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NATURAL HISTORY SURVEY DIVISION

INFLUENCE OF LAND USE, CALCIUM, AND WEATHER ON THE DISTRIBUTION AND ABUNDANCE OF PHEASANTS IN ILLINOIS

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Fig. 1. Aerial view of farmland in Ford and McLean counties, September, 1961. This view is characteristic of east-central Illinois, the most productive pheasant region in the state. Corn and soybeans are dominant crops. A legume hayfield appears as a dark rectangle near center of picture and to the right of the drainage ditch.

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THE EXOTIC RING-NECKED PHEASANT (*Phasianus colchicus*), introduced into Illinois in the 1890's (Robertson 1958:3), has established thriving self-maintaining populations in the northeastern third of the state (Greeley, Labisky, & Mann 1962:6–16). By the middle 1930's, pheasants had established a center of abundance in Livingston and Ford counties of east-central Illinois (Fig. 1), a center that has persisted and prospered to the present time. In winters of the late 1950's, pheasants numbered between 60 and 90 birds per square mile in portions of east-central Illinois.

Pheasants have never established self-maintaining populations in the west-central and southern counties of Illinois (Fig. 2), even though many propagated birds have been liberated in some of these counties by both private and public agencies during the past 50 years. There is much variation in the abundance of pheasants in different portions of the range occupied by these birds. The phenomenon of limited distribution and variable abundance of pheasants is not unique to Illinois but is common over much of the pheasant range in the midwestern states. This paper reviews published findings and presents new data on three factors, land use, calcium, and weather, all commonly considered as influencing the distribution and abundance of pheasants in Illinois.

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Pheasants and Land Use

Although the distribution and abundance of pheasants are the result of a web of interrelated factors, the relationship between pheasants and land use merits primary consideration because land use is an important determinant of habitat. In an evaluation of the components of pheasant habitat in Illinois, land use is of special importance because of pronounced differences in agricultural practices within the pheasant range. Topography and soil characteristics exert an appreciable effect on land use, but they will not be discussed specifically in this report.

In the midwestern states, pheasants appear to be tolerant of considerable variation in the proportion of the land cultivated (land in agricultural crops). Kimball, Kozicky, & Nelson (1956:213) reported that between 50 and 75 per cent of the land area within the best pheasant range of the Plains and Prairie States (the Dakotas, Nebraska, Minnesota, and Iowa) was cultivated. Leedy & Hicks (1945:101) suggested that land cultivated to the extent of 75 to 95 per cent provided one of the conditions for superior pheasant range in Ohio. Shick (1952:18) reported that in 1941 about 70 per cent of the land on the Prairie Farm in Michigan, a highly productive pheasant area, was cultivated. Investigators in Minnesota (Erickson et al. 1951:40–41) reported "heavy production of corn and grain" as one characteristic of good pheasant habitat. Robertson (1958:13) stated that over most of the range of the pheasant in Illinois as much as 95 per cent of the land area might be classed as agricultural.

In Illinois, the numbers of pheasants counted along roadsides by rural mail carriers during periods of 5 consecutive days in February, April, and August of 1957 and January, April, and August of 1958 (Greeley et al. 1962:4) were used to classify the 102 counties of the state with respect to the relative abundance of pheasants. Twenty-eight of the southern counties of Illinois in which no pheasants were observed during the February, 1957, census (Greeley et al. 1962, Fig. 2) were classed as nonpheasant range. These counties, the last 28 in Table 1, were not included in subsequent censuses; in all analyses, they were considered as nonpheasant habitat.

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As an aid to biological interpretations of the relationships between land use and pheasant abundance in Illinois, the data were analyzed for statistical significance on an IBM 7090 digital computer; the mathematics involved a multiple regression analysis by the least squares method.

Test statistics included 10 independent variables involving land use (Table 1) and three dependent variables involving pheasant abundance. Indices of abundance were based on the mean number of pheasants observed by rural mail carriers per 100 miles of driving in Illinois counties during six counts in 1957 and 1958 (Table 1).

Table 1.—Abundance of pheasants in relation to land-use practices in Illinois counties. Abundance for each county within the pheasant range was determined by calculating the mean number of pheasants reported by rural mail carriers per 100 miles of driving during six 5-day census periods, 1957 and 1958. All counties of the state were included in the first census; 28 southern counties (75–102 below) in which no pheasants were reported were not included in later cenususes.

Abundance Ranking	County	Mean Number of Pheasants Per 100 Miles of Driving	Per Cent of County in		Per Cent of Farms‡ in			Per Cent of Cropland and Pastureland** in				
			Cropland*	Woodland†	Cash Grain	Dairy	Livestock	Row Crops	Small Grain	Hay	Pasture	Idle Land
1	Livingston	75.2	88	1	74	2	7	56	26	5	12	1
2	Ford	55.2	88	0	71	1	10	55	24	5	13	1
3	Marshall	22.5	70	11	46	2	30	46	22	6	23	1
4	McLean	22.2	85	2	58	3	18	57	22	5	15	1
5	Iroquois	21.5	85	2	67	2	10	60	21	5	12	1
6	De Kalb	20.8	88	1	13	14	54	47	24	11	13	1
7	La Salle	19.6	78	4	58	3	20	50	24	7	17	1
8	Kendall	19.1	84	4	31	6	36	49	28	9	13	1
9	Kankakee	16.5	78	4	64	4	7	59	22	5	12	1
10	Woodford	16.2	75	9	54	4	21	47	24	6	21	1
11	Champaign	15.1	87	1	77	2	7	65	21	3	10	1
12	Grundy	13.8	79	4	76	2	7	54	23	5	16	1
13	McHenry	13.4	68	4	5	65	9	31	18	19	28	1
14	Stephenson	11.5	76	4	4	42	33	28	22	17	31	1
15	Lee	10.9	80	2	36	7	28	46	24	9	18	1
16	Vermilion	9.3	78	5	49	3	16	60	18	3	15	1
17	Putnam	8.0	64	17	41	4	38	41	20	8	29	1
18	Kane	6.4	76	3	10	36	26	41	24	14	18	1
19	Boone	5.6	81	3	6	66	16	32	21	13	24	1
20	Logan	5.5	85	3	76	1	12	56	24	5	13	2
21	Will	5.5	69	4	44	14	10	49	26	8	14	1
22	Du Page	5.2	51	5	12	18	16	41	26	12	17	2
23	Piatt	4.9	88	2	74	1	8	63	21	3	11	1
24	Douglas	4.5	85	2	69	3	9	67	20	2	10	1
25	Carroll	3.8	65	7	2	14	68	28	19	15	35	1
26	Stark	3.8	81	3	27	1	58	46	21	9	22	1
27	Menard	3.5	75	8	49	2	25	51	20	5	22	1
28	Tazewell	3.0	73	9	49	6	16	48	21	6	19	2
29	Lake	2.9	44	7	6	32	10	27	23	19	24	4
30	Cook	2.9	28	5	10	17	9	34	22	14	13	3
31	Edgar	2.9	75	6	48	3	27	57	18	3	20	1
32	De Witt	2.8	79	4	60	2	17	59	17	4	18	1
33	Ogle	2.7	76	6	12	16	43	34	24	12	23	2
34	Winnebago	2.1	66	7	7	29	22	32	22	15	27	1
35	Jo Daviess	2.1	49	15	1	21	58	17	13	16	53	1
36	Henry	2.1	78	3	12	2	67	45	21	10	23	1
37	Bureau	1.8	76	6	22	3	54	45	21	9	23	1
38	Effingham	1.5	64	15	23	16	11	44	17	7	28	3
39	Mason	1.4	69	13	73	1	10	45	26	4	13	5
40	Coles	0.9	76	7	45	2	25	57	16	4	20	2
41	Whiteside	0.8	77	4	18	14	43	45	22	9	23	1
42	Moultrie	0.8	82	4	57	3	14	60	19	4	16	1
43	Jasper	0.8	68	11	25	2	20	51	14	8	23	4
44	McDonough	0.6	68	11	26	2	48	44	21	4	29	1
45	Henderson	0.5	62	14	30	1	55	43	17	6	29	3
46	Macon	0.5	82	3	56	2	9	61	21	4	13	1
47	Adams	0.4	58	17	18	7	45	30	22	7	38	3
48	Warren	0.3	71	7	17	1	68	45	19	7	28	1
49	Cass	0.2	54	19	57	0	26	47	18	4	24	3
50	Sangamon	0.2	73	4	43	4	24	54	21	4	19	2

Table 1.—(Continued)

Abundance Ranking	County	Mean Number of Pheasants Per 100 Miles of Driving	Per Cent of County in: Crop-land*	Wood-land†	Per Cent of Farms‡ in: Cash Grain	Dairy	Live-stock	Per Cent of Cropland and Pastureland** in: Row Crops	Small Grain	Hay	Pas-ture	Idle Land
51	Schuyler	0.2	49	25	29	2	41	32	18	5	43	1
52	Peoria	0.2	57	13	26	5	36	38	20	8	32	1
53	Christian	0.2	79	3	60	2	15	56	24	4	15	1
54	Cumberland	0.2	68	14	29	2	23	51	12	5	28	3
55	Shelby	0.2	70	11	38	8	18	50	17	5	26	2
56	Rock Island	0.2	57	13	8	6	54	36	16	9	36	2
57	Hancock	0.1	63	9	26	2	44	38	21	5	34	1
58	Fayette	0.1	58	18	27	9	15	42	13	7	32	5
59	Bond	0.1	60	15	19	21	12	39	18	7	32	4
60	Montgomery	0.1	64	10	33	11	15	44	21	6	28	1
61	Knox	0.1	61	9	14	2	63	40	18	8	33	1
62	Greene	0.1	58	16	26	5	42	41	15	5	36	3
63	Mercer	0.1	67	8	10	1	74	39	16	9	34	2
64	Clay	0.1	64	15	23	2	14	43	11	10	28	7
65	Morgan	0.1	67	8	39	3	35	46	20	5	28	1
66	Clark	0.0+	65	18	23	4	21	45	15	5	29	5
67	Pike	0.0+	58	18	18	2	54	32	14	5	40	8
68	Macoupin	0.0+	60	17	33	7	24	43	16	6	33	2
69	Scott	0.0+	66	13	35	1	43	44	19	4	29	3
70	Richland	0.0+	67	13	14	5	15	37	12	13	26	11
71	Fulton	0.0+	51	17	18	2	52	35	17	5	40	2
72	Crawford	0.0+	63	14	21	6	22	41	12	7	29	10
73	Jersey	0.0+	52	28	28	9	24	37	18	6	33	5
74	Brown	0.0	47	21	14	2	67	28	15	4	49	3
75	White	0.0	69	9	33	2	32	45	13	3	21	16
76	Wabash	0.0	66	10	35	1	26	46	20	6	18	7
77	Wayne	0.0	63	16	18	2	21	40	7	9	31	12
78	Washington	0.0	65	17	36	15	4	26	38	5	20	7
79	Clinton	0.0	64	19	27	21	6	37	33	7	19	4
80	Monroe	0.0	63	24	33	1	11	28	37	5	15	13
81	Lawrence	0.0	61	14	26	3	21	45	15	6	23	10
82	Edwards	0.0	71	14	19	2	33	39	15	7	27	10
83	Madison	0.0	59	12	20	18	12	36	27	8	24	4
84	St. Clair	0.0	58	13	35	8	13	35	35	6	15	7
85	Randolph	0.0	58	22	19	14	22	28	26	7	25	13
86	Perry	0.0	54	22	11	10	14	26	19	6	28	17
87	Pulaski	0.0	56	26	12	4	21	41	6	9	29	10
88	Massac	0.0	51	28	15	3	32	37	5	9	40	7
89	Saline	0.0	55	18	15	4	17	39	10	7	31	11
90	Gallatin	0.0	57	26	28	2	30	43	8	4	26	13
91	Franklin	0.0	53	22	11	5	10	29	16	6	30	17
92	Hamilton	0.0	58	19	14	2	23	38	10	6	29	15
93	Jefferson	0.0	57	17	14	3	19	35	13	7	31	13
94	Marion	0.0	55	17	21	4	18	36	14	7	32	8
95	Calhoun	0.0	41	43	12	0	48	23	9	5	46	10
96	Jackson	0.0	43	32	16	10	18	31	12	7	33	13
97	Union	0.0	42	38	11	9	21	26	6	12	36	13
98	Alexander	0.0	40	47	32	0	14	50	4	8	22	11
99	Johnson	0.0	48	36	2	4	36	18	2	13	54	10
100	Pope	0.0	31	41	12	3	28	23	3	11	48	12
101	Hardin	0.0	42	38	5	1	32	18	0	10	58	13
102	Williamson	0.0	40	21	7	6	16	27	5	9	40	17
	Mean	*4.5*	*65*	*13*	*30*	*8*	*27*	*42*	*18*	*7*	*26*	*5*

* Calculated from data published by the United States Bureau of the Census (1952:40–47); data are for 1950.

† From King & Winters (1952:21–22); wooded areas in narrow strips and areas of less than 1 acre are not included in the statistics, which are for 1948.

‡ Calculated from data published by Ross & Case (1956:35, 40, 42, 45, 49, 52, 55, 58, 60). A farm classified as one of these types derived 50 per cent or more of its total income from sales of the product from which it derived its name (Ross & Case 1956:33). Only cash-grain, livestock, and dairy farms are included here because they are the dominant specialized types in and around the major portion of the Illinois range occupied by pheasants (Fig. 3). Most of the farms not included in the three types are classified as general farms.

** From Ross & Case (1956:38, 40, 43, 47, 50, 53, 56, 58, 60). The classification *pasture* includes woodland that was grazed by livestock. In all counties, a small percentage (in some counties less than one-half of 1 per cent) of cropland was planted to crops not included in the five types specified below; the approximate percentage for the "other crops" can be found by subtracting the percentage for these five types from 100 per cent.

TABLE 2.—Variance ratios obtained from analysis of variance tests between (i) three different statistical transformations of pheasant abundance as expressed in pheasants observed by rural mail carriers per 100 miles of driving (dependent variables) and (ii) 10 different land-use statistics (independent variables) for the 102 counties of Illinois.

Pheasants per 100 Miles of Driving	Source	Degrees of Freedom (*d.f.*)	Sum of Squares	Mean Square	Variance Ratio (*F*)
Mean number	Regression	10	5,370.503	537.050	7.20*
	Deviation	91	6,791.512	74.632	
		101	*11,162.015*	*110.515*	
Square root of mean number	Regression	10	189.394	18.939	14.60*
	Deviation	91	118.073	1.298	
		101	*307.468*	*3.044*	
Log transformation of mean number†	Regression	10	17.017	1.702	19.91*
	Deviation	91	7.783	0.086	
		101	*24.800*	*0.246*	

* Significant at the 0.01 level of probability.
† Log_{10} of 1 plus the mean number of pheasants observed by rural mail carriers per 100 miles of driving.

The three dependent variables were (i) the mean number of pheasants per 100 miles, (ii) the square root of the mean number of pheasants per 100 miles, and (iii) the log_{10} of 1 plus the mean number of pheasants per 100 miles of driving. The log transformation of the mean number of pheasants (iii) proved to be better than the two other dependent variables because with it more of the variations of data could be explained by the 10 independent variables (Table 2): it was used as the dependent variable in all subsequent statistical analyses.

The *total correlation* (positive or negative) of individual independent variables with the log transformation of pheasant abundance was found to be statistically significant at the 0.01 level (with 101 degrees of freedom) for 7 of the 10 independent variables (Table 3). This finding suggested that variations in 7 of the 10 land-use factors tested statistically were associated with variations in the abundance of pheasants in Illinois.

The significant correlation between the abundance of pheasants and the percentage of cropland ($r = 0.629$, Table 3) demonstrated that pheasants were most abundant in counties having a high proportion of cultivated land (Table 1). In 9 of the 10 counties in which pheasants were most abundant, at least 75 per cent of the land was in crops, whereas in 20 of 28 southern counties from which pheasants were absent less than 60 per cent of the land was in crops.

The amount of woodland in Illinois counties varied inversely with the relative amount of cropland and the abundance of pheasants (Table 1 and Fig. 3). A highly significant negative correlation ($r = -0.612$) was obtained between pheasant abundance and the relative amount of woodland in the counties (Table 3). The best pheasant counties of Illinois had little or no woodland (Fig. 2 and 3).

The abundance of pheasants was significantly correlated ($r = 0.476$) with the relative number of cash-grain farms among all farms in the counties (Table 3). Cash-grain farms comprised 74 and 71 per cent of all farms in Livingston and Ford counties, the counties in which pheasants were most abundant, and more than 50 per cent of all farms in many of the other counties in which pheasants were numerous (Table 1). The abundance of pheasants was less associated with the relative number of dairy and livestock farms in the counties than with the relative number of cash-grain farms (Tables 1 and 3).

In most of the counties within the range occupied by pheasants in Illinois, a high proportion of cropland (referred to as cropland and pastureland in Table 1) was devoted to row crops, mainly corn (*Zea mays*) and soybeans (*Glycine max*). The proportion of cropland

TABLE 3.—Test of significance by analysis of total correlation for each of 10 independent variables with the log transformation of pheasant abundance* in the 102 counties of Illinois.

Independent Variable	Correlation Coeffiecient (r)	Level of Significance (101 *d.f.*)
Per cent of county in		
Cropland	0.629	0.01
Woodland	−0.612	0.01
Per cent of farms in		
Cash grain	0.476	0.01
Dairy	0.217	0.05
Livestock	−0.177	NS†
Per cent of cropland in		
Row crops	0.444	0.01
Small grain	0.414	0.01
Hay	0.125	NS†
Pasture (including grazed woodland)	−0.544	0.01
Idle land	−0.549	0.01

* Log_{10} of 1 plus the mean number of pheasants observed by rural mail carriers per 100 miles of driving.
† Not significant at 0.05 level of probability.

planted to corn and soybeans was greatest in counties in which pheasants were most abundant; the correlation of pheasant populations with the acreage of row crops ($r = 0.444$) was highly significant (Table 3). A high proportion of the land planted to row crops was characteristic of counties in which cash-grain farms predominated. A lower proportion of the land in row crops was found in counties in which dairy and livestock farming necessitated greater acreages of tame hay and pasture. Pheasants were most abundant in counties in which at least 45 per cent of the cropland was planted to row crops (Table 1).

The proportion of cropland planted to small grains, mainly oats (*Avena sativa*) and wheat (*Triticum aestivum*), was also significantly correlated ($r = 0.414$) with the abundance of pheasants (Table 3). Small grains occupied 20 to 25 per cent of the cropland in most counties where pheasants were abundant. Small grains, particularly oats, were important in that they usually

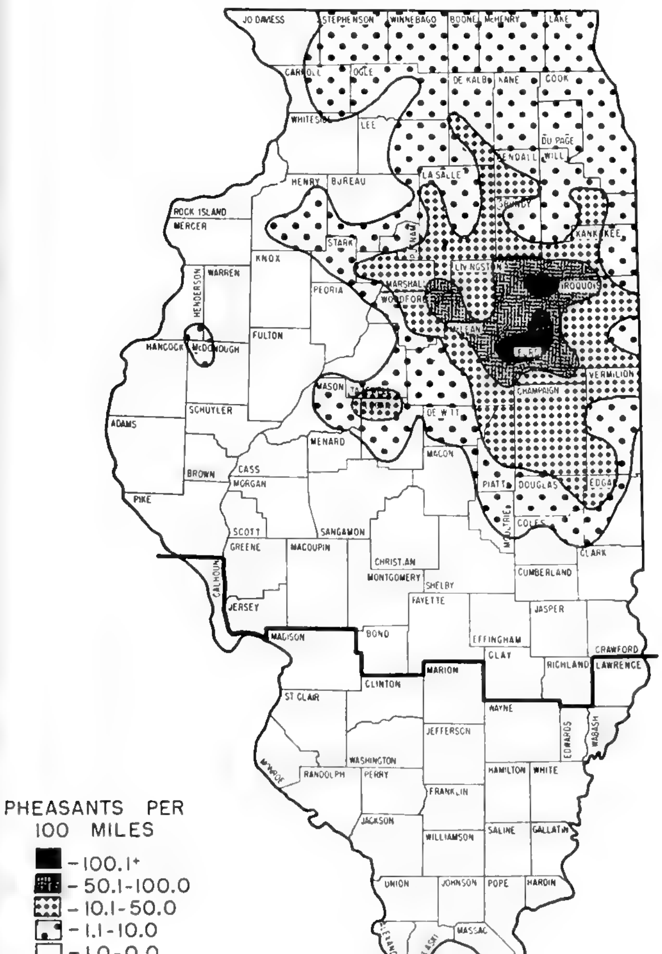

Fig. 2.—Distribution and abundance of pheasants in Illinois as mapped from data obtained from six censuses by rural mail carriers, 1957 and 1958 (modified from maps by Greeley et al. 1962:6–12). Twenty-eight counties in which no pheasants were observed during the February, 1957, census were classed as nonpheasant range (south of heavy line).

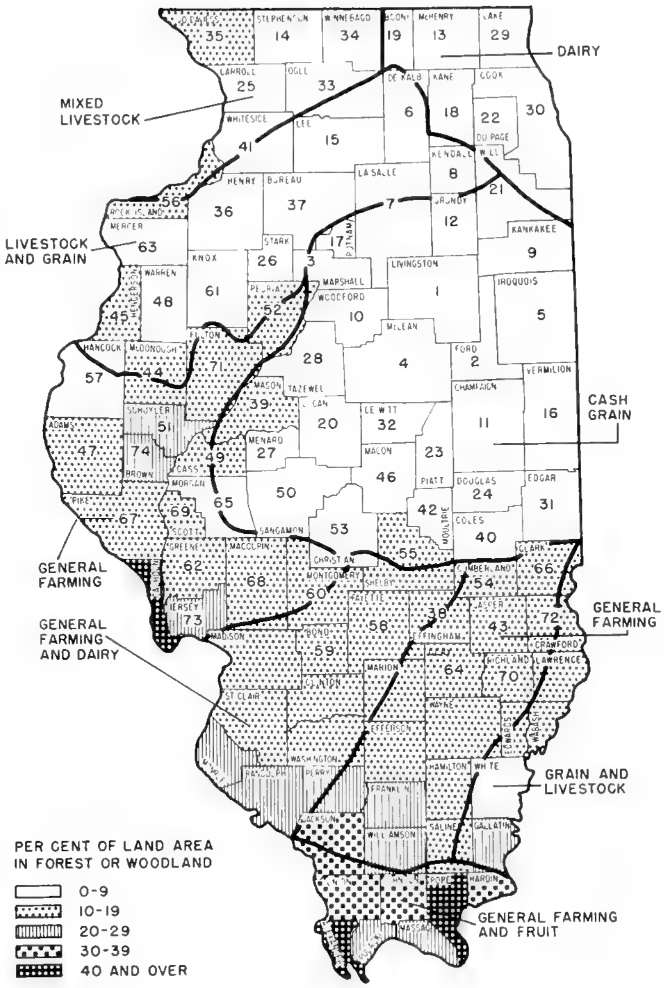

Fig. 3.—Rank of Illinois counties in pheasant abundance (1–74 in Table 1) in relation to farming-type areas (after Ross & Case 1956:32) and forestation (after King & Winters 1952:22). Counties are ranked in order of pheasant abundance as determined from censuses by rural mail carriers, 1957 and 1958. No rank is assigned to 28 southern counties.

provided a nurse crop for grass-and-legume seedings, which produced hay and pasture crops in the subsequent year or years. Small grains were important also in that the stubble provided top-quality roosting habitat—an often overlooked requirement—for pheasants during late summer, fall, winter, and early spring.

Pheasants were most abundant in counties with proportionately small acreages of hay and pasture, both of which consisted mainly of tame grasses and legumes. Yet studies of the nesting ecology of pheasants in the cash-grain area of east-central Illinois during a 5-year period, 1957–1961, showed that between 50 and 75 per cent of the annual hatch of pheasant chicks was produced in tame hay. Fewer acres of hay were reported in the cash-grain area than in other farming-type areas; the forage crops, hay and pasture, were not utilized by farmers so intensively in the cash-grain area as in the dairy and livestock areas. The counties of Livingston and Ford, which supported the greatest abundance of pheasants in the state, had 5 per cent of the cropland in hay and 12.5 per cent in pasture. As might be expected, pheasant abundance for all counties combined was negatively correlated ($r = -0.544$) with the amount of cropland in pasture (Table 3). Surprisingly, however, there was no significant correlation between pheasant abundance and the amount of cropland planted to tame hay.

Idle land did not constitute an important habitat for pheasants in Illinois, as indicated by a significant negative correlation ($r = -0.549$) between the abundance of pheasants and the relative amount of idle land per county (Table 3).

When the independent variables were treated in an analysis of *multiple regression*, interactions among the individual variables were clearly defined. This analysis indicated that a combination of three factors of land use, (i) per cent of county in cropland, (ii) per cent of cash-grain farms among all farms in county, and (iii) per cent of cropland in hay, when tested against the other land-use statistics, exerted the most important influence on the distribution and abundance of pheasants in Illinois (Table 4). The degree of importance of these three factors or independent variables was further exemplified by a comparison (Table 5) of the variance ratio of these three variables combined ($F = 63.27$) with the variance ratio of the seven other independent variables combined ($F = 1.15$).

In summary, the following factors of land use were found to be characteristic of many of the counties in Illinois where pheasants were most abundant: (i) a high proportion of the land area in cultivated crops and a low proportion in woodland, (ii) a high proportion of the farms classified as cash-grain farms and a lower proportion as dairy farms and livestock farms, and (iii) about 50 per cent of the cropland in row crops (corn and soybeans), about 5 per cent in hay, and about 15 per cent in pasture. A multiple regression analysis indicated that a combination of three land-use variables, (i) the relative amount of land in cultivated crops, (ii) the relative number of cash-grain farms among all farms, and (iii) the relative amount of cropland in hay, when tested against all other land-use characteristics, exerted the greatest influence on the distribution and abundance of pheasants in the state.

Table 4.—Test of significance by analysis of multiple regression for the 10 independent variables of land use with the log transformation of pheasant abundance* in the 102 counties of Illinois.

Independent Variable	Regression Coefficient (b)	Level of Significance (101 *d.f.*)
Per cent of county in		
Cropland	0.014	0.01
Woodland	−0.003	NS†
Per cent of farms in		
Cash grain	0.019	0.01
Dairy	−0.002	NS†
Livestock	0.003	NS†
Per cent of cropland in		
Row crops	−0.036	NS†
Small grain	−0.034	NS†
Hay	0.051	0.05
Pasture (includes grazed woodland)	−0.032	NS†
Idle land	−0.039	NS†

* Log_{10} of 1 plus the mean number of pheasants observed by rural mail carriers per 100 miles of driving.
† Not significant at 0.05 level of probability.

Table 5.—Variance ratios obtained from analysis of variance tests between the groupings of significant and nonsignificant independent land-use variables (Table 4) and the log transformation of pheasant abundance.*

Source	Degrees of Freedom (*d.f.*)	Sum of Squares	Mean Square	Variance Ratio (F)
Regression				
Cropland, cash-grain farms, and hay	3	16.323	5.441	63.27†
Other independent variables	7	0.694	0.099	1.15‡
Deviation	91	7.783	0.086	
	101	*24.800*	*0.246*	

* Log_{10} of 1 plus the mean number of pheasants observed by rural mail carriers per 100 miles of driving.
† Significant at 0.01 level of probability.
‡ Not significant at 0.05 level of probability.

Pheasants and Calcium

A supposed deficiency of calcium in soils and glacial drift has long been regarded as a factor limiting the southward extension of the range of the pheasant in the North Central States, as well as a factor limiting the abundance of this bird in other parts of the United States. Leopold (1931:125–126) noted that the successful establishment of pheasants in the North Central States appeared to be confined within the exterior boundary of the Wisconsinan glacier — that is, confined to soils of recent glacial origin. He advanced the hypothesis that some plant growing on these glacial soils or some substance, such as kind of lime or gravel, present in these soils was necessary for the welfare and breeding vigor of exotic game birds. Dale (1954:320) noted that there seemed to be a correlation between the availability of calcium and the abundance of pheasants in the major pheasant centers of the eastern half of the United States. McCann (1961:189–190) contended that grit high in calcium and low in magnesium was of paramount importance to wild pheasants in Minnesota. The importance of calcium in reproduction, growth, and other physiological processes of birds is so great that, obviously, a critical shortage or the absence of this mineral could prevent the establishment of self-maintaining pheasant populations.

Although calcium is an essential element for many physiological processes of birds, more emphasis in research has been placed on the role that this element plays in reproduction than in any other process. To obtain a picture of the importance of calcium in reproduction of the pheasant, we must draw heavily from literature on the domestic chicken (*Gallus domesticus*) and, also, we must assume that the physiological processes of the pheasant approximately parallel those of the chicken.

About 98.2 per cent (2.2 grams) of the shell of the egg laid by the domestic hen consists of calcium; approximately 6.0 per cent of the contents of the egg is calcium (Romanoff & Romanoff 1949:353–354). This calcium comes either directly from the daily diet of the hen or from her body reserves of calcium; the body reserves are, of course, dependent upon the calcium intake. Prior to the onset of laying, the hen will store a reserve of calcium along the shaft cavities of the long or medullary bones; this deposition of reserve calcium is under the control of estrogens (Höhn 1961:109; Marshall 1961:196).

The circulatory system transports calcium from the viscera or the bones, or both, to the oviduct, where the calcium is deposited on and in the egg as calcium carbonate and other calcium salts. The shell gland of the oviduct is about 20 per cent efficient in removing calcium from the plasma in the blood stream during early as well as late stages of shell formation (Winget, Smith, & Hoover 1958:1327).

Common (1943:218–219) demonstrated that the average daily retention of calcium from the food of laying hens was about 50 per cent of the intake if the daily intake averaged 1–3.5 g, but that on days of shell secretion the retention of calcium might rise to about 70 per cent. He found that, whenever the average daily intake was as low as about 2 g calcium, mobilization of the reserves of skeletal calcium was practically certain; he estimated that a daily intake of 4 g calcium might suffice to protect the skeletal reserves of hens on sustained schedules of egg laying. Tyler (1940:211) reported that in the laying hen no more than about 1 g calcium can be withdrawn from the bones on any day the hen lays an egg and no more than about 1 g calcium can be deposited in her bones on any day she does not lay an egg. Approximately 25 per cent of the body reserves of calcium (about 98 per cent of which is found in the skeleton) at the commencement of laying can be used in egg formation (Common 1938:354–357); under favorable conditions, prelaying storage of calcium in the body of the hen is sufficient for the laying of about six eggs. That prelaying storage of calcium sufficient for about six eggs takes place in pheasants, also, is indicated by the findings of Harper (1964:267), who reported that the amount of calcium found in the grit from gizzards of wild pheasant hens increased from less than 1 per cent to more than 2 per cent after the hens had laid six or seven eggs and remained relatively stable until the second or third day of incubation; midway through the 23-day incubation period, the amount of calcium found in the gizzard grit of wild hens decreased to near zero.

Phosphorus as well as calcium is mobilized during egg formation in some birds (Marshall 1961:197) and is closely associated with the calcium complex. If a diet is deficient in calcium during the period of egg laying, phosphorus is excreted more rapidly than normally (Common 1936:96) and may even be drawn from the body reserves (Romanoff & Romanoff 1949:240). As with reserves of calcium, reserves of phosphorus must be replenished through the diet.

Although a deficiency of calcium has never been detected in populations of pheasants in the wild, dietary levels of calcium below which penned pheasants cannot carry on normal reproduction have been reported by several investigators. In an experiment with penned pheasants, Dale & DeWitt (1958:293) found that during the reproductive season 600 mg of calcium per kg of body weight per day (calculated by us to be equivalent to 1.2 per cent of the diet) and 385 mg of phosphorus per kg of body weight per day were necessary to insure satisfactory production of pheasant eggs and young from hens that had received adequate calcium and phosphorus during the previous winter. In another experiment with penned pheasants, Greeley (1962:188–190) found that a diet containing 1.09 per cent, or less, calcium resulted in reduced (i) egg production, (ii) eggshell thickness, (iii) weight of eggs, and (iv) ash content and weight of tibiae and femora of laying pheasant hens; a diet containing 2.01 per cent calcium seemed adequate for normal reproductive activities of penned pheasant hens.

The level of calcium required by wild pheasant hens to complete successfully the annual reproductive cycle has not been measured directly. Without doubt, some of the calcium required by wild hens, as well as by penned birds, must come from the daily diet and some from the body reserves. Throughout much of the pheasant range in the United States, cereal grains, which are notably low in calcium, comprise a large percentage of the diet of the pheasant. Trautman (1952:25–26) in South Dakota and Fried (1940:30) in Minnesota reported that grains comprised 81.7 and 81.3 per cent of the annual diet of pheasants in their respective states. Dalke (1937:204) reported that grains constituted 74.0 per cent of the annual diet of pheasants he studied in southern Michigan.

Dale (1954:318) estimated that calcium made up approximately 0.23 per cent of the annual diet, including all food items, of the pheasants studied by Trautman in South Dakota and by Dalke in Michigan. Harper & Labisky (1964:726) found that, in the established pheasant range in Illinois, calcium comprised 0.21 per cent of the food items from the crops of hens collected during the nesting seasons (May and June) of 1961 and 1962. If the calcium requirements of wild pheasants are similar to those of penned pheasants, then obviously the food items consumed by wild pheasants do not supply sufficient calcium to allow normal reproduction, and a supplemental source of calcium must be available to laying hens. The belief among most biologists who have studied game birds is that this source of calcium is calcareous grit.

For a number of years, investigators disagreed on the function of grit in the diet of gallinaceous birds—whether grit was required by the birds for its mineral content or as a grinding agent in the mastication of food. Nestler (1946:141) reported that grit as a grinding agent in the gizzard was not essential for the growth, welfare, or reproduction of pen-raised bobwhites (*Colinus virginianus*). McCann (1939:33–36) concluded that the consumption of grit by pheasants appeared to be conditioned primarily by a need for calcium.

The belief that glacial grit is required as a source of calcium for pheasants represents an elaboration of the glacial hypothesis set forth by Leopold (1931:125–126). Leopold's hypothesis is strengthened by the fact that many years after the initial establishment of the pheasant in the North Central States its distribution still nearly coincides with the area of most recent glacial activity.

In Illinois, the relationship between pheasant distribution and the area of most recent glacial activity is evident. Four independent stages of glaciation have been recognized in Illinois; these are, from oldest to most recent, the Nebraskan, Kansan, Illinoian, and Wisconsinan (Horberg 1950:17). The major patterns of distribution of pheasants in Illinois approximately coincide with the moraines deposited by the substages of the Wisconsinan ice sheet. The center of greatest pheasant abundance, located in Livingston and Ford counties of east-central Illinois, is closely associated with the Chatsworth and Cropsey moraines of the Wisconsinan ice sheet. The southwestern boundary of the contiguous range occupied by pheasants terminates approximately at the southwestern boundary of the Shelbyville moraine, terminal moraine of the Wisconsinan glacier (Fig. 4). Some self-maintaining pheasant populations of relatively low numbers are found in areas in which the Illinoian was the most recent glacier and even on the unglaciated areas in the northwestern corner of Illinois, but areas supporting the greatest numbers of pheasants are found within the area of Wisconsinan drift (Fig. 4).

The logic behind Leopold's glacial hypothesis on the positive relationship between pheasant distribution and recently glaciated areas and the subsequent hypothesis that grit from recent glacial drift is needed to provide a source of calcium for pheasants becomes apparent when we recognize that the drift from recent glacial activity has undergone less weathering and, consequently, less leaching than have the older drifts. The availability to pheasants of grit from the less weathered and less leached glacial drift must then be considered. With the exception of areas of some alluvial deposits, lake sediments, and sand dunes, the state of Illinois is covered by windblown deposits of loess originating from the Wisconsinan age. These loess deposits can be eliminated from consideration as a source of calcium over much of the pheasant range in Illinois. In a large portion of Illinois, including most of the northeastern third of the state where pheasants are most abundant, deposits of loess are shallow—4 feet or less in depth—and noncalcareous (Leighton & Willman 1950:604, 607). The speculation may be made that pheasants are more abundant in some areas of shallow loess than in areas of deep loess because erosion, plowing, or some other activity has exposed the glacial drift, thus making calcium-bearing grit that may be in this drift available to the pheasants. If this speculation is valid, the drift on which pheasants are most abundant (Wisconsinan) should contain more calcium available to the birds than the drift on which pheasants are not established (Illinoian).

In 1956, 1,726 pheasants originating from stock obtained from California were released by the Illinois Natural History Survey and the Illinois Department of Conservation on an area of Illinoian drift in Cumberland County. The release was made as part of a program

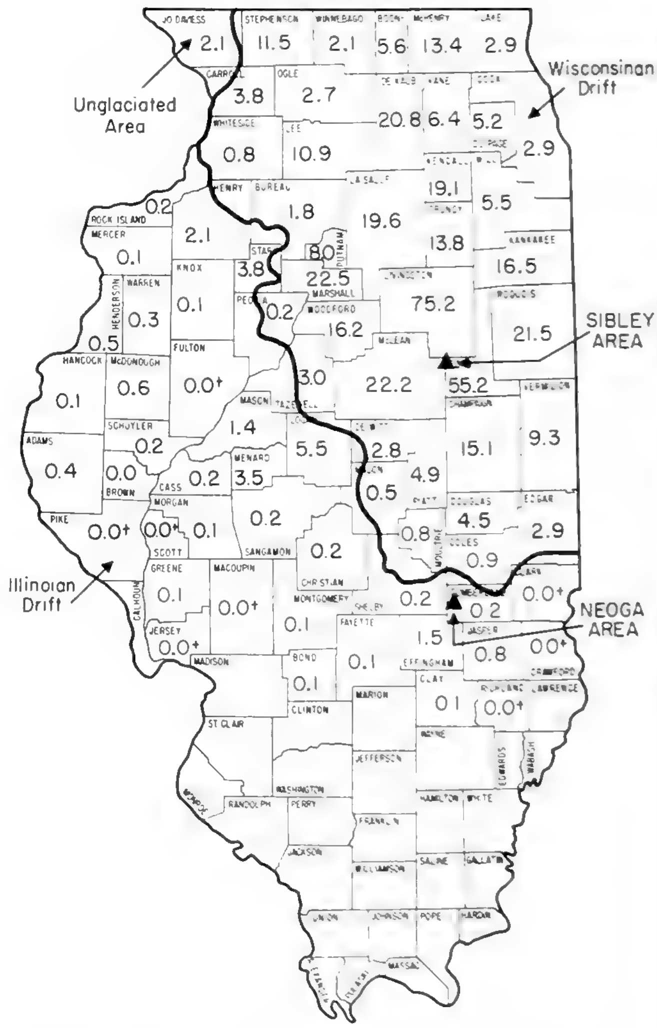

Fig. 4.—Distribution and abundance of pheasants in Illinois in relation to the most recent glaciation, the Wisconsinan. The heavy line designates the terminal boundary of the Wisconsinan ice sheet (after Ekblaw & Lamar 1964:4). The figure for each county within the pheasant range represents pheasant abundance, as determined by the mean number of pheasants reported by rural mail carriers per 100 miles of driving during six censuses in 1957 and 1958 (Table 1).

to introduce a strain of pheasants that would survive and produce huntable populations south of the contiguous range occupied by pheasants in Illinois (Ellis 1959; Ellis & Anderson 1963). By 1959, the population had nearly disappeared, indicating that one or more factors were preventing the establishment or maintenance of pheasants on this study area.

An investigation was begun to determine if a deficiency of calcium might be a factor in preventing the establishment of pheasants on this area of Illinoian drift. The availability of calcium and its ingestion and subsequent utilization by pheasants on the Cumberland County area were compared with like information from a study area on Wisconsinan drift within the established pheasant range. Only pheasants that had been hatched and reared on the Cumberland County area were used in the comparative analysis of calcium ingestion because the effect of possible mineral deficiencies on the Illinoian drift might not be immediately detectable in released birds.

The study area on Wisconsinan drift was located near Sibley in Ford and McLean counties of east-central Illinois (Fig. 4); it contained 23,200 acres, 19,040 in northwestern Ford County and 4,160 acres in northeastern McLean County. The soils of Ford County were formed from material deposited by the last invasion of the Wisconsinan ice sheet together with wind-blown material and some water-deposited outwash (Smith et al. 1933:8–9). McLean County soils were formed primarily from loess deposited after the Wisconsinan glacier receded (Hopkins et al. 1915:2). Ford County ranked second and McLean County fourth among Illinois counties in the order of abundance of pheasants in 1957 and 1958 (Table 1).

The study area in Cumberland County consisted of 10,240 acres located near Neoga, about 20 miles south of established pheasant range in Illinois (Fig. 4). According to Smith & Smith (1940:7), both the Illinoian and the Wisconsinan glaciers contributed to the soils of Cumberland County. The Illinoian ice sheet covered the county and left a broad undulating plain that still persists over much of the county. The Wisconsinan glacier entered a small portion of the extreme northern edge of the county (Fig. 4) and subsequently formed narrow outwash plains in a number of places on the old Illinoian glacial plain. Wisconsinan glacial drift did not extend to the Cumberland County study area. No loess deposits in Cumberland County are more than about 40 inches in depth and, in large portions of the county, the deposits are so shallow that they are almost indistinguishable.

Calcium was available to the pheasants on both study areas in the carbonate form as calcitic limestone, $CaCO_3$, and as dolomitic limestone, $CaMg(CO_3)_2$. Alder (1927:232) reported that the use of dolomite for approximately 4 months caused domestic pullets to become nervous and sensitive, develop diarrhea, and produce fewer eggs—eggs with progressively thinner eggshells; these symptoms rapidly cleared up when practically pure calcium carbonate was substituted for dolomite. Dale (1955:328–329) found that penned pheasant hens fed crushed dolomitic limestone were much more successful in producing eggs and chicks than were hens fed granite grit. Harper (1963:366; 1964:269) reported that grit from gizzards of wild pheasants, both young birds and adult hens, contained amounts of calcite that were disproportionately greater than the amounts of dolomite when availabilities of the two materials were measured; in fact, wild pheasants consumed only trace amounts of dolomite. These reports suggest that calcitic limestone is desirable for maximum reproductive performance by pheasant hens.

Samples (excluding grit) of both the Illinoian and Wisconsinan glacial soils were tested. The Illinoian sample contained 0.23 per cent calcium and the Wisconsinan sample 0.15 per cent calcium (Harper & Labisky 1964: 725–726), indicating that calcium was at least as abundant in soils of the Illinoian drift as in soils of Wisconsinan drift; phosphorus and magnesium levels were slightly higher in soils from the Wisconsinan drift than in those from the Illinoian drift.

The amount of calcium in the grit from fields and secondary roads on the Illinoian drift was equal to that from fields and secondary roads on the Wisconsinan drift (Harper & Labisky 1964:725–726). The grit from roads on both the Illinoian and Wisconsinan drift yielded 5.5 g of calcium per 100 g of grit. The grit in soil samples collected from fields of Illinoian and Wisconsinan glacial soils contained 0.2 g of calcium per 100 g of grit.

The amount of calcium found in the grit from gizzards of wild pheasant hens during the nesting season (May and June) averaged 2.3 g per 100 g of grit on the Illinoian drift, 1960–1961, and 1.9 on the Wisconsinan drift, 1957–1962 (Harper & Labisky 1964:727). Femora and tibiae from the pheasant hens collected from an area on the Illinoian drift in Cumberland County contained a percentage of mineral ash that was slightly higher than the percentage of ash in the femora and tibiae of penned pheasant hens that had received diets containing 2.34 per cent calcium and equal to the percentage of ash in the femora and tibiae of wild hens collected from areas of Wisconsinan drift (Greeley 1962:190, 192). Harper & Labisky (1964:727–728) reported no significant differences in amounts of mineral ash or calcium ash per unit of wet tissue weight of hens collected on Illinoian and Wisconsinan drift during the spring of 1962. Too, grit from the gizzards of young pheasants collected on Illinoian drift had amounts of calcium similar to the amounts from the gizzards of young birds that were collected on the Wisconsinan drift (Harper & Labisky 1964: 727–728).

In the nesting seasons of 1961 and 1962, pheasant hens on the area of Illinoian drift in Cumberland County (including hens released and hens hatched and reared on the area) compared favorably with hens from self-maintaining populations on Wisconsinan drift in (i) number of eggs per nest, (ii) number of eggs hatched per successful nest, and (iii) number of chicks per brood (Anderson 1964:259). These criteria of successful reproduction indicate that the physiological utilization of calcium by hens on the Illinoian drift was similar to that by hens on the Wisconsinan drift.

Even if soils on the Illinoian drift contained less available calcium than the soils on the Wisconsinan drift, the difference might be compensated for by the apparent ability of pheasants to be selective in the type of grit they consume. Sadler (1961:340–341) found that penned hen pheasants selected calcareous grit (limestone) rather than noncalcareous grit (granite) during the egg-laying period. Harper (1963:365–366; 1964:269) reported that wild pheasants in Illinois, both young and adults, selected calcitic over dolomitic grit, as well as calcareous over noncalcareous grit. Also, pheasant hens may possess the ability to select calcitic grit containing high rather than that containing low levels of calcium (Harper & Labisky 1964:730).

Native gallinaceous birds, the bobwhite and the prairie chicken (*Tympanuchus cupido*), counterparts of the pheasant, have established self-maintaining populations on areas of Illinoian drift in Illinois. These birds, like the pheasant, have high calcium demands.

Our conclusion is that, in Illinois, calcium is as available to pheasants on Illinoian glacial drift as on Wisconsinan drift, which is of more recent origin. We found that hen pheasants and young pheasants in areas of Illinoian drift ingested calcium in amounts similar to the amounts ingested by birds in areas of Wisconsinan drift; also, that the physiological utilization of calcium by hen pheasants in an area of Illinoian drift appeared to be equal to that by hens from a thriving population of pheasants in an area of Wisconsinan drift. It seems unlikely that, in Illinois, the establishment and maintenance of pheasant populations in areas of Illinoian glacial drift are prevented by a deficiency of calcium. This conclusion, however, does not disprove Leopold's hypothesis that a deficiency of some element or vitamin may prevent the establishment of pheasants on areas of pre-Wisconsinan glacial drift.

Pheasants and Weather

Weather, as well as a deficiency of calcium, has long been regarded as a factor limiting (i) the southward spread of the pheasant, particularly in the eastern portion of the United States, and (ii) the abundance of pheasants within portions of their established range. Pheasants have become widely established in the northern sectors of the midwestern and eastern United States, but, with few exceptions, they have failed to establish self-maintaining populations south of a line designating 40 degrees north latitude.

Of the many stimuli or stresses to which the pheasant is subjected, some of the most important are associated with weather. The description Selye (1949:837) gives of the "stage of resistance," the second stage of the general-adaptation-syndrome, indicates that a pheasant hen is capable of adapting to one or more stresses but at the expense of resistance to others. The description of the "stage of exhaustion," the third and final stage of the syndrome, indicates that the hen may die as a result of very prolonged exposure to stresses to which she has become adapted; the hen cannot indefinitely maintain adaptation to certain stresses. Even stresses that do not cause death may interfere seriously with the physiological functions of the hen, particularly those associated with reproduction. Very likely, the stresses that weather exerts on the pheasant are fewer, less intense, less prolonged, and less critical in the established contiguous range of the bird than in range where the bird experiences difficulty in maintaining even meager, disjunct populations.

Extensive losses of pheasants as a result of unfavorable weather conditions in winter are well documented in the Plains and Prairie States. Winter losses of pheasants as high as 90 per cent have been reported in portions of South Dakota (Kimball et al. 1956: 211, 229); severe winter losses have been reported in Iowa (Scott & Baskett 1941:28), Minnesota (Erickson et al. 1951:33–34) North Dakota (Miller 1948:4–5), and Nebraska (McClure 1948:268–269). These reported losses of pheasants during winter in the Plains and Prairie States were attributed mainly to the birds' freezing and choking during severe winter storms—storms characterized by heavy snowfall and strong winds. That starvation is probably not an important cause of winter mortality was demonstrated by Tester & Olson (1959:308–309), who reported that, in Minnesota, pheasants penned out-of-doors, although losing considerable weight, could survive at least 2 weeks without food during severe winter weather. The cases of starvation reported by Nelson & Janson (1949:308) in South Dakota were confined to small, scattered areas; only about 5 per cent of the pheasants in these areas died from starvation.

Losses of pheasants to winter weather in the Lake States, which include Illinois, are usually much less severe than in the Plains and Prairie States because prolonged periods of deep snow and low temperatures are less frequent, and food in the form of waste grains is generally abundant (Fig. 5, 6).

Even though winter weather is seldom so severe as to cause direct losses of pheasants in the Lake States, and particularly in Illinois, unfavorable weather conditions during winter may so weaken the birds physiologically that they enter the breeding season in less than adequate physical condition. Kozicky et al. (1955:140) pointed out that in Iowa "two months of consecutive low temperatures from December through February were detrimental to fall pheasant populations by reducing the breeding stock." Recently, Edwards, Mikolaj, & Leite (1964:278) suggested that depressed reproductive performance of pheasants was directly related to low body weights resulting from exposure of the birds to severe weather during the preceding winter. This promising area of investigation—the relationship between winter weather and reproduction — merits attention in future pheasant research.

Rainfall and temperature, particularly during the breeding season, have long been considered two of the major weather factors affecting productivity and abundance of pheasants. During the 1940's, pheasant populations in most midwestern states suffered drastic reductions in their numbers (Kimball 1948:292). In Illinois, the decline of pheasants was probably of shorter duration than in most other states (Robertson 1958:122). There was fairly general agreement among investigators that unfavorable spring weather, persisting for several years in widely separated areas, may have caused the widespread reduction in numbers of pheasants in the 1940's (Allen 1950:107).

Investigators in the Midwest have reported that the production of young pheasants has been adversely influenced by unusually cool, wet springs (Allen 1947:234–236; Ginn 1948:4–5; Erickson et al. 1951:31–32). Kimball (1948:309) reported that pheasant populations in South Dakota during the 1940's did not increase in years (with one exception) in which the weather during June was either wet and cold or unusually hot and dry. Kozicky et al. (1955:141) reported that fall populations of pheasants in Iowa showed decreases in years during which the breeding season was characterized by below normal temperatures and above normal rainfall, but that, with above normal temperatures, amounts of precipitation apparently had no adverse effect on the numbers of pheasants in fall. Dale (1942:18) reported that wet years (greater than average rainfall in June, July, and August) were not detrimental to pheasants in Michigan. The evidence regarding the influence of gross spring weather on pheasant production and survival is not clear-cut.

Buss, Meyer, & Kabat (1951:34–35) reported that both wild and artificially propagated pheasants deposited their first eggs on approximately the same dates each year regardless of year-to-year variations in spring weather. Although the dates of first eggs are approximately

Fig. 5.—Flock of pheasants in woody cover along fencerow during period of deep snow in 1960. Heavy accumulations of snow are infrequent in east-central Illinois. In winter, many of the pheasants in this area are found within about 100 yards of woody vegetation, even though such vegetation is scarce. Pheasants are associated more often with the type of cover shown here than with hedgerows of osage orange or multiflora rose.

the same each year, the dates of establishment of nests are not. Kabat, Thompson, & Kozlik (1950:4–5, 15) postulated that weather that causes a delay in the annual hatch may place prolonged reproductive stress on adult pheasant hens and result in an increase in the mortality rate of these hens; stress in these hens, as indicated by loss in body weight, appeared to be related directly to the number of eggs laid. Buss, Swanson, & Woodside (1952:280) concluded that adverse weather in early June, 1950 (weather characterized by unseasonably heavy precipitation and low temperatures), delayed renesting among pheasants in southeastern Washington; the delay subjected the hens that attempted to renest to the prolonged physical stress of additional egg-laying and increased the rate of mortality among them. Kabat et al. (1956:33–34) pursued further the problems of stress in hen pheasants and showed that adult hens were in their poorest physiological condition in July and August, toward the end of the reproductive season and during molt. Wagner (1957:308–310) more fully expounded the evidence of accelerated late-summer mortality of adult hens, linking it with the physiological stresses caused by prolonged reproductive efforts, particularly egg-laying.

Although numerous investigators have provided convincing evidence that many pheasant hens die during the reproductive and molting periods, the relationship between their deaths and the autumn populations of young has not been well defined. A high proportion of young in the fall population does not necessarily indicate a good hatch in the preceding breeding season. Wagner (1957:313) pointed out that late-summer hen mortality "appears to bias hen age ratios or total-population age ratios from unhunted areas sufficiently to cause one to form erroneous conclusions if not taken into account."

The time of death of adult hens has an important effect on the hatch of chicks and on efforts made to measure the hatch. If a hen dies prior to the completion

Fig. 6. One of several hundred feeding sites of pheasants in an Illinois cornfield in early March, 1960. About 400 pheasants had scratched through more than a foot of compacted snow to reach waste corn in this field.

of incubation or early in the brooding period, she adds few, if any, young to the population. If she dies after the chicks are able to survive on their own, but prior to fall, her death has little or no effect on the annual production of young; however, the absence of this and similar hens from the fall population results in higher young-to-adult age ratios than are justified by the hatch.

Adverse weather that during the reproductive season places unusual stress on adult hens may reduce the production and survival of chicks by causing the hens to give less than the normal attention to eggs or young. Laboratory experiments by MacMullan & Eberhardt (1953:330) suggested that inattentive incubation by nesting hens, particularly during late incubation in cold and wet spring weather, might cause lethal exposure of eggs. These workers reported that young chicks were less tolerant of cold, especially when accompanied by precipitation, than were eggs. If production of young is depressed and death of adult hens accelerated by adverse weather during the reproductive season, age ratios the following autumn might indicate erroneously that an average hatch of young pheasants had occurred.

When Graham & Hesterberg (1948:10–13) compared rainfall-temperature climographs for four areas in Oregon, Minnesota, North Dakota, and Michigan where pheasants had established self-maintaining populations, they found the greatest similarities in the climographs of these four areas during April and May. Climographs for areas in Missouri, Ohio, and Tennessee where pheasants had not established themselves showed little or no similarity during April and May to the climographs for the four areas occupied by pheasants. Graham & Hesterberg (1948:10) concluded that "if the distribution of pheasants is limited in any way by temperature or precipitation the effects must be during the spring season."

Thus far, in this paper, little attention has been given to measuring directly the influence of summer rainfall on the hatch of pheasant chicks. In the established pheasant range in Illinois, June is the month during which about 50 per cent of the annual crop of chicks is hatched. Heavy rainfall during June might exert two opposing influences on the hatch of pheasant chicks in this area. First, heavy rainfall so timed as to occur during a period when a sizable portion of the annual hatch was very young might result in the mortality of many young chicks, particularly if the rains were accompanied by cold (MacMullan & Eberhardt 1953:330). Second, excessive rainfall during early June would tend to delay mowing of tame hay, thereby allowing many nests to hatch that would normally be destroyed by mowing.

To determine what effect, if any, the amount of rainfall in June, 1957 and 1958, had upon the hatch of chicks within the established range of pheasants in Illinois, we plotted rainfall for this month against the number of chicks observed per 100 miles of driving by rural mail carriers during August of the same years in each of the 25 counties in which pheasants were most abundant (Fig. 7). The long-term average rainfall during June for these 25 counties (Page 1949:201–294) was 3.9 inches. In 1957 and 1958, rainfall in June averaged 5.1 and 7.0 inches, respectively, for the 25 counties; thus, in June of both years, rainfall was above the long-term average. The average amount of rainfall recorded in June, 1958, was significantly greater than that recorded in June, 1957 ($t = 3.73$; $P < 0.01$). The mean number of chicks per 100 miles of driving in the

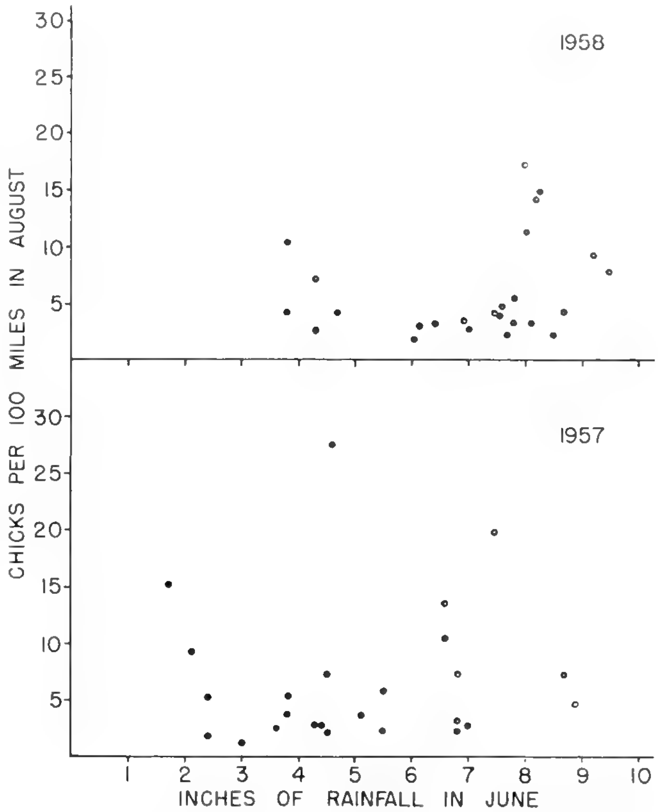

FIG. 7.—Abundance of pheasant chicks reported by rural mail carriers per 100 miles of driving during August in relation to rainfall during the preceding June for each of the 25 Illinois counties in which pheasants were most abundant (Table 1), 1957 and 1958. The rainfall data are from the United States Weather Bureau (1957, 1958).

25 counties during August was 6.8 in 1957 and 6.0 in 1958. The difference in the abundance of chicks between August of 1957 and August of 1958 was not significant ($t = 0.48$; $P > 0.50$), but fewer chicks were observed in 1958, which was characterized by more rain during June than was 1957.

Statistical tests by linear regression indicated that there was no significant correlation (0.05 level) between the amount of June rainfall and the abundance of chicks in the 25 top-ranked pheasant counties of Illinois in August of 1957 or 1958 (Fig. 7; 1957: $b = 0.216$, $F = 0.10$, Reference $F = 4.28$ at 1 and 23 *d.f.*; 1958: $b = 0.589$, $F = 1.25$, Reference $F = 4.28$ at 1 and 23 *d.f.*).

The abundance of chicks in August appeared to be less in counties where rainfall measured between 5 and 6 inches during June than in counties with amounts of rainfall less than 5 inches or greater than 6 inches (Fig. 7). However, when tested for curvilinearity of regression (Snedecor 1956:452–457), these data yielded no statistical significance (0.05 level) for either August, 1957, or August, 1958 (1957: estimated $Y = 220.0 - 1.189X + 0.1343X^2$, $F = 0.15$, Reference $F = 3.42$ at 2 and 22 *d.f.;* 1958: estimated $Y = 22.94 - 6.490X + 0.5518X^2$, $F = 0.67$, Reference $F = 3.42$ at 2 and 22 *d.f.*).

Another weather factor, that of evapotranspiration (evaporation from the soil surface and transpiration from plants) has been suggested by McCabe, MacMullan, & Dustman (1956:322–325) as a possible influence on the distribution of pheasants in the Lake States. These workers reported "an almost perfect correlation" between the distribution of pheasants in the Lake States and the mesothermal B'_1 region as classified by the climatologist Thornthwaite (1948:81, 87, and pl. 1*C*). This region has a potential evapotranspiration of 22.44 inches along its northern boundary (north of the central portions of Wisconsin and Michigan) and 28.05 inches along its southern boundary (near the central portions of Indiana and Illinois). An exception to this "correlation" is found in Illinois, where a portion of the best pheasant range in the east-central sector of the state falls south of the mesothermal B'_1 region. The cause-and-effect mechanisms of the apparent relationship between evapotranspiration and pheasant distribution are not known.

Bennitt & Terrill (1940:428) established a working hypothesis that the barrier limiting the southward extension of the range of the pheasant might be "high egg temperature and the resulting mortality of embryos," or, in other words, embryonic mortality resulting from the exposure of clutches to high air temperatures in spring or summer. Graham & Hesterberg (1948:12, 14) postulated that the southern limit of pheasant distribution might be determined by the extent of embryonic mortality caused by direct exposure of clutches of eggs to the sun's rays during the preincubation period.

Yeatter (1950:529–530) was the first worker to conduct experiments to determine the influence of air temperatures in defining the southern limits of the range of the pheasant. He observed a sharp decline in successful hatches and in the number of chicks produced per clutch along the southern fringe of the pheasant range in east-central Illinois after the first week of July; nest studies suggested that this decline in production resulted from a decline in hatchability of eggs, a decline resulting from embryonic mortality and not from decreased fertility. To test the postulate that the mortality of embryos might be attributed to exposure of the clutch to high temperatures during the preincubation period, a time at which the hen does not control the temperature of the clutch, Yeatter obtained pheasant and bobwhite eggs from Illinois game farm stock and exposed them to different air temperatures between 62 degrees F (control) and 88 degrees F during 9-hour periods (8:00 a.m. to 5:00 p.m.) for 7 consecutive days prior to incubation. The pheasant eggs exposed under these conditions showed a progressive decline in hatchability from a high of 75.0 per cent at 62 degrees F, the control temperature, to a low of 42.1 per cent at 88 degrees F, while hatchability of the quail eggs, similarly exposed, declined from a high of 76.2 per cent at 62 degrees F to 68.4 per cent at 88 degrees F. These data suggested that high air temperatures during the laying period had an important influence in limiting the southward spread of the pheasant in Illinois and other states.

To further test this postulate, Yeatter obtained eggs from two strains of pheasants, one strain from California and the other from Wisconsin. When the eggs from these two strains were subjected to similar preincubation temperatures of 62 degrees F (control) to 88 degrees F, the eggs from the California stock showed greater hatchability than did the eggs from the Wisconsin stock (Ralph E. Yeatter, Illinois Natural History Survey, Urbana, 1962, personal communication). These experiments, when considered alone, suggested that the ability of pheasant embryos to survive under conditions of high air temperatures may have been the operative force in the natural selection of a strain of pheasants able to withstand the climate of California, and that the pheasant now resident in the Midwest has failed to become established when it has been released south of its present contiguous range because of its lack of genetic adaptation to high air temperatures. However, it seems illogical to assume that natural selection of individuals with the genetic aptitude necessary to withstand higher air temperatures would not occur along the southern margin of the range currently occupied by the pheasant in the Midwest, thus allowing the bird to gradually extend its range southward into previously unoccupied range. Perhaps not enough time has elapsed to create a gene pool of traits that would allow a measurable and permanent spread of the pheasant into areas of higher temperatures.

That high air temperatures alone probably do not limit the southward extension of pheasants is indicated by the observations of Ellis & Anderson (1963:225). Pheasants originating from California stock failed to establish self-maintaining populations after being released on two areas south of the contiguous pheasant range in Illinois (Ellis & Anderson 1963:225). Among the California pheasants and their progeny, Ellis & Anderson (1963:234) reported, "There were no differences in the average number of chicks in broods hatched from nests exposed to temperatures that exceeded 79 F on 7 or more days during the preincubation period when compared to the average number of chicks in broods from nests not exposed to such temperatures." These workers (Ellis & Anderson 1963:236; Anderson 1964:263) concluded that the failure of liberated pheasants and their progeny to establish themselves south of the contiguous range occupied by pheasants in Illinois was due more to inadequate survival, particularly during fall and winter, than to inadequate reproduction.

This discussion of pheasants and climate has shown the degree of complexity with which we are faced when we attempt to explain abundance and distribution of pheasants by weather factors. We know too little about these factors and their effects. As McCabe et al. (1956: 324) pointed out, "What to the pheasants are ideal climatic conditions are not necessarily those measured by weather stations, ..." Undoubtedly, weather exerts a considerable influence on established pheasant populations, particularly with respect to annual fluctuations. On areas occupied by only a few pheasants, unfavorable weather may limit the dispersion and abundance of the population by annually depressing production or by increasing the mortality rates, or both. In unoccupied range, the cumulative effect of these factors might be so great as to preclude the establishment of self-maintaining populations.

We hypothesize that, in areas where factors other than weather are favorable to the bird, pheasant populations may be limited not by adverse weather conditions in any one year but rather by the frequency, severity, and duration of adverse conditions over a period of years. We may therefore speculate that adverse weather, as well as other adverse environmental factors, occurs less frequently, with less severity, and for shorter periods in the range occupied by pheasants than in the range unoccupied by pheasants. The validity of this hypothesis will be determined only after completion of long-term ecological studies of pheasants in areas characterized by different levels of pheasant abundance.

Summary

In Illinois and other midwestern states, populations of pheasants are characterized by discontinuous distribution and by variable abundance. This paper reviews published findings and presents new data on three factors, land use, calcium, and weather, all commonly considered as important influences on the distribution and abundance of pheasants in Illinois.

The intensively cultivated cash-grain area of east-central Illinois has consistently supported the best populations of pheasants in the state since the late 1930's. The following land-use practices were found to be characteristic of many of the counties in Illinois where pheasants were most abundant: (i) a high proportion of the land in cultivated crops and a low proportion in woodland, (ii) a high proportion of the farms classified as cash-grain farms and a lower proportion as dairy farms and livestock farms, and (iii) about 50 per cent of the cropland in corn and soybeans, about 5 per cent in hay, and about 15 per cent in pasture. A multiple regression analysis indicated that a combination of three land-use factors, (i) the proportion of land in cultivated crops, (ii) the proportion of farms classified as cash-grain farms, and (iii) the proportion of cropland in hay, when tested against all other land-use factors, exerted the greatest influence on the distribution and abundance of pheasants in Illinois.

In Illinois and other North Central States, the distribution of pheasants coincides closely with that area blanketed by the Wisconsinan glacier, the last of the major ice sheets. Pheasants have seldom established themselves on Illinoian glacial drift, which in Illinois underlies and extends south and west of the Wisconsinan drift. The Illinoian glacier was the immediate predecessor of the Wisconsinan glacier. A supposed deficiency of calcium in the soils and grit on areas of exposed Illinoian drift has long been regarded as a factor limiting the southward spread of the pheasant in the North Central States. In Illinois, the amounts of calcium in the soils and grit in an area of Illinoian drift, where pheasants have not established self-maintaining populations, were equal to or greater than the amounts from similar items in an area of Wisconsinan drift, where pheasants are abundant. The amounts of calcium in the grit from gizzards of hen pheasants and young pheasants on Illinoian drift were very similar to those amounts found in the grit from gizzards of hens and young on Wisconsinan drift; also, the subsequent utilization of ingested calcium by hen pheasants on the Illinoian drift appeared to be equal to that by hens from a thriving population on the Wisconsinan drift. It is unlikely that, in Illinois, the establishment of self-maintaining pheasant populations on areas of Illinoian drift is prevented by a deficiency of calcium.

Unfavorable weather is partially responsible for year-to-year fluctuations in numbers of pheasants within their established range. On areas occupied by only a few pheasants, unfavorable weather may limit the dispersion and abundance of the population by annually depressing production and by increasing mortality rates. In unoccupied range, the cumulative effect of these factors might be so great that the establishment of pheasants would be prevented. In areas where factors other than weather are favorable to the bird, pheasants may be limited not by unfavorable weather in any one year but rather by the frequency, severity, and duration of adverse weather over a period of years. Adverse weather, as well as other adverse environmental factors, probably occurs less frequently, with less severity, and for shorter periods in the range occupied by pheasants than in the range not occupied by pheasants.

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