970 are presented in Appendix A, Figures 11, 12, 13, and 14, respectively.

The third independent variable included in the multiple regression equations was the total snowfall for December through March preceding the hunting season. All of the weather parameters in Table 1 during single months and the critical periods were examined by stepwise multiple regression programs with the favorable habitat index and the July census included as independent variables. In all game regions, total snowfall for December through March in conjunction with favorable habitat and the July census gave consistent relationships with the rabbit harvest and increased the multiple regression coefficients by a noticeable amount. Maximum temperature from January through July and April through July, which was found to have some relationship to high and low years of cottontail harvest, contributed a negligible amount to the regional multiple correlation coefficients. Other weather parameters undoubtedly influenced the cottontail populations from 1956 through 1970, but these parameters and their effects were not revealed in the multiple regression analyses. There are other factors that should have been included in the multiple regression equations to present a more complete picture of Illinois cottontail populations. However, such things as predation, disease, population cycles, and reproductive characteristics are difficult to quantify.

The multiple regression equations for Regions 2, 3, 4, and 4a and their predicted results are presented in Appendix A, Figs. 15, 16, 17, and 18, respectively. The deviations between the observed and predicted cottontails per hunter trip are given in Appendix B, Tables 7, 8, 9, and 10 for Regions 2, 3, 4, and 4a, respectively. The linear correlation coefficients between the independent variables and the dependent variable of the multiple regression equations are given in Appendix B, Table 6.

The statistics of the multiple regression equations are presented in Table 22. The best relationship between each of the independent variables and the dependent variable was found to be linear. Second- and third-order independent variable terms did not add a significant amount to the sum of squares of the multiple regression. Interaction terms between the independent variables and log transformations of the independent variables also did not significantly increase the sum of squares of the multiple regression.

Examination of the standardized regression coefficients for the independent variables of the multiple regression equations in Table 22 reveals that the favorable habitat index accounted for most of the variance in the cottontails killed per hunter trip in the four game regions. Except for Region 4a, the standardized regression coefficient for the July census was greater than the standardized regression coefficient for total snowfall from December through March. Only the t values for favorable habitat were significant ($P \leq 0.05$, 11 df). All regression equations were significant ($P \leq 0.05$), and the multiple correlation coefficients (R) ranged from 0.94 for Region 4 to 0.75 for Region 3. The amount of variance that the favorable habitat index, the July census, and total snowfall for December through March accounted for in the number of cottontails killed per hunter trip in Regions 2, 3, 4, and 4a was 0.79, 0.56, 0.88, and 0.62, respectively.

The number of cottontails killed per hunter trip in 1971 as predicted by the regression equations formulated on data from 1956 through 1970 is given in Table 23. The 1971 agricultural data were not available for use

Table 22. Regression equation parameters for the number of cottontails killed per hunter trip based on 1996-70 data.

Game Region	Independent Variable	Dependent Variable Intercept	Regression Coefficients	Standardized Regression Coefficients	t-values (11 d.f.)	Correlation Coefficients (r) Between the Independent Variables and the Dependent Variable (13 d.f.)	Multiple Correlation Coefficient (R)	Coefficient of Determination (R^2)	F(3,11 d.f.) Value
2	Favorable Habitat	-0.9523	7.605×10^{-7}	0.709	4.462[a]	+0.84[a]	0.89	0.79	13.300[a]
	July Census		1.300×10^{-2}	0.170	0.889	+0.61[a]			
	December-March Snowfall		-9.400×10^{-3}	-0.167	-0.943	-0.49			
3	Favorable Habitat	-0.5540	1.191×10^{-6}	0.579	2.870[a]	+0.62[a]	0.75	0.56	4.587[a]
	July Census		2.830×10^{-2}	0.355	1.738	+0.44			
	December-March Snowfall		-6.300×10^{-3}	-0.166	-0.817	-0.24			
4	Favorable Habitat	-0.0643	5.662×10^{-7}	0.790	4.006[a]	+0.92[a]	0.94	0.88	27.829[a]
	July Census		3.110×10^{-2}	0.173	0.874	+0.84[a]			
	December-March Snowfall		-5.500×10^{-3}	-0.124	-1.115	-0.07			
4a	Favorable Habitat	-0.0497	1.623×10^{-6}	0.674	3.495[a]	+0.74[a]	0.79	0.62	6.089[a]
	July Census		3.520×10^{-2}	0.134	0.701	+0.33			
	December-March Snowfall		-9.800×10^{-3}	-0.225	-1.201	-0.35			

[a] $\underline{P} \leq 0.05$.

Table 23. Data for the Multiple Regression Equations of Game Regions 2, 3, 4, and 4a and the Corresponding Predicted Number of Cottontails Killed Per Hunter Trip; 1971

Game Region	Year	Acres of Favorable Habitat	July Census	Snowfall For Dec-March	Observed Kill	Predicted Kill	Deviation of Observed - Predicted Kill	% Error Deviation Over Observed Kill
2	1970	3,538,200	14	29.8	1.5			
	1971	3,361,888	11	6.9	1.4	1.68	-0.28	-20.0
3	1970	1,953,100	7	24.7	1.9			
	1971	1,817,293	19	9.7	1.9	2.09	-0.19	-10.0
4	1970	1,804,900	4	28.4	0.9			
	1971	1,653,274	3	14.1	0.7	0.89	-0.19	-27.1
4a	1970	887,300	2	30.5	1.3			
	1971	852,057	4	10.4	1.1	1.37	-0.27	-24.6

in the formation of the multiple regression equations. In all regions, the 1971 predicted kill was greater than the 1971 observed kill. This lower than expected kill may have partially resulted from the unusually light accumulation of total snowfall for December through March. The percentage error in the 1971 predicted kill ranged from 27.1% for Region 4 to 10.0% for Region 3. In 1971, the acres of favorable habitat continued to decrease in all regions and the cottontail kill decreased in all regions except Region 3, where there was no change from 1970.

SUMMARY AND CONCLUSIONS

The purpose of this research project was to evaluate relationships between Illinois weather and cottontail populations from 1955 through 1971. The basic tasks undertaken were 1) the determination of relationships of monthly weather parameters to indices of cottontail abundance and harvest, 2) determination of relationships of weather parameters during critical periods of the rabbit's life cycle to rabbit harvest, 3) determination of the effect of total precipitation on cottontail harvest, 4) determination of the relationships of crop acreages to cottontail harvest, and 5) the modeling of weather, crop, and cottontail data. A contiguous 68-county block of Illinois was examined. This area consisted of four game regions (Preno and Labisky, 1971) that encompassed most of Illinois except for the northern, northwestern, and southern extremes.

Linear correlation and stepwise multiple regression analyses of monthly weather parameters with cottontail harvest and census data revealed that several weather parameters were associated with fluctuations in cottontail abundance during the study interval. The cottontail populations were apparently influenced by several weather factors during the same year and the same weather factor affected the rabbit populations differently at various times of the same year. Generally, during the months of December, February, and March, snowfall was unfavorable to cottontail populations. Warm temperatures in January along with precipitation were weakly favorable to Illinois rabbits. During the spring, cottontails were unfavorably related to the percentage of possible sunshine in March, and warm temperatures and total precipitation in April. Cottontails reacted favorably to precipitation and reduced sunshine in July. Minimum temperature in August was favorable. The number of days with precipitation ≥0.10 inch during September and October were negatively correlated with the rabbit data.

Examination of cottontail harvest data with weather factors during critical periods of the cottontail life cycle revealed relationships similar to those just discussed. In all game regions, maximum temperature was negatively related to cottontail harvest in the first half of the year. Minimum temperature was favorably related to hunter success during the period of May through September. Warm fall temperatures were positively correlated with the rabbit harvest. Mean monthly temperature in August and October and maximum temperature in September were favorably related in all of the regions to the rabbit kill. Total precipitation in the months of January and April appeared unfavorable to rabbit harvest and total precipitation during the hunting season months of November and January apparently favored hunter success. The number of days with precipitation ≥0.10 inch during the summer months of May through August and July through August favored the cottontail harvest. However, in the fall from September through November, the number of days with light rain was negatively correlated to the rabbit kill. Total snowfall during the winter and spring months was negatively correlated with cottontail harvest but snowfall and snowcover during the hunting season apparently favored the hunters rather than the cottontails. The percentage of possible sunshine was negatively correlated with the cottontail kill throughout the winter, spring, and early summer months.

The weather parameter that had the best relationship with high and low years of cottontail harvest was total snowfall from December through March. Years of heavy snowfall, especially in February and March, tended to be related to a decrease in cottontail hunter success in the fall. Heavy snowfall during the late winter months may decrease the breeding stock of cottontails, reduce their physical condition, and delay the onset of the breeding season, which may result in lessened juvenile reproduction.

Generally, the magnitudes of the linear correlation coefficients between weather and cottontail population parameters were well below the 5% level of significance.

The effects of monthly precipitation on the cottontail populations varied throughout the year. Positive correlation of population parameters with precipitation occurred in February, May-June-July, and November. Negative correlation of cottontail abundance indices with total precipitation occurred in January, April, and September-October. The most critical months for precipitation appeared to have been April and July. Precipitation in April was negatively related to the cottontail populations and precipitation in July was positively correlated.

Total precipitation during the period of May through August was positively correlated with cottontail harvest and appeared more important than total precipitation during any other period of the rabbit's life cycle. Precipitation in the summer months has a favorable effect on vegetation which is vital to cottontail nutrition, protection, and reproduction.

Based on data from 1956 through 1971, increased total precipitation in July and August that does not exceed normal limits would be expected to have little direct effect on the cottontail harvest. The number of days with precipitation ≥0.10 inch generally had higher correlation coefficients than total precipitation with cottontail populations in the summer months and during other times of the year.

Cottontail harvest had a significant and negative correlation with corn and soybean acreages. Both of these row crops increased in the game regions and in the entire state from 1956 through 1970, and the soybean increase was remarkable. The index to favorable cottontail habitat substantially decreased during the study period with corn, soybeans, modern farming techniques, and urban expansion being the principal reasons for the decline.

Models for the cottontail harvest from 1956 through 1970 in the game regions include the independent variables of the favorable habitat index, the July census, and total snowfall from December through March. The favorable habitat index was the most important of the independent variables. The models accounted for 79, 56, 88, and 62% of the variance in the cottontail harvest data in Game Regions 2, 3, 4, and 4a, respectively.

It appeared that the decreases in Illinois cottontail populations was due primarily to habitat deterioration. It is the amount and quality of the habitat that determines the carrying capacity for animals, and any abnormal weather factor, such as heavy snowfall, can cause fluctuations around the level determined by the habitat. The cottontail in Illinois evolved under the climate prevailing in this region. However, climate is the interaction of many measurable and immeasurable factors. Climatic factors that biologists feel are important to rabbits or the parameters measured at weather stations may vary greatly from the climatic factors that influence the numbers of cottontails. It is difficult to single out one or a few weather factors and say that they are the most influential weather parameters on cottontail populations. Any weather factor may affect animal populations if it becomes exceedingly extreme. A number of weather factors acting at different times of the year and interacting among themselves are important to the overall picture of cottontail:weather relationships. Perhaps more complex computer modeling of the future may give a more complete answer to weather:animal interactions.

Although the direct effect of precipitation enhancement would not appear to jeopardize cottontail abundance, we cannot say that increased precipitation would not be important. The study interval was not long enough to get the true picture of the cottontail:precipitation relationship. There may be other species of wildlife that are more sensitive to precipitation or changes in precipitation than cottontails. Although additional summer rainfall in moderate amounts may favor the growth of succulent vegetation that is necessary for the maintenance and growth of cottontails, succeeding years of increased summer rainfall may favor succession to more mesic types of plants that may be favorable or unfavorable to different species of animals. If the changes in the type of vegetation are great enough, an entirely different community of plants and animals will exist. Animals that cannot adapt to or exist in the new habitat will be replaced by ones that can.

Other indirect effects of increased precipitation must be considered. The types of diseases, the susceptibility to diseases, changes in reproductive rates., changes in predation or other such factors that influence populations but are hard to quantify would not be revealed in a study such as mine. Cottontail populations are strongly tied to the kinds of crops grown in Illinois. The two crops of primary importance to the Precipitation Enhancement Program are corn and soybeans. Corn and soybeans are significantly and negatively correlated with cottontail populations. Precipitation enhancement along with the recent high prices offered for cash-grain crops , would very probably influence farmers to increase corn and soybean acreage. This increase would result in a reduction of favorable habitat not only for cottontails, but for other wildlife species as well.

RECOMMENDATIONS

Other game species in Illinois should be examined to determine the relationship between total summer precipitation and their population numbers. The bobwhite quail (Colinus virginianus) would be the next logical choice because of its high population densities near the Precipitation Enhancement Study Area. There are also intensive quail data available near the Precipitation Enhancement Project center for two study areas in Marion and Wayne Counties from 1963 through 1972 as well as the extensive population data in Preno and Labisky (1971). Precipitation may affect birds differently than mammals.

To gain a better understanding of weather:animal relationships, more than 15 or 16 years of population data are desired. A longer time span would allow population fluctuations or cycles to be more clearly defined, it would also better show relationships between years of abnormal weather and animal populations, and it would provide more degrees of freedom for modeling of the populations.

Weather effects on populations numbers may be more refined on a smaller study area with a population of known size and where exact measurements of weather parameters, including ones that may be of biological importance but are not measured at weather stations, are possible. Climatological chambers in which environmental factors can be controlled may yield valuable information on the direct effect of increased precipitation on a given animal species.

REFERENCES

Allen, D. L., 1938: Breeding of the cottontail rabbit in southern Michigan. American Midland Naturalist, 20, No. 2, 464-469.

Allen, D. L., 1939: Michigan Cottontails in winter. Journal of Wildlife Management, 3, No. 4, 307-322.

Allen, D. L., 1954: Our Wildlife Legacy. Funk and Wagnalls, New York, 422 pp.

Andersen, J., 1952: Fluctuations in the field hare population in Denmark compared with certain climatic factors. Papers of Game Research, 8, 41-43.

Atzenhoefer, D., 1953: Rabbit nests are death traps. . .sometimes. Ohio Conservation Bulletin, 17, No. 6, 10-11.

Bailey, J. A., 1968: Regionwide fluctuations in the abundance of cottontails. North American Wildlife and Natural Resources Conference Transactions, 33, 265-277.

Bailey, J. A., 1969: Trap responses of wild cottontails. Journal of Wildlife Management, 33, No. 1, 48-58.

Barklow, F. S., Jr., 1962: Latitude related to reproduction in the cottontail rabbit. Journal of Wildlife Management, 26, No. 1, 32-37.

Besadny, C. D., 1963: Wisconsin cottontails. Wisconsin Conservation Bulletin, 28, No. 5, 13-15.

Beule, J. D., 1946: The cottontail rabbit in Pennsylvania. Pennsylvania Game Commission, Pittman—Robertson Project 6 - R, 58 pp.

Beule, J. D., 1947: Pennsylvania's Cottontail problem. Pennsylvania Game News, 18, No. 2, 10-13, 34-37.

Beule, J. D., and A. T. Studholme, 1942: Cottontail rabbit nests and nestlings. Journal of Wildlife Management, 6, No. 2, 133-140.

Carson, J. D., and D. E. Cantner, 1963: West Virginia Cottontails. Division of Game and Fish, West Virginia Department of Natural Resources, Charleston, West Virginia, 24 pp.

Casteel, D. A., and W. R. Edwards, 1964: Two instances of multiparous juvenile cottontails. *Journal of Wildlife Management*, 28, No. 4, 858-859.

Changnon, S. A., Jr., and F. A. Huff, 19 71: *Evaluation of potential benefits of weather modification on agriculture*. Illinois State Water Survey, University of Illinois, Urbana, 77 pp.

Conaway, C. H., and H. M. Wight, 1962: Onset of reproductive season and first pregnancy of the season in cottontails. *Journal of Wildlife Management*, 26, No. 3, 278-290.

Conaway, C. H., H. M. Wight, and K. C. Sadler, 1963: Annual productivity by a cottontail population. *Journal of Wildlife Management*, 27, No. 2, 171-175.

Crawford, B. T., 1952: The Ozark rabbit dilemma. *Missouri Conservationist*, 13, No. 12, 4-5.

Dalke, P. D. , 1937: A preliminary report of the New England cottontail studies. *North American Wildlife Conference Transactions*, 2, 542-548.

Dalke, P. D., and P. R. Sime, 1938: Home and seasonal ranges of the eastern cottontail in Connecticut. *North American Wildlife Conference Transactions*, 3, 659-669.

Dell, J., 1951: Cottontail. *The New York State Conservationist*, 5, 16-17.

Dell, J., 1958: Rabbit season. *The New York State Conservationist*, 12, No. 4, 12-13.

Dinesman, L. G., 1960: The effect of snow depth upon the destructive activity of hares in the southern regions of European Russia. *Trudy Inst. Lesa Akad. Nauk SSSR*, 48, 189-199.

Dudley, E. F. , 1963: *Age structure of populations of Michigan cottontail rabbits (Sylvilagus floridanus) as determined by an improved lens weight technique for age determination*. Ph.D. Thesis, University of Michigan, Ann Arbor, 139 pp.

Dusi, J. L., 1952: The food habits of several populations of cottontail rabbits in Ohio. *Journal of Wildlife Management*, 6, No. 2, 180-186.

Ecke, D. H., 1948: *The cottontail rabbit in central Illinois*. M. S. Thesis, University of Illinois, Urbana, 136 pp.

Ecke, D. H., 1955: The reproductive cycle of the mearns cottontail in Illinois. *American Midland Naturalist*, 53, 294-311.

Edwards, W. R., 1964a: *Population dynamics of the cottontail rabbit*. Illinois Cooperative Wildlife Research, Pittman—Robertson Project W-66-R-4, 14 pp.

Edwards, W. R., 1964b: Evidence for a normal age composition for cottontails. Journal of Wildlife Management, 28, No. 4, 738-742.

Evans, R. D., K. C. Sadler, C. H. Conaway, and T. S. Baskett, 1965: Regional comparison of cottontail reproduction in Missouri. American Midland Naturalist, 74, No. 1, 176-184.

Fitch, H. S., 1947: Ecology of the cottontail rabbit (Sylvilagus audubonii) population in central California. California Game and Fish, 33, 159-184.

Grinnel, J., 1939: Effects of a wet year on mammalian populations. Journal of Mammalogy, 20, No. 1, 62-64.

Hamilton, W. J., Jr., 1940: Breeding habits of the cottontail rabbit in New York State. Journal of Mammalogy, 21, No. 1, 8-11.

Hanson, J. C., J. A. Bailey, and R. J. Siglin, 1969: Activity and use of habitat by radio tagged cottontails during winter. Illinois State Academy of Science, 62, No. 3, 294-302.

Haugen, A. 0., 1942: Life history studies of the cottontail rabbit in southwestern Michigan. American Midland Naturalist, 28, No. 1, 204-244.

Heard, L. P., 1962: Rabbit studies. Missouri Game and Fish Commission, Pittman—Robertson Project W-48-R, 28 pp.

Hickie, P., 1940: Cottontails in Michigan. Game Division, Michigan Department of Conservation, 109 pp.

Hill, E. P., III, 1965: Some effects of weather on cottontail reproduction in Alabama. S. E. Association Game and Fish Commission Conference Proceedings , 19 , 48-57.

Hill, E. P., III, 19 72: The cottontail rabbit in Alabama. Agricultural Experiment Station Bulletin 440, Auburn University, 103 pp.

Illinois Cooperative Crop Reporting Service, 1956-1972: Assessors' annual farm census, Illinois Agricultural Statistics, S.F.C. - 19-35.

Ingles, L. G., 1941: Natural history observations on the Audubon cottontail. Journal of Mammalogy, 22, No. 3, 227-250.

Johnson, A. M., and G. 0. Hendrickson, 1958: Effects of weather conditions on the winter activity of mearns cottontail. Proceedings of the Iowa Academy of Science, 65, 554-558.

Kline, P. D., 1962: Vernal breeding of cottontails in Iowa. Proceedings of the Iowa Academy of Science, 69, 244-252.

Kline, P. D., and G. 0. Hendrikson, 1954: Autumnal decimation of mearns cottontails in Decatur County, Iowa, 1952: Proceedings of the Iowa Academy of Science, 61, 524-527.

Kriz, J. J., 1971: The ups and downs of rabbits. Pennsylvania Game News , 42, No. 5, 7-13.

Leopold, A., and H. G. Anderson, 1938: The 1936 cottontail scarcity in Wisconsin. Journal of Mammalogy, 19, No. 1, 110-111.

Linder, P., and G. 0. Hendrickson, 1956: Use of rearing cover by mearns cottontail. Proceedings of the Iowa Academy of Science, 63, 732-736.

Linduska, J. P., 1947: Winter den studies of the cottontail in southern Michigan. Ecology, 28, 448-454.

Lord, R. D., Jr., 1958: The importance of juvenile breeding to the annual cottontail crop. North American Wildlife Conference Transactions, 23, 269-275.

Lord, R. D., Jr., 1960: The eyes have it. Illinois Wildlife, 15, No. 4, 4-5.

Lord, R. D., Jr., 1961a: Magnitudes of reproduction in cottontail rabbits. Journal of Wildlife Management, 25, No. 1, 28-33.

Lord, R. D., Jr., 1961b: Mortality rates of cottontail rabbits. Journal of Wildlife Management, 25, No. 1, 33-40.

Lord, R. D., Jr., 1963: The cottontail rabbit in Illinois. Illinois Department of Conservation, Technical Bulletin, No. 3, 94 pp.

Marsden, H. M. , and C. H. Conaway, 1963: Behavior and the reproductive cycle in the cottontail. Journal of Wildlife Management, 27, No. 2, 161-170.

Meslow, E. C. and L. B. Keith, 1971: A correlation analysis of weather versus snowshoe hare population parameters. Journal of Wildlife Management, 35, No. 1, 1-15.

Mossman, A. S. , 1955: Reproduction of the brush rabbit in California. Journal of Wildlife Management, 19, No. 2, 177-184.

Myers, K., and W. E. Poole, 1961: A study of the biology of the wild rabbit, Oryctolagus cuniculus in confined populations. CSIRO, 6, No. 1, 1-41.

Negus, N. C., 1959: Breeding of subadult cottontail rabbits in Ohio. Journal of Wildlife Management, 23, No. 4, 451-452.

Page, J. L., 1949: Climate of Illinois: summary and analysis of long-time weather records. Agricultural Experiment Station Bulletin No. 532, University of Illinois, Urbana, 364 pp.

Pelton, M. R., 1969: The incidence of young of the year breeding by Georgia cottontails. Proceedings of the 23rd Annual Conference of the S. E. Association Game and Fish Commissioners, 182-184.

Preno, W. L., and R. F. Labisky, 1971: Abundance and harvest of doves, pheasants, bobwhites, squirrels, and cottontails in Illinois, 1956-69: Illinois Department of Conservation and Illinois Natural History Survey, Technical Bulletin No. 4, 76 pp.

Redd, J. B., Jr., 1956: A closer look at the cottontail rabbit. Virginia Wildlife, 17, No. 12, 18-19, 25.

Rose, G. B., 1972: Evaluation of factors affecting the ecology and management of cottontail rabbits. Illinois Department of Conservation and Illinois Natural History Survey, Pittman—Robertson Project W-66-R, 17 pp.

Ross, R. C, and H. C. M. Case, 1956: Types of farming in Illinois: an analysis of differences by areas. Agricultural Experiment Station Bulletin No. 601, University of Illinois, Urbana, 88 pp.

Schierbaum, D., 1965: Evaluation of cottontail rabbit productivity. New York Conservation Department. Pittman—Robertson Project W-84-R-11, 16 pp.

Schultz, V., 1951: Game mortality resulting from a severe snow and ice storm in Tennessee. 5th Annual Meeting of the S. E. Association of Game and Fish Commissioners, 1-23.

Schwartz, C. W., 1942: Breeding season of the cottontail in central Missouri. Journal of Mammalogy, 23, No. 1, 1-16.

Sheffer, D. E., 1957: Rabbit propagation experiments. Maryland Conservationist , 35, No. 3, 6-8.

Shelford, V. E., 1951: Fluctuations of nonforest animal populations in the upper Mississippi basin. Ecological Monographs 21, 149-181.

Siivonen, L. , 1956: The correlation between the fluctuations of partridge and European hare populations and the climatic conditions of winters in southwest Finland during the last 30 years. Papers on Game Research, Finnish Game Foundation, 17, 1-30.

Siltman, D. B., W. C. Rollins, K. Siltman, and R. B. Casady, 1964: Seasonal variation in reproductive traits of New Zealand white rabbits. Journal of Reproduction and Fertility, 8, 29-37.

Steele, J. L., 1957: Wildlife and the big blizzard. Oklahoma Game and Fish News, 13, No. 6, 14-15.

Sweetman, H. L., 1949: Further studies of the winter feeding habits of cottontail rabbits. Ecology, 30, No. 3, 371-376.

Trethewey, D. E., and B. J. Verts, 1971: Reproduction in eastern cottontail rabbits in western Oregon. American Midland Naturalist, 86, No. 2, 463-476.

U. S. Department of Commerce, 1955-1971: Climatological data, 60, No. 1, — 76, No. 12.

Wainwright, L. C., 1969: A literature review on cottontail reproduction. Colorado Division of Game, Fish and Parks, Special Report No. 19, 24 pp.

Wight, H. M. , 1959: Eleven years of rabbit population data in Missouri. Journal of Wildlife Management, 23, No. 1, 34-39.

Wight, H. M., and C. H. Conaway, 1961: Weather influences on the onset of breeding in Missouri cottontails. Journal of Wildlife Management, 25, No. 1, 87-89.

Wight, H. M., and C. H. Conaway, 1962: Determination of pregnancy rates of cottontail rabbits. Journal of Wildlife Management, 26, No. 1, 93-95.

APPENDIX A

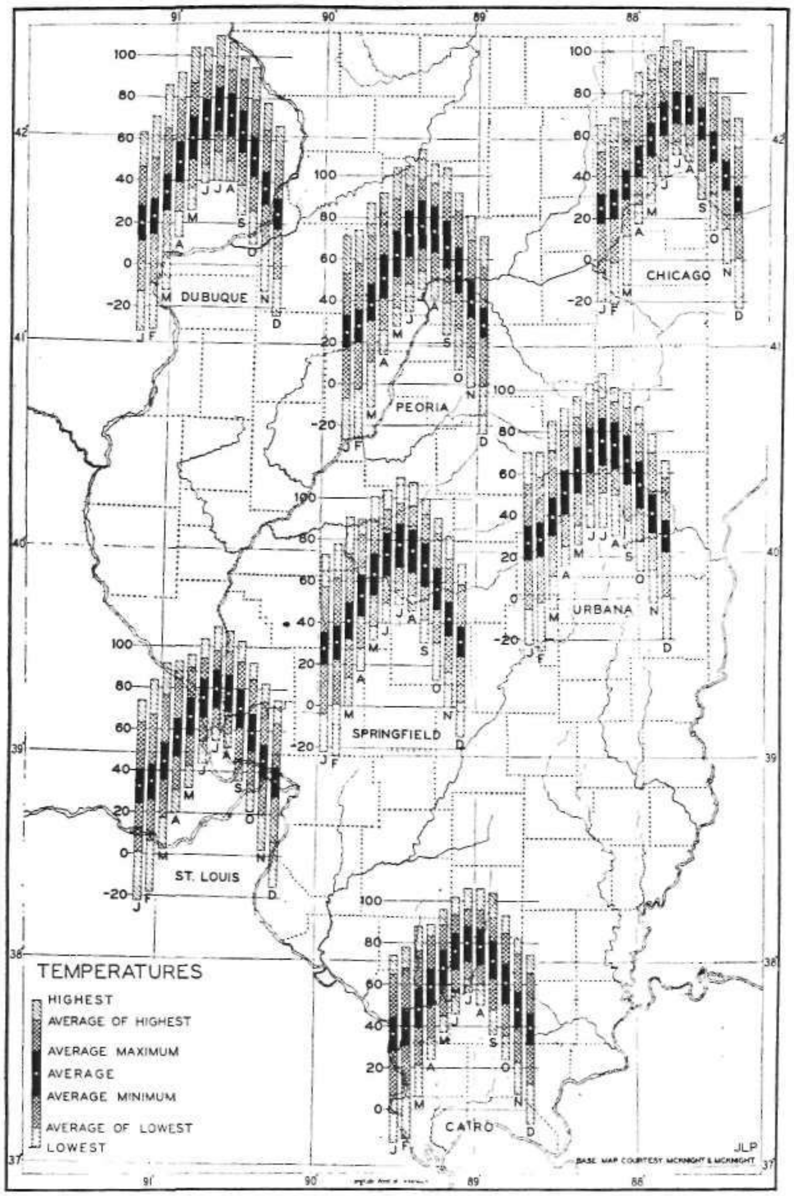


Figure 1. Average temperatures, average extremes, and extremes for each month of seven long-record stations (° F.). Highest and lowest temperatures each month are the extremes regardless of year; average of highest and average of lowest are averages of monthly extremes for all years; average maximum and average minimum for each month are the averages of daily extremes for all years [Figure and legend–Page, 1949].

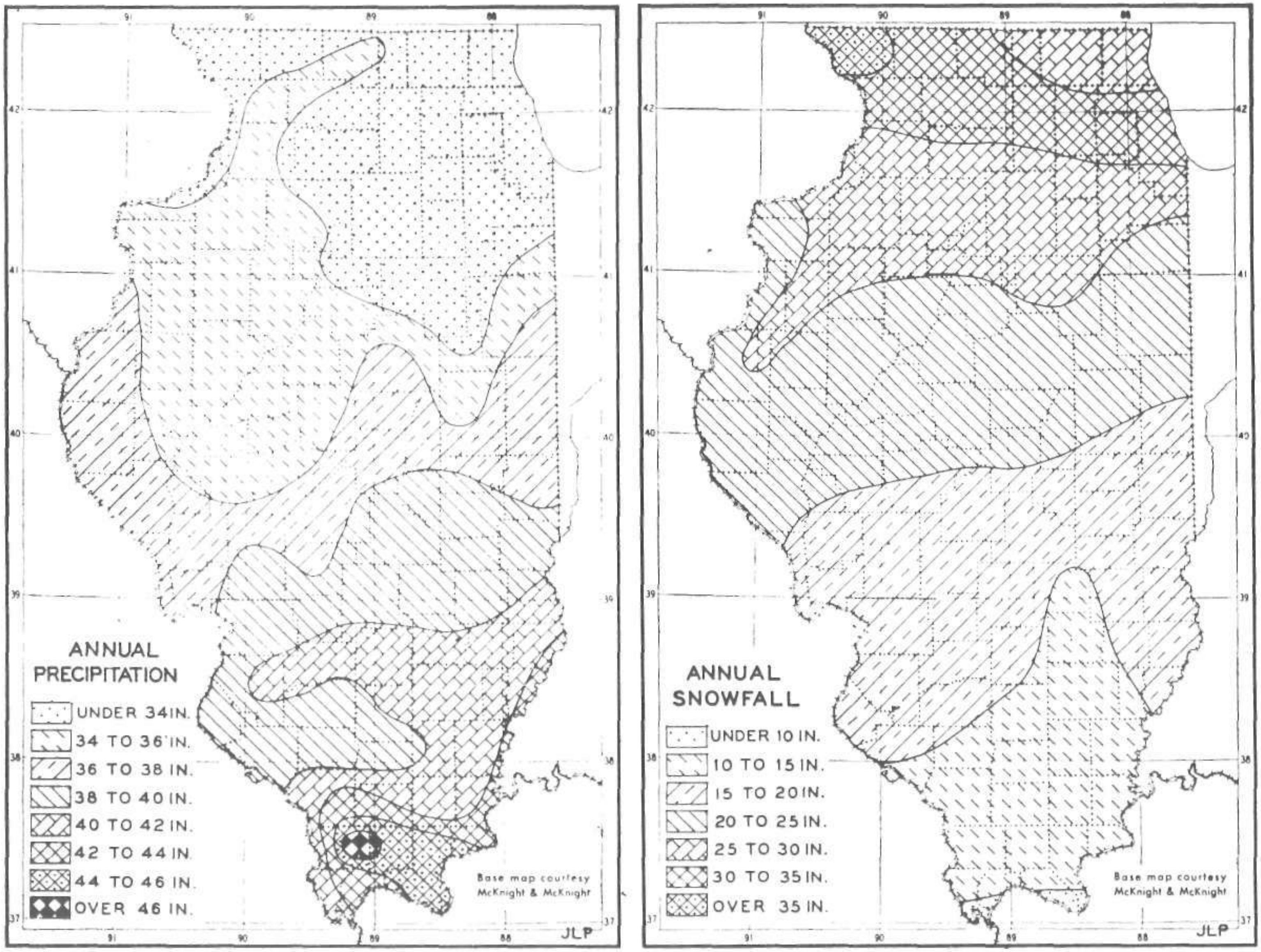


Figure 2. Distribution of average annual precipitation and snowfall in Illinois. There is a decrease in precipitation and snowfall from south to north [Figure--Page, 1949].

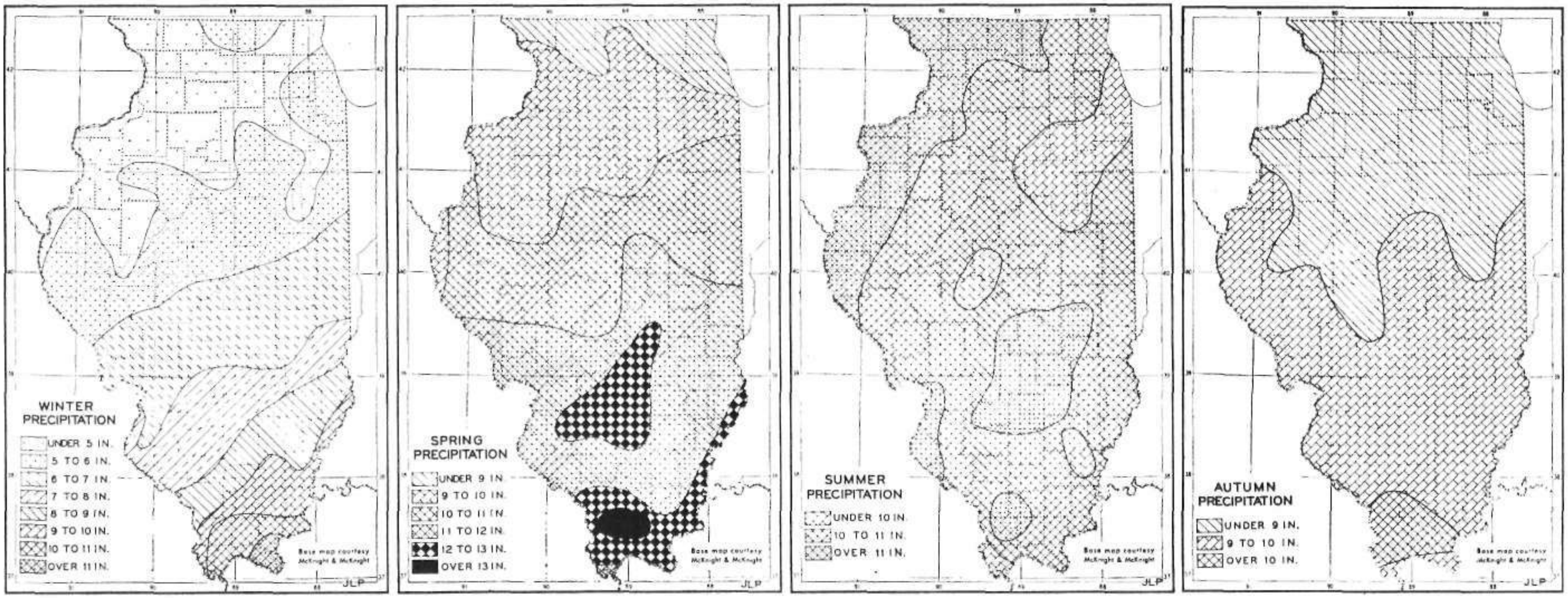


Figure 3. Winter, spring, summer, and autumn precipitation in Illinois, Total precipitation is greale?? in soutuern Illinois during the winter, spring, and autumn, but there is less variation throughout the state in the summer [Figure–Page, 1949].

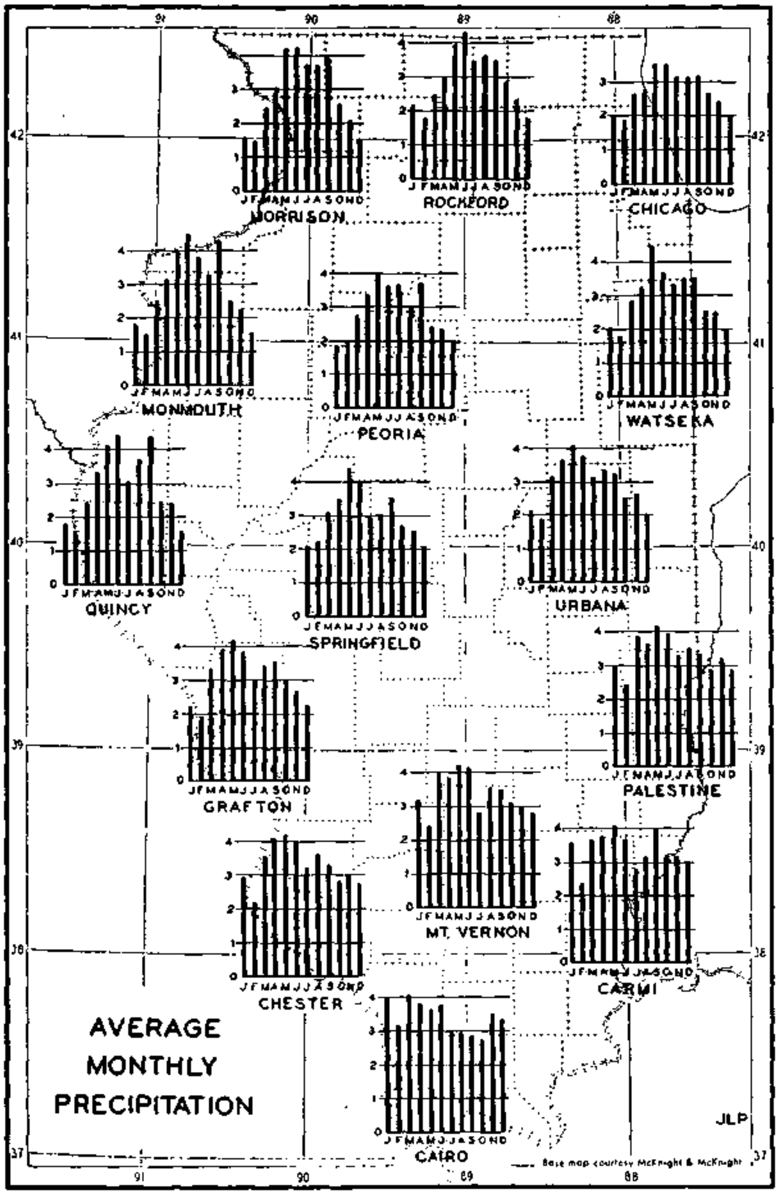


Figure 4. Average monthly precipitation, in inches, throughout Illinois. Southern Illinois receives more total precipitation, but the amount during the growing season is about the same throughout the state [Figure—Page 1949].

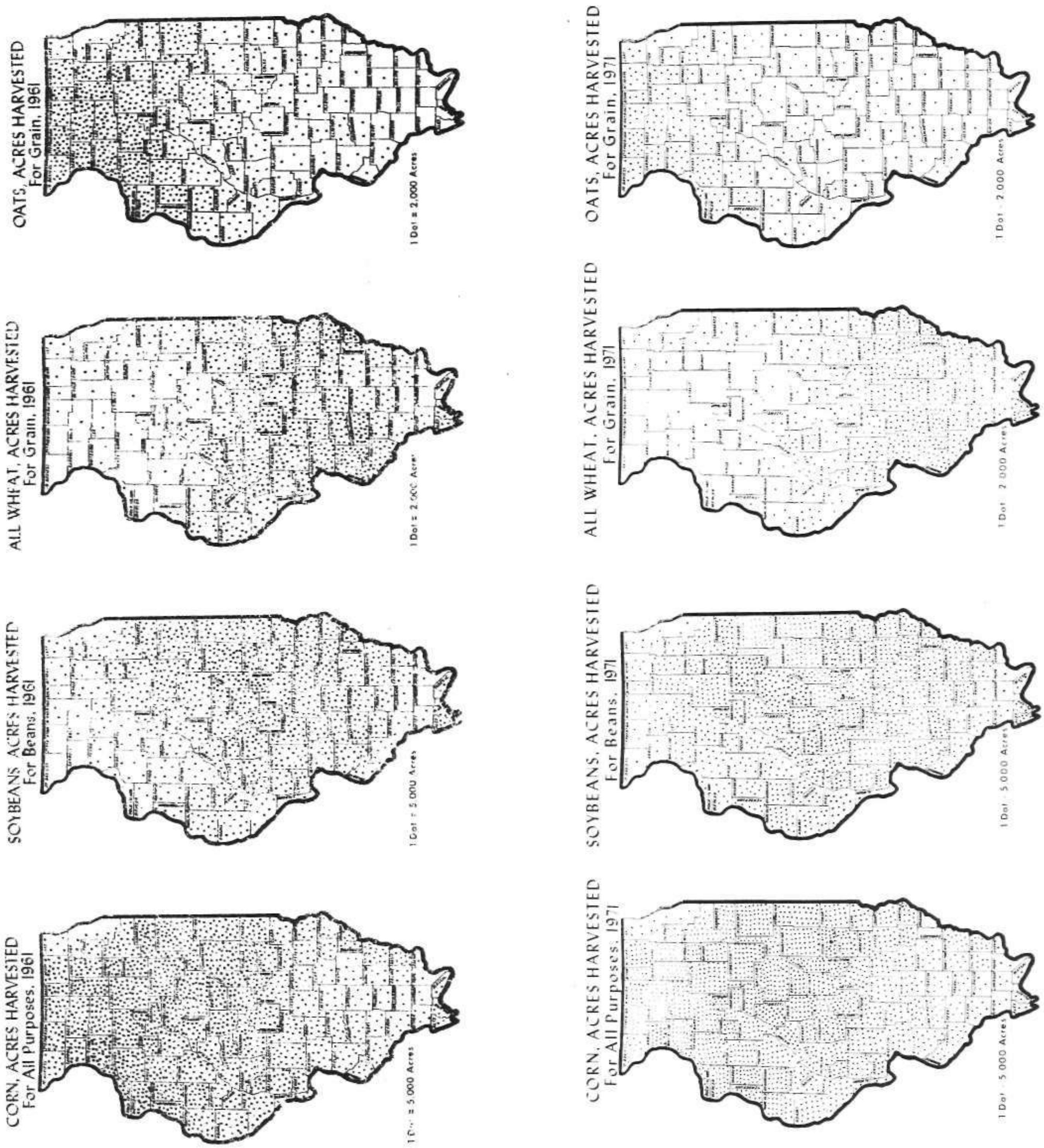


Figure 5. *Distribution of the principal crop acreages in Illinois for 1961 and 1971 [Maps—Illinois Cooperative Crop Reporting Service, Illinois Agricultural Statistics, S.F.C.-25, 1962, and S.F.C.-35, 19721.*

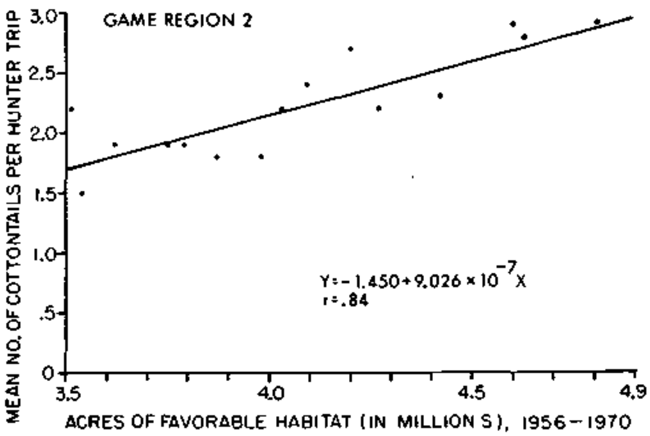


Figure 6. Relationship between the acres of favorable cottontail habitat and the mean number of cottontails killed per hunter trip in Illinois Game Region 2, 1956-70 ($P<0.01$, 13df)

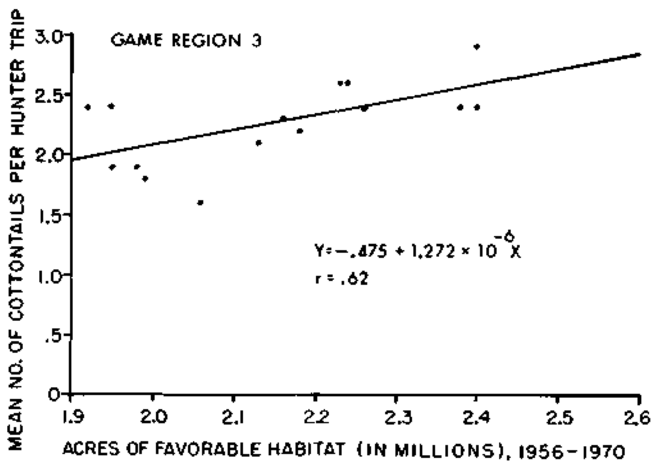


Figure 7. Relationship between the acres of favorable cottontail habitat and the mean number of cottontails killed per hunter trip in Illinois Game Region 3, 1956-70 ($P<0.05$, 13df)

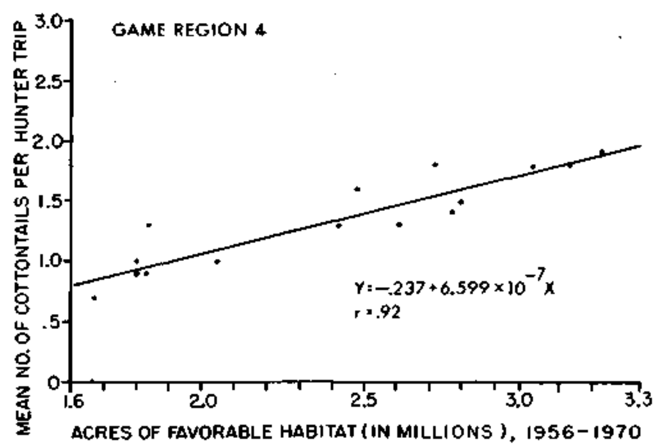


Figure 8. Relationship between the acres of favorable cottontail habitat and the mean number of cottontails killed per hunter trip in Illinois Game Region 4, 1956-70 ($P<0.01$, 13df)

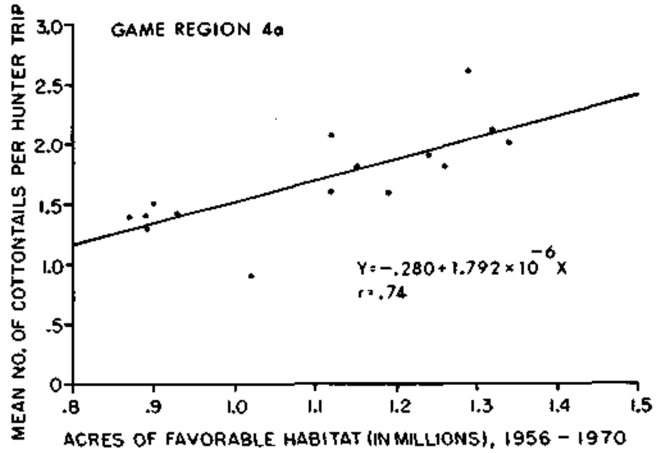


Figure 9. Relationship between the acres of favorable cottontail habitat and the mean number of cottontails killed per hunter trip in Illinois Game Region 4a, 1956-70 ($P<0.05$, 13df)

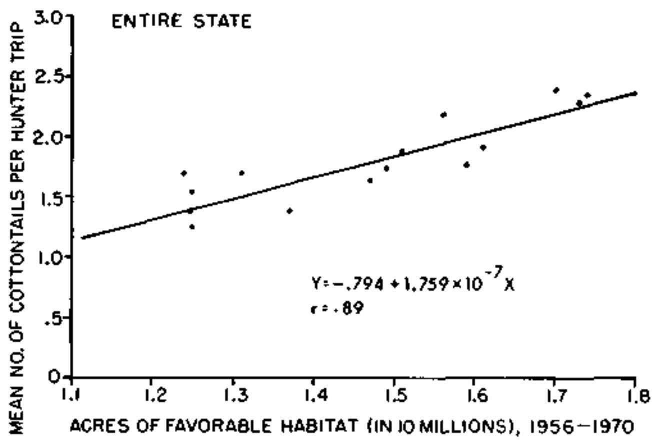


Figure 10. Relationship between the acres of favorable cottontail habitat and the mean number of cottontails killed per hunter trip in Illinois, 1956-70 ($P<0.01$, 13df)

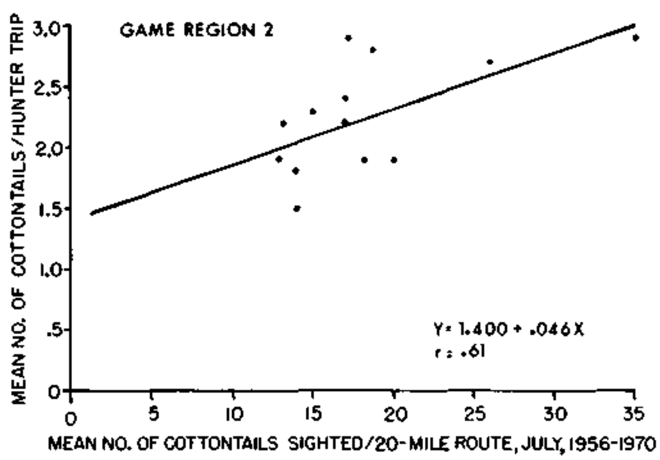


Figure 11. Relationship between the July cottontail census and the number of cottontails killed per hunter trip the following fall in Illinois Game Region 2, 1956-70 ($\underline{P}<0.05$, 13df)

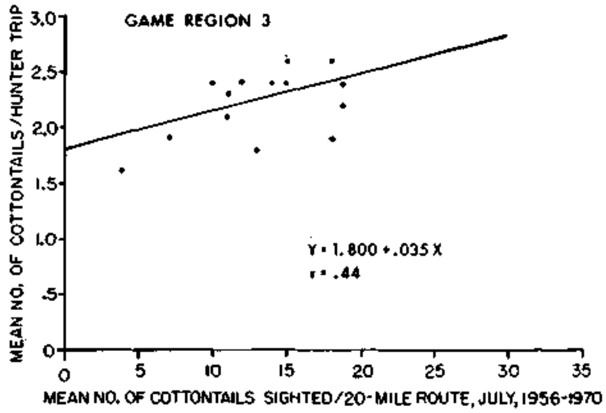


Figure 12. Relationship between the July cottontail census and the number of cottontails killed per hunter trip the following fall in Illinois Game Region 3, 1956-70 ($\underline{P} > 0.05$, 13df)

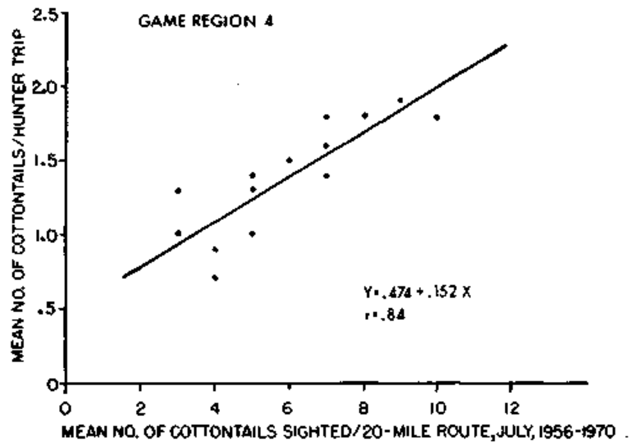


Figure 13. Relationship between the July cottontail census and the number of cottontails killed per hunter trip the following fall in Illinois Game Region 4, 1956-70 ($\underline{P} < 0.01$, 13df)

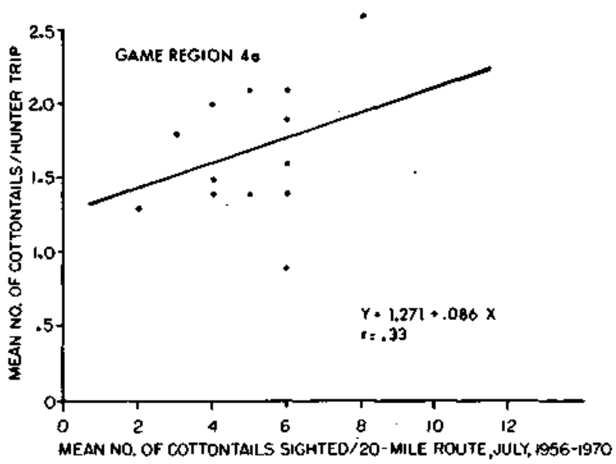


Figure 14. Relationship between the July cottontail census and the number of cottontails killed per hunter trip the following fall in Illinois Game Region 4a, 1956-70 ($P > 0.05$, 13df)

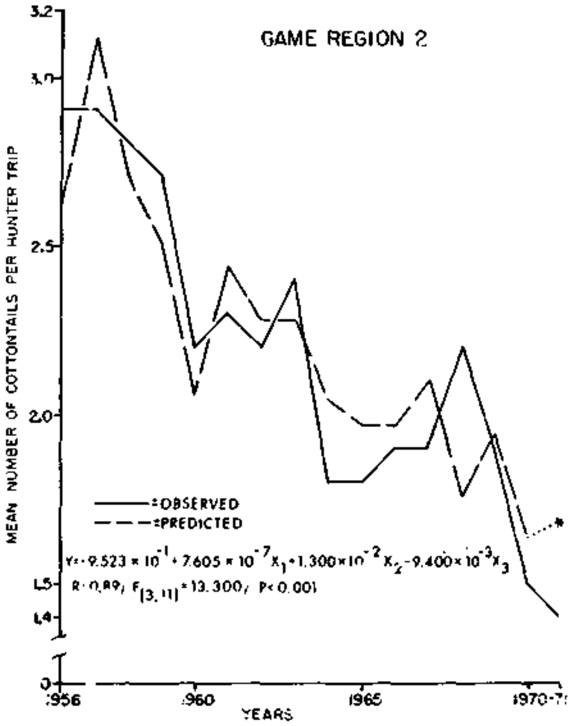


Figure 15. Observed and predicted cottontails killed per hunter trip in Illinois Game Region 2, 1956-71. Predicted values are from the multiple regression equation derived from 1956-70 data. The independent variables are favorable cottontail habitat, the July census, and total snowfall for December-March preceding the hunting season

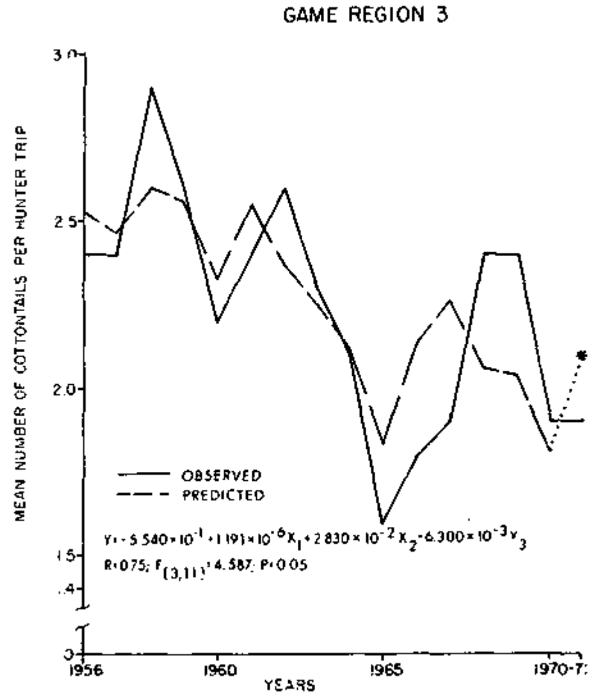


Figure 16. Observed and predicted cottontails killed per hunter trip in Illinois Game Region 3, 1956-71. Predicted values are from the multiple regression equation derived from 1956-70 data. The independent variables are favorable cottontail habitat, the July census, and the total snowfall for December-March preceding the hunting season.

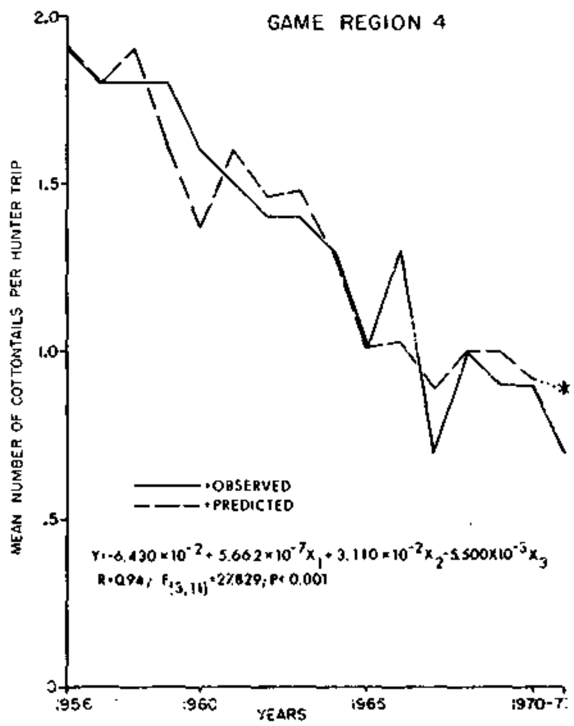


Figure 17. Observed and predicted cottontails killed per hunter trip in Illinois Game Region 4, 1956-71. Predicted values are from the multiple regression equation derived from 1956-70 data. The independent variables are favorable cottontail habitat, the July census, and total snowfall for December-March preceding the hunting season.

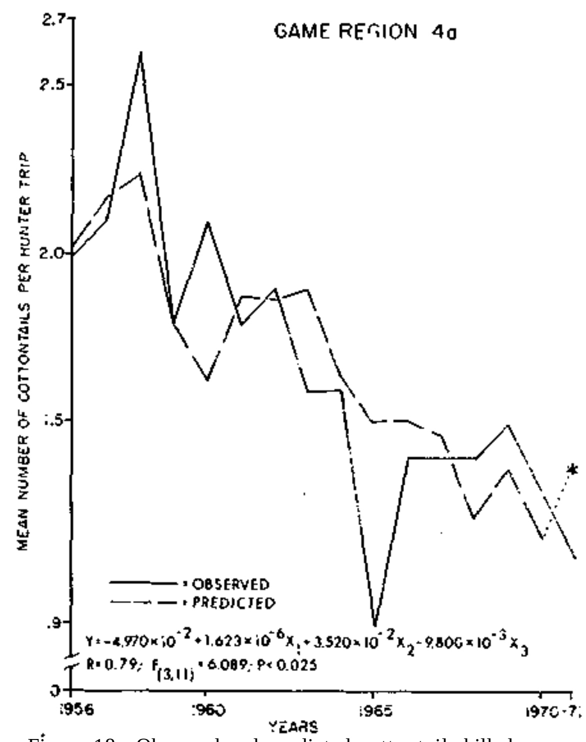


Figure 18. Observed and predicted cottontails killed per hunter trip in Illinois Game Region 4a, 1956-71. Predicted values are from the multiple regression equation derived from 1956-70 data. The independent variables are favorable cottontail habitat, the July census, and total snowfall for December-March preceding the hunting season.

APPENDIX B

Table i. Average monthly temperature parameters for Illinois Game Regions 2, 3, 4, and 4a, 1956-70.

Month	Maximum Temperature Game Region				Minimum Temperature Game Region				Mean Temperature Game Region			
	2	3	4	4a	2	3	4	4a	2	3	4	4a
January	37.8	34.8	31.7	33.9	19.6	15.8	15.3	16.9	28.7	25.3	23.5	25.4
February	42.4	39.6	36.4	38.8	23.7	20.7	19.5	21.1	33.1	30.2	28 0	30.0
March	52.2	50.2	47.1	49.1	31.9	29.2	28.5	29.7	42.1	39.7	37.8	39.4
April	67.1	65.7	62.9	64.6	44.4	42.4	40.9	42.7	55.8	54.1	51.9	53.6
May	76.9	75.9	74.2	75.1	53.7	52.6	51.2	52.7	65.3	64.3	62.7	63.9
June	85.1	83.7	83.1	83.9	61.8	61.0	60.0	61.2	73.5	72.4	71.6	72.6
July	87.9	86.9	85.3	86.6	65.2	64.6	63.7	64.9	76.6	75.8	74.5	75.8
August	86.9	85.7	84.1	85.2	63.3	62.9	61.9	63.0	75.1	74.3	73.0	74.1
September	81.0	79.3	78.3	79.7	56.2	55.3	54.8	55.9	68.6	67.3	66.6	67.8
October	70.2	68.7	67.2	68:4	44.9	44.9	44.1	44.8	57.6	56.8	55.6	56.6
November	54.7	53.1	50.5	52.0	34.4	33.0	32.7	33.2	44.5	43.1	41.6	42.7
December	42.4	40.0	36.9	39.0	25.5	22.6	21.8	23.0	33.9	31.4	29.4	31.0
Mean	52.3	50.9	49.2	50.4	35.0	33.7	33.0	33.9	43.7	42.3	41.1	42.2

Table 2. Average monthly precipitation parameters for Illinois Game Regions 2, 3, 4, and 4a, 1956-70.

Month	Total Precipitation In Inches				Number of Days With Precipitation ≥ 0.10 Inch				Number of Days With Precipitation ≥ 1.0 Inch			
	Game Region				Game Region				Game Region			
	2	3	4	4a	2	3	4	4a	2	3	4	4a
January	2.18	1.49	1.76	1.93	4.8	3.4	4.1	4.2	0.5	0.2	C.3	0.3
February	2.27	1.38	1.37	1.80	5.0	3.3	3.7	4.5	0.4	0.3	0.2	0.2
March	3.28	2.47	2.25	2.82	6.6	5.1	5.5	6.2	0.7	0.6	0.3	0.5
April	4.16	4.02	4.33	4.37	7.8	7.4	8.2	7.7	0.9	1.0	1.1	1.1
May	4.59	4.25	3.78	3.84	7.4	7.3	7.0	7.1	1.3	1.1	0.9	0.9
June	4.32	4.18	3.86	4.26	6.5	6.4	6.0	6.1	1.3	1.3	1.2	1.2
July	4.31	4.37	4.37	4.15	6.6	6.6	6.5	6.8	1.3	1.5	1.3	'.2
August	3.34	3.73	2.86	3.01	4.8	4.9	4.8	5.1	1.1	1.2	0.8	0.8
September	3.11	4.15	3.69	3.37	5.0	6.0	5.6	5.4	0.9	1.2	1.0	1.0
October	2.27	3.04	2.40	2.42	4.5	5.6	4.7	4.4	0.5	C.8	0.5	0.6
November	3.12	2.04	2.22	2.76	5.4	4.2	4.9	5.0	1.0	0.4	0.5	0.7
December	3.09	1.99	1.99	2.66	5.7	4.7	4.8	5.9	0.7	0.2	0.3	0.5
TOTAL	40.05	37.05	34.95	37.39	70.1	64.9	65.7	68.4	10.3	9.7	8.3	8.8

Table 3. Average monthly total snowfall, number of days with snowcover ≥ 1.0 inch, and percent of possible sunshine for Illinois Game Regions 2, 3, 4, and 4a, 1956-70.

Month	Total Snowfall in Inches				Days with Snowcover ≥1.0 Inch				Percent of Possible Sunshine			
	Game Region				Game Region				Game Region			
	2	3	4	4a	2	3	4	4a	2	3	4	4a
January	4.6	5.5	6.9	6.5	8.3	12.2	15.3	12.9	49	49	48	49
February	4.9	5.1	6.0	6.5	4.3	5.8	10.4	6.5	50	53	52	53
March	4.0	4.2	5.0	4.6	2.7	3.7	4.5	3.9	52	52	51	52
April	0.2	0.4	0.9	0.3	--	0.1	0.2	0.1	55	55	54	55
May	--	--	--	--	--	--	--	--	63	65	60	65
June	--	--	--	--	--	--	--	--	67	68	66	68
July	--	--	--	--	--	--	--	--	69	71	67	71
August	--	--	--	--	--	--	--	--	71	74	70	74
September	--	--	--	--	--	--	--	--	65	72	63	72
October	--	--	0.1	--	--	--	--	--	64	66	63	66
November	1.1	1.0	1.3	1.2	0.6	0.7	1.0	0.8	51	50	47	50
December	2.6	4.4	5.0	4.5	3.4	6.0	7.5	5.8	44	43	40	43
Total	17.2	20.5	25.1	23.5	19.3	28.5	39.0	30.0				
Mean									47	48	45	48

Table 4 . Land use expressed as the percentage of operated farm acreage in 1956 and 1970 for Illinois Game Regions 2, 3, 4, 4a and the entire state.

Land Use	Game Regions												Mean of Game Regions			Entire State		
	2			3			4			4a								
	1956	1970	Change	1956	1970	Change	1956	1970	Change	1956	1970	Change	1956	1970	Change	1956	1970	Change
Harvested Corn	22.29	24.99	+2.70	22.97	27.70	+4.73	35.26	43.31	+8.58	29.32	40.05	+10.73	27.46	34.14	+6.68	28.05	34.42	+6.37
Harvested Soybeans	18.33	28.23	+9.90	14.33	19.83	+5.50	18.29	30.20	+11.91	26.13	30.79	+4.66	19.27	27.26	+7.99	15.01	23.50	+8.49
Total Row Crops Harvested	41.09	53.59	+12.50	37.65	47.77	+10.12	54.54	74.98	+20.44	55.70	71.33	+15.63	47.25	61.92	+14.67	43.89	58.61	+14.72
Harvested Oats	3.67	0.52	-3.15	5.71	1.04	-4.67	15.83	2.12	-13.71	7.49	1.18	-6.31	8.18	1.22	-6.96	9.81	2.16	-7.65
Harvested Wheat	10.37	7.80	-2.57	6.79	3.31	-2.98	2.16	1.26	-0.90	7.83	3.80	-4.03	6.79	4.17	-2.62	5.17	3.47	-1.70
Total Small Grains Harvested	15.47	8.46	-7.01	13.33	4.91	-8.42	18.12	3.43	-14.69	16.07	5.34	-10.73	15.75	5.54	-10.21	15.66	5.75	-9.91
Harvested Hay	5.96	3.98	-1.98	7.15	4.15	-3.00	7.70	2.26	-5.44	5.78	1.77	-4.01	6.65	3.04	-3.61	7.98	4.17	-3.81
Harvested Hay and Harvested Seed Crops	6.40	4.55	-1.85	7.40	4.22	-3.18	7.84	2.29	-5.55	6.02	1.80	-4.22	6.92	3.22	-3.70	8.44	4.37	-4.07
Plowland Pasture	6.82	2.99	-3.83	5.26	4.10	-1.16	6.22	0.88	-5.34	3.85	1.27	-2.58	5.54	2.31	-3.23	6.48	2.78	-3.70
Other Pasture	12.24	10.51	-1.73	26.09	21.19	-4.90	6.63	4.62	-2.01	9.77	6.79	-2.98	13.68	10.78	-2.91	14.03	10.96	-3.07
Total Pasture	19.06	13.50	-5.56	31.36	25.29	-6.07	12.85	5.51	-7.34	13.63	8.07	-5.56	19.23	13.09	-6.14	20.51	13.74	-6.77
All Other Land[a]	17.75	21.32	+3.57	9.90	18.29	+8.39	6.54	15.06	+8.52	8.56	15.19	+6.63	10.69	17.47	+6.78	11.42	18.63	+7.21
Harvested Small Grains, Harvested Hay and Seed Crops, Total Pasture, and All Other Land (Favorable Habitat)	58.67	47.82	-10.85	61.98	52.72	-9.26	45.36	26.29	-19.07	44.28	30.41	-13.87	52.57	39.31	-13.26	56.03	42.50	-13.53
Operated Farm Acreage			-5.54			-4.17			-3.50			-3.54			-4.19			-5.55

Consists mainly of farmsteads, land in federal farm programs, idle cropland, wasteland and timber.

Table 5. Acreages of Favorable Cottontail Habitat Used in the Multiple Regression Equations of Game Regions 2, 3, 4, and 4a, 1956-70

Year	Game Region			
	2	3	4	4a
1956	4,595,300	2,396,000	3,226,700	1,339,800
1957	4,810,100	2,376,300	3,126,300	1,316,300
1958	4,625,800	2,404,700	3,017,800	1,288,900
1959	4,198,600	2,233,700	2,717,000	1,149,500
1960	4,031,900	2,181,600	2,482,600	1,119,400
1961	4,424,800	2,259,100	2,798,900	1,262,800
1962	4,273,900	2,240,600	2,768,100	1,241,400
1963	4,090,900	2,164,800	2,605,900	1,189,700
1964	3,984,400	2,127,700	2,415,500	1,116,900
1965	3,866,600	2,064,400	2,049,600	1,024,100
1966	3,786,600	1,993,400	1,844,600	926,100
1967	3,746,500	1,982,800	1,666,600	889,700
1968	3,506,600	1,923,500	1,796,000	873,900
1969	3,617,200	1,945,500	1,826,000	896,100
1970	3,538,200	1,953,100	1,804,900	887,300

Table 5. Correlation coefficients between multiple regression ecuation variables for Illinois Game Regions 2. 3, 4, 4a, and the entire state, 1956-70.

Region	July Census and Cottontails per Trip	Favorable Habitat and Cottontails per Trip	Favorable Habitat and July Census	December-March Snowfall and Cottontails per Trip	December-March Snowfall and July Census	December-March Snowfall and Favorable Habitat
2	+0.61*	+0.84**	+0.45	-0.49	-0.62*	-0.31
3	+0.44	+0.62*	+0.10	-0.24	-0.17	-0.03
4	+0.84**	+0.92**	+0.82**	-0.07	-0.13	+0.10
4a	+0.33	+0.74**	+0.25	-0.35	-0.11	-0.16
Entire State	+0.73**	+0.89**	+0.58*	--	--	--

* $\underline{P} \leq 0.05$.

** $\underline{P} \leq 0.01$.

Table 7. Observed and predicted cottontails killed per hunter trip in Game Region 2, 1956-70. Data are from multiple correlation of cottontails killed per hunter trip and three independent variables (favorable habitat, July census, and total snowfall for December-March preceding the hunting season).

Year	Observed Kill	Predicted Kill	Deviation of Predicted From Observed Kill	Percent Error, Deviation Over Observed Kill
1956	2.90	2.61	+0.29	+10.00
1957	2.90	3.11	-0.21	-7.24
1958	2.80	2.70	+0.10	+3.57
1959	2.70	2.50	+0.20	+7.41
1960	2.20	2.06	+0.14	+6.36
1961	2.30	2.44	-0.14	-6.09
1962	2.20	2.28	-0.08	-3.64
1963	2.1*0	2.28	+0.12	+5.00
1964	1.80	2.04	-0.24	-13.33
1965	1.80	1.97	-0.17	-9.44
1966	1.90	1.97	-0.07	-3.68
1967	1.90	2.10	-0.20	-10.53
1968	2.20	1.76	+0.44	+20.00
1969	1.90	1.94	-0.04	-2.11
1970	1.50	1.64	-0.14	-9.33
Mean	2.23	2.23	0.17[a]	7.85[a]

[a] Mean was computed from the absolute values of the data.

Table 8. Observed and predicted cottontails killed per hunter trip in Game Region 3, 1956-70. Data are from multiple correlation of cottontails killed per hunter trip and three independent variables (favorable habitat, July census, and total snowfall for December-March preceding the hunting season).

Year	Observed Kill	Predicted Kill	Deviation of Predicted From Observed Kill	Percent Error, Deviation Over Observed Kill
1956	2.40	2.53	-0.13	-5.42
1957	2.40	2.47	-0.07	-2.92
1958	2.90	2.60	+0.30	+10.34
1959	2.60	2.56	+0.01*	+1.54
1960	2.20	2.33	-0.13	-5.91
1961	2.40	2.55	-0.15	-6.25
1962	2.60	2.37	+0.23	+8.85
1963	2.30	2.25	+0.05	+2.17
1964	2.10	2.11	-0.01	-0.48
1965	1.60	1.83	-0.23	-11*. 38
1966	1.80	2.13	-0.33	-18.33
1967	1.90	2.26	-0.36	-18.95
1968	2.40	2.06	+0.34	+14. 17
1969	2.40	2.04	+0.36	+15.00
1970	I.90	1.81	+0.09	+4.74
Mean	2.26	2.26	0.20[a]	8.63[a]

[a] Mean was computed from the absolute values of the data.

Table 9. Observed and predicted cottontails kilted per hunter trip in Game Region 4, 1956-70. Data are from multiple correlation of cottontails killed per hunter trip and three independent variables (favorable habitat, July census, and total snowfall for December-March preceding the hunting season).

Year	Observed Kill	Predicted Kill	Deviation of Predicted From Observed Kill	Percent Error, Deviation Over Observed Kill
1956	1.90	1.92	-0.02	-1.05
1957	1.80	1.80	0	0
1958	1.80	1.90	-0.10	-5.56
1959	1.80	1.61	+0.19	+10.56
1960	1.60	1.37	+0.23	+14.38
1961	1.50	1.60	-0.10	-6.67
1962	1.40	1.46	-0.06	-4.29
1963	1.40	1.48	-0.08	-5.71
1964	1.30	1.29	+0.01	+0.77
1965	1.00	1.01	-0.01	-0.01
1966	1.30	1.03	+0.27	+20.77
1967	0.70	0.89	-0.19	-27.14
1968	1.00	1.01	-0.01	-0.01
1969	0.90	1.01	-0.11	-12.22
1970	0.90	0.92	-0.02	-2.22
Mean	1.35	1.35	0.09[a]	7.42[a]

[a] Mean was computed from the absolute values of the data.

Table 10. Observed and predicted cottontails killed per hunter trip in Game Region 4a, 1956-70. Data are from multiple correlation of cottontails killed per hunter trip and three independent variables (favorable habitat, July census, and total snowfall for December-March preceding the hunting season).

Year	Observed Kill	Predicted Kill	Deviation of Predicted From Observed Kill	Percent Error, Deviation Over Observed Kill
1956	2.00	2.03	-0.03	-1.50
1957	2.10	2.18	-0.08	-3.81
1958	2.60	2.24	+0.36	+13.85
1959	1.80	1.79	+0.01	+0.56
1960	2.10	1.63	+0.47	+22.38
1961	1.80	1.88	-0.08	-4.44
1962	1.90	1.87	+0.03	+1.58
1963	1.60	1.90	-0.30	-18.75
1964	1.60	1.64	-0.04	-2.50
1965	0.90	1.51	-0.61	-67.78
1966	1.40	1.51	-0.11	-7.86
1967	1.40	1.47	-0.07	-5.00
1968	1.40	1.22	+0.18	+12.86
1969	1.50	1.37	+0.13	+8.67
1970	1.30	1.16	+0.14	+10.77
Mean	1.69	1.69	0.18[a]	12.15[a]

[a] Mean was computed from the absolute values of the data.