THE INFLUENCE OF CALCIUM ON THE DISTRIBUTION OF THE RING-NECKED PHEASANT (PHASIANUS COLCHICUS) IN NORTH AMERICA

by
Frederick Harold Dale

Thesis submitted to the Faculty of the Graduate School
of the University of Maryland in partial
fulfillment of the requirements for the
degree of Doctor of Philosophy

1954

ACKNOWLEDGMENTS

Few research projects constitute the sole work of one person, and the study reported here is no exception. It represents a cooperative venture between the University of Maryland and the Fish and Wildlife Service of the United States Department of Interior. Grateful acknowledgment is made of the assistance of Professor Robert A. Littleford, of the University of Maryland, who directed graduate studies and provided advice and inspiration for both academic and experimental work in connection with this study. Appreciation also is expressed for assistance of faculty members of the zoology and poultry husbandry staffs of the University of Maryland for help in various phases of the program of graduate studies and research.

Arnold L. Nelson, Director of the Patuxent Research Refuge, and Durward L. Allen, Assistant Chief of the Branch of Wildlife Research, of the United States Fish and Wildlife Service were instrumental in setting up the program of research under which the project was financed. Both have been helpful in encouraging its furtherance and in giving advice on methods of procedure. James B. DeWitt, biochemist in charge of the chemistry laboratory of the Patuxent Research Refuge, has given valued advice in the nutrition study and has assisted in interpretation of results. Acknowledgment is also made to James V. Derby, Jr. for chemical analyses of materials and to Clark G. Webster and Clyde Vance for maintenance of captive pheasants and for assistance in weighing, collecting eggs and other routine work. Many others have given help, both directly and indirectly, acknowledgment for which is made here.

Appreciation is also expressed to the Chas. Pfizer Company of Terre Haute, Indiana, for their courtesy in providing the "Bicon" APF supplements used in this study.

TABLE OF CONTENTS

List of Tables

List of Figures

INTRODUCTION

Local distribution of the ring-necked pheasant (*Phasianus colchicus*) in North America has received much study by game biologists in recent years. Applied aspects of the problem are of especial significance to game managers in several regions, and ecological relationships offer a valuable field of study for the general biologist with more academic interests.

The North American ring-necked pheasant has been derived from several Old World races, some of which have been considered to be distinct species by Delacour (1945). Nevertheless, the American Ornithologists' Union (1931) refers to the American pheasant as being most closely related to *Phasianus colchicus torquatus* Gmelin, from eastern China. This treatment considers all forms from which the American pheasant has been derived as conspecific, with the exception of the Japanese green pheasant (*Phasianus versicolor* Vieillot), which Greenhalgh (1949) reports as having been mixed into some game-farm stock of the American bird. In the absence of any clear-cut proof that wild pheasants in North America are hybrids between *P. colchicus* and *P. versicolor*, the name *P. colchicus* is used in this thesis.

Since its first successful introduction in northwestern United States late in the Nineteenth Century (Walcott, 1945), this bird has become established in all major parts of the country except the Southeast and has become the most important upland game bird of the northern states (Leedy, 1949). It was estimated by Nelson (1946) that 7,500,000 pheasants were killed by hunters in South Dakota alone in 1945, and estimates from several states have indicated hunting-season kills approaching or exceeding a million birds each (Dustman, 1949; Buss, undated; Pennsylvania Game Commission, 1949; Michigan Department of Conservation, 1950: Ledin and Bue, 1953).

In becoming adapted to its wide range in North America, the pheasant has demonstrated exceptional adaptability to a variety of ecological conditions. It is found in the Imperial Valley of California below sea level (Rasmussen and McKean, 1945), and in areas over a mile above sea level in Colorado (ibid). In Imperial Valley, official summer temperatures reach 120 degrees Fahrenheit (Sprague, 1941), whereas in South Dakota, winter temperatures as low as -57 degrees Fahrenheit have occurred (Laskowski, 1941). Sprague (op. cit.) indicates that rainfall in the Imperial Valley is only about 3 inches annually, whereas in Lancaster Valley, Pennsylvania, where a relatively high population of pheasants occurs, the annual rainfall is about 41 inches (Bliss, 1941).

Despite this wide adaptation to a variety of basic ecological conditions, the pheasant seems highly sensitive to some obscure factors which strikingly restrict local distribution. Adjacent to areas of relatively high population there are spots of apparently comparable range in which the pheasant is scarce or absent (Leopold, 1931). In western United States distribution seems to be controlled largely by availability of water and corresponding agricultural practices. In almost all northwestern irrigated valleys, pheasants are common (Rasmussen and McKean, 1945). However, in the Lake States and in northeastern United States local distribution has not been easily explained (Leopold, 1931).

In Iowa, pheasants are abundant in the northwestern counties but are relatively scarce in southern and eastern parts of the State (Nomsen, 1953). Minnesota has a high population along its western border, but numbers decrease rapidly toward the eastern half of the State (Ledin and Bue, 1953). In Wisconsin there are high populations in the southeastern quarter of the State, but pheasants are relatively scarce in western and northern counties (Buss, undated; Kozlik and Kabat, 1949). States to the eastward are marked by centers of fair to high populations generally surrounded by scarce areas. In Indiana there is no part of the State that can be classed as good pheasant range (Barnes, 1950). In Ohio, according to Leedy and Hicks (1945), although there is a high population in the northwestern counties, pheasants have never become established in the southeastern part of the State.

This spotty distribution offers a challenge to the game biologist, who is charged with the responsibility for improving pheasant habitat. Until the limiting factors within poor range can be identified, management of the habitat must proceed on a basis of trial and error. Marshall (1953) summarizes the habitat-management work that has been done under the Federal Aid in Wildlife Restoration Program, which was initiated in 1937. He shows that much of this work is open to question because of the uncertain state of knowledge about ecological factors involved. No one has as yet demonstrated any significant increase in pheasant populations as a direct result of this work.

Thus, the problem of local distribution of the pheasant offers a fertile field for the pure ecologist and the game manager alike. It is clear that no such simple solution as the requirement of the

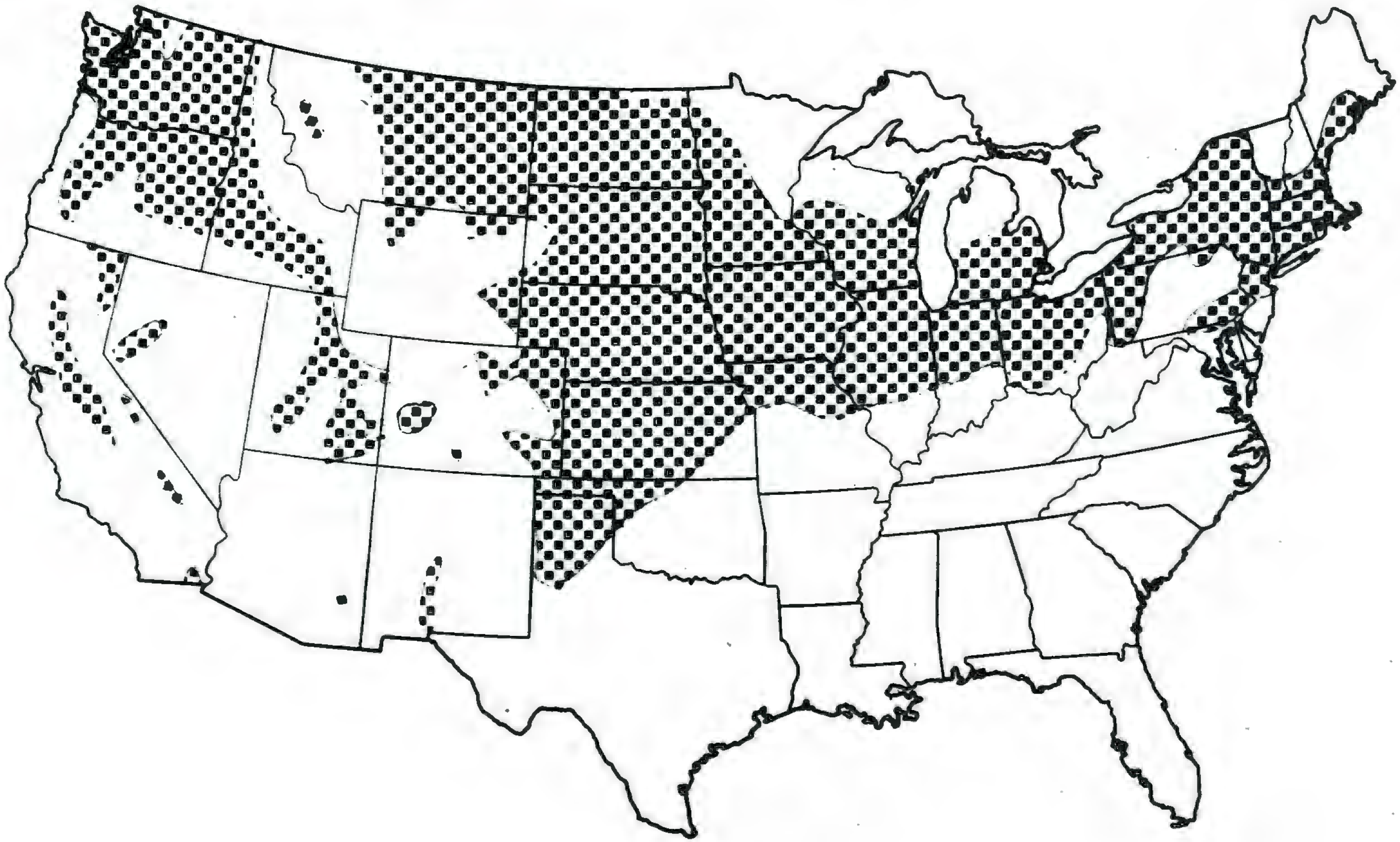


Fig. 1. Generalized map of pheasant distribution in the United States. Modified from McAtee (1945).

pheasant for a specific cover type, level of rainfall, elevation, or kind of food supply will suffice to explain the bird's distribution. It is likewise apparent that a more specific knowledge of the ecology of this species will be required before the game biologist can hope to apply techniques for improving populations in the field. The present problem was undertaken in the hope of adding to knowledge of the ecology for the benefit of both groups of biologists.

Studies of Distribution Factors

There have been relatively few controlled experiments dealing with distribution of pheasants, but several workers have speculated on possible limiting factors.

Climatic Factors. Cahn (1938) attempted to show that the Tennessee Valley was outside limits of tolerance for high temperature and rainfall during nesting and rearing seasons by comparing climographs of that area and more favorable pheasant ranges. This report, however, did no more than point out a correlation. The Imperial Valley of California also falls far outside typical temperature range tolerated by pheasants but the birds have become established there, albeit in low numbers.

It was also suggested (Bennitt and Terrill, 1940) that high temperature might be the limiting factor for southern distribution of pheasants, and it was pointed out that ground temperatures along the southern edge of pheasant range seemed to approach the limit of tolerance for egg viability. The discussion was largely speculative, as no experimental data referring to critical temperatures for viability were cited.

Somewhat the same arguments were advanced by Graham and Hesterberg (1948) who plotted climographs for several successful and unsuccessful ranges to show that unsuccessful ranges tended to exceed an assumed maximum temperature for viable eggs during the critical period of the year. These authors also suggested that degree of insolation might become a critical factor in southern latitudes, especially in view of the fact that the pheasant nest usually is not covered.

In Michigan, English (1941) exposed pheasant eggs to temperatures up to 85 degrees Fahrenheit for three-hour periods but there was no great drop in hatchability, even after three such exposures.

More recently, Yeatter (1950) in Illinois subjected eggs to preincubation temperatures as high as 88 degrees Fahrenheit for fourteen days. Although quail eggs seemed to show no ill effects, pheasant eggs so treated failed to hatch. Yeatter proposed that a difference in tolerance to high preincubation temperatures might explain the fact that quail are successful in southern states while the pheasant is preponderantly northern in distribution. He recognized the difficulty of applying this conclusion in the Southwest where pheasants nest successfully as far south as Baja California but assumed that racial stock of western pheasants might be more tolerant toward high temperature.

These studies of climatic influence deal with factors that may be highly significant in some parts of the pheasant's range. As pointed out elsewhere, however (Dale, in press), the problem is much more complex than that of the direct influence of temperature on viability of pheasant eggs. In the Imperial Valley of California and southward into Baja California, pheasants breed successfully in the wild despite summer temperatures in excess of those experienced in southeastern United States. Scattered populations of pheasants exist also in isolated valleys of Arizona and New Mexico where hot summers are characteristic.

There has been little if any study of effects of micro-climates in various parts of the pheasant's range. Possibly some combinations of climatic factors such as daily temperature change, length of exposure to high temperatures each day, or effects of evaporation at ground levels at different humidities are of greater significance than has been recognized.

Nutritional Factors. Commenting on the apparent restriction of pheasants in the Midwest to glaciated areas, Leopold (1931) suggested that there might be some nutritional factor present in greater abundance in glaciated soils than elsewhere. Such a factor, he reasoned, might have a direct effect or might be expressed indirectly through influencing plant growth or even the presence of some species of insect that could provide a growth factor necessary for pheasants. Lime was suggested as a possible factor, since this is known to be more abundant in glaciated than in unglaciated areas of the Midwest.

McCann (1939) in experiments on penned birds found calcareous grit to be essential when other sources of calcium were not available to pheasants. When quartz was substituted for limestone, there was an increase in the amount of grit consumed and there were evidences of deterioration in the birds. He postulated that calcareous grit available in glaciated areas might be responsible for success of pheasants there, and that the general absence of calcareous gravel might explain failure of pheasants in southeastern United States. This is one of the more significant controlled nutrition studies bearing on mineral requirements of the pheasant, but the report does not include analyses of diet or grit. "Glacial gravel" was found to be satisfactory but quartz was not suitable. Furthermore the study was restricted to maintenance diets. Reproduction was not considered.

Poultry nutrition studies indicate that suitability of a particular kind of grit depends upon the calcium balance of the entire diet. Black (1946) found chicks on a low calcium diet to require limestone grit, but those on a medium calcium diet made better progress with flint grit than with limestone. It has been found (Bethke, et al, 1929) that additions of calcium or phosphorus in excess of requirements generally result in depressed growth and increased mortality. From these and other studies it seems that the need for calcareous grit by pheasants might depend upon the calcium available to them in the remainder of the diet.

Gerstell (1937) pointed out that all high populations of pheasants in Pennsylvania were in limestone sections, especially around outcroppings of Trenton limestone, but he did not attempt to draw further conclusions from the fact.

It has been noted that pheasants are able to conserve grit in their gizzards for a considerable period, but they seem especially eager to obtain grit after long periods in winter when it is not available (Hawkins, 1937). This fact, however, has not been considered as a factor in distribution of the pheasant.

Randall (1940) questioned the correlation between pheasant distribution and limestone outcroppings in Pennsylvania. He thought agricultural practices were more significant, especially the amount of corn grown and the method of harvest. He believed that picking of corn by machine or cutting and removing the stalks resulted in poor winter cover, and that first-class range was generally characterized by picking corn by hand.

Agricultural Factors. Relationships between agricultural practices and pheasant abundance have been pointed out by a number of writers. Rowan (1948) mentioned that some of the best pheasant shooting "on the continent" was provided in the irrigated Brooks area of southern Alberta. Clarke (1949), also writing of Alberta, says that best pheasant conditions are found where about 80 percent of the land is in crops and the rest broken-up woodlots or brush. Glading (1946) shows the relation between irrigated farming, particularly rice culture, and pheasant distribution in California.

Other studies not particularly concerned with distribution have revealed correlations between changes in agricultural practices and pheasant population trends. Leedy and Dustman (1947) thought that trends in agriculture toward increased fall plowing, night mowing of alfalfa, decreased hay acreage and clipping of stubble fields might have influenced the decline of pheasants in years following 1942 in Ohio. Faber (1948) showed agricultural trends in Iowa which he interpreted as unfavorable to pheasants to have accompanied a similar decline in that State. Wight (1950) reported trends toward earlier mowing of hay and greater use of power machinery in Pennsylvania and speculated that these trends might have been factors in reducing pheasant populations there.

The chief weakness of studies of effects of agricultural practices on pheasant abundance has been failure to establish more than correlations. Over a period of three or four years prior to 1947, there was a major and unexplained decline in pheasant populations from Nebraska and South Dakota eastward. The fact that the decline may be correlated with some agricultural trends for those years does not necessarily establish a cause and effect relationship.

Allen (1950) referred to lack of concrete evidence on which theories of pheasant distribution are based and pointed out exceptions to many generalizations commonly made. He emphasized need for basic studies on physiology, nutrition and reproduction to clear up some of the uncertainties.

Differences in nutritive value of feeds produced on different soils and under varying soil treatment have been demonstrated in a number of studies, and it has been shown that soil type may influence both abundance and size of animals. For example, Denny (1944) shows that soil fertility affects distribution and size of raccoons, muskrats, rabbits, wild turkeys, and prairie chickens, and Crawford (1950) demonstrates that bone strength of rabbits also bears a direct relationship to fertility of the soil on which they live. Dalke, Leopold, and Spencer (1946) show that about 97 percent of the wild turkeys of Missouri occur on limestone soils, whereas a habitat apparently similar but with soil derived from non-calcareous rock has but 3 percent of these birds.

Albrecht and Smith (1941) fed hay from different soil types in Missouri to rabbits and found that there was significant variation in nutritive value of hay according to fertility of the soil on which it was raised. Where soils were fertilized there was less difference in quality of feeds from good and poor soil, but not all inequalities were eliminated by fertilization.

Selection of Problem

A natural and logical approach to a study of limiting environmental factors is to compare areas in which a given species is abundant with other places in which it is rare or absent. This has been done for pheasants with varying degrees of exactness in several places (Leedy, 1948; Errington, 1945; Sharp and McClure, 1945; Leopold, 1931; Faber, 1948). However, the resulting information has been difficult to interpret. Usually it is found that any two areas differ in so many characteristics that clear-cut comparison of them for any one environmental factor is hampered. The difficulty of establishing valid controls in many ecological studies has caused them to be neglected or even ignored in many studies. In fact, the ecologist must at times choose whether to search out clues of a lower order of reliability than are acceptable in laboratory research or to avoid certain biological problems because of inherent difficulties of interpretation.

To some extent, the dilemma can be resolved by judicious selection of areas with relatively few or minor differences. Then, by comparison of results with those of similar studies in other localities a gradually increasing fund of tested hypotheses can be built up approaching the validity of conclusions from rigidly controlled studies. In addition, it may be possible to isolate some environmental factors to test under artificial situations with suitable controls. The latter procedure may be questioned on grounds that artificiality in an environment might be conducive to abnormal results. Nevertheless, indications from these two imperfect approaches offer insight into some fields otherwise closed.

The present study involves such an attempt. Its aim is to investigate distribution of pheasants as influenced by a single deficiency factor, calcium.

Two study areas unusually well suited for pheasant research were selected in Lancaster County, Pennsylvania. One, the limestone-rich Lancaster Valley in the central part of the county, supports a high pheasant population. The other, more typically Piedmont, to the south is almost devoid of pheasants. The two areas are adjacent, so that there are no major differences in climate. Agricultural practices are similar, and both areas can be classed as fertile, although the limestone area is superior in this respect. The most outstanding difference appears to be in geological history and consequent difference in parent materials from which soils have been derived.

The Lancaster Valley is characterized by outcroppings of limestones varying in age from Cambrian to Ordivician (Knopf and Jonas, 1929) and most soils are residual, having been derived from calcareous underlying rock (Shaw, 1914). There are numerous limestone quarries in the valley and it seems that the exceptionally high fertility results from a combination of calcareous origin of soils and the care with which they have been handled by the "Pennsylvania Dutch" farmers.

Soils of the southern part of the county are non-calcareous in origin (Shaw, op. cit.). Like those of the limestone valley, they are either residual or colluvial. Consequently, they reflect composition of local rocks.

In both areas there are rock outcroppings and loose rock fragments on the surface of the soil. In the limestone area these fragments were observed to be largely limestone, quartzite, and sandstone, whereas in the southern part of the county they may be sandstone, quartzite or granite, often with noticeable amounts of mica. Thus, in addition to any difference in soil fertility, in the Lancaster area there are bits of calcareous grit which are not available in the southern area except along a few roads where crushed limestone has been spread.

Field study in these two areas was designed to investigate pheasant populations in order to verify the supposition that pheasants were largely restricted to the limestone area, and to make a rough ecological survey to determine whether there might be other factors than calcium availability that might help to explain the distribution of pheasants in the area.

In addition to field observations in these areas, investigations were made of nutritional requirements by controlled experiments on penned pheasants at the Patuxent Research Refuge, near Laurel, Maryland. Dietary materials from the two areas were collected to represent, as closely as feasible, natural foods of pheasants. Possible effect of calcareous grit in supplementing mineral deficiencies has been tested by providing crushed limestone from one of the areas to some of the birds. The nutrition experiment was designed to test (a) whether foods produced on the limestone soils are superior to those from the southern half of Lancaster County, (b) whether the limestone available to pheasants in the Lancaster Valley might be significant as a mineral supplement, and (c) whether any combination of foods and grit from the two areas would be shown to be clearly superior in meeting nutritional requirements of the pheasant.

MATERIALS AND METHODS

Information discussed in this section involves two aspects of the study, field observations and experimental data. These two aspects are described separately for convenience, although they were investigated concurrently during most of the period of research. Field studies were begun on June 6, 1951, and were continued at intermittent periods until August 6, 1952. The experimental part of the study was started on November 1, 1951, and was continued until July 15, 1953.

Field Observations

Field studies comprised a relatively minor part of the study, although they are considered to be essential in establishing certain basic facts. Nineteen days were spent in the two areas for the purpose of ascertaining what the distribution of pheasants is and to make a rough ecological survey in an attempt to correlate this distribution with any factors of land use, composition of farm crops, cover pattern of the area, or methods of crop harvesting.

Selection of Areas. After a brief preliminary survey, two areas were selected as being representative of the limestone valley and the non-calcareous Piedmont area, respectively. The first of these is in the vicinity of New Holland. It comprises approximately 25 square miles and forms a rough triangle with the villages of New Holland, Brownstown, and Hinklestown at the apices. This area is referred to as the New Holland area, since it lies about in the center of the

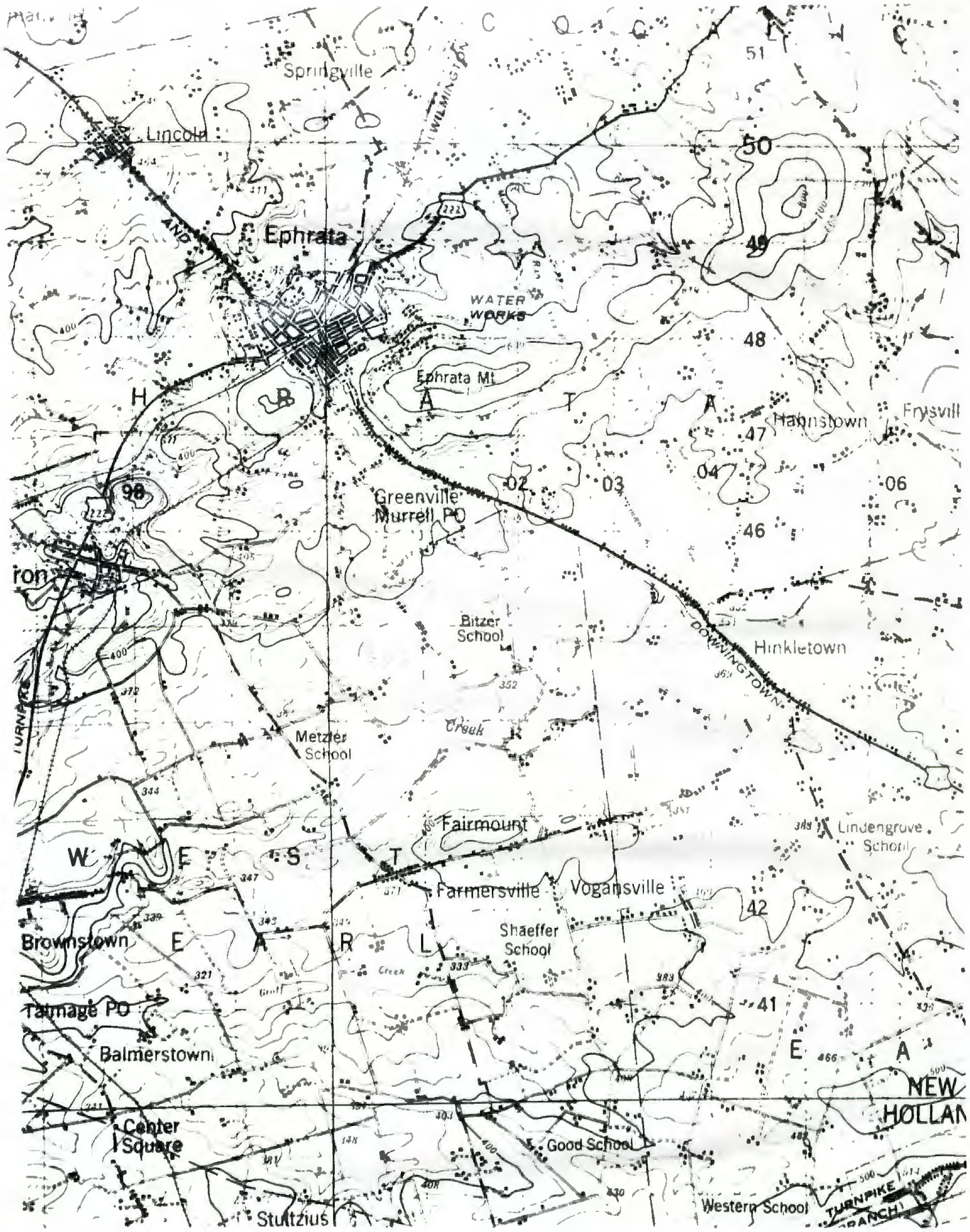


Fig. 2. New Holland Area Lying South of Ephrata Pennsylvania.

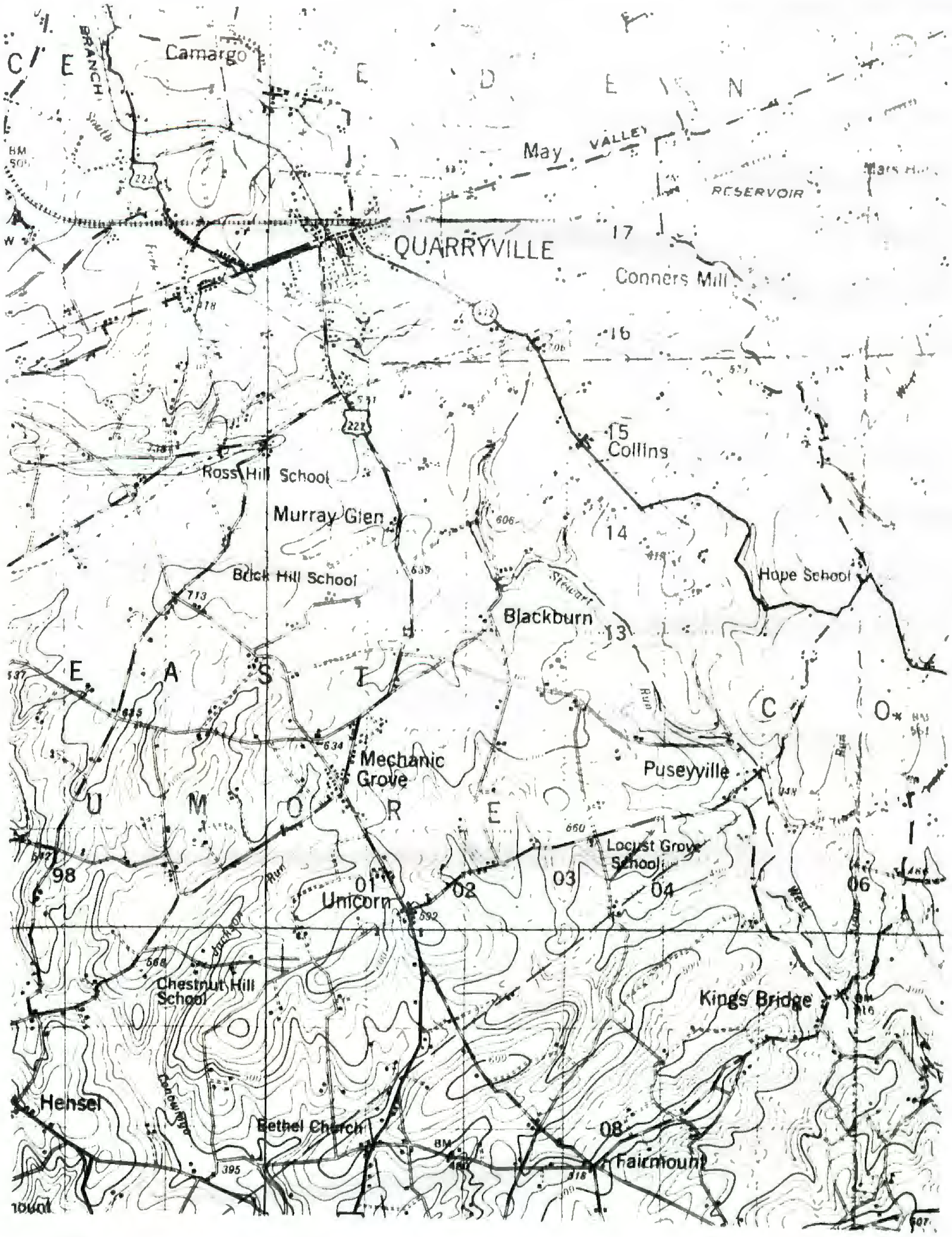


Fig. 3. Quarryville Area Lying South of Quarryville, Pennsylvania

New Holland quadrangle of the Army Map Service's topographic map (see figure 2).

The second area, representative of the Piedmont, lies south of the village of Quarryville. This is referred to as the Quarryville area. It is situated almost in the center of the Quarryville quadrangle and is about the same size as the New Holland area. Most of the field work in this area was done within a radius of about 2 miles of the village of Mechanic Grove (see figure 3).

Agricultural Patterns. Gross measurement of crops was made by driving through the farming regions at speeds of from 15 to 20 miles per hour and measuring the roadside length of each crop field by speedometer. Distances were estimated to the nearest hundredth of a mile, and the speedometer reading was called to a recorder at each change of crop on either side of the road. It was assumed that the total roadside length of each crop would be a function of the total acreage. This, of course, would not necessarily be true for any one field, but inequalities should tend to be compensated for by the large number of samples. Total figures included 74.25 miles of crop edge in the two areas.

Methods of Harvesting Corn. Corn harvest method was studied in the New Holland area by driving roads through farm country on December 27, 1951, and noting the method that had been used. Five methods were observed: (1) cutting for ensilage, (2) cutting corn stalks, after which the ears are plucked off and the stalks disposed of, (3) picking by machine, which breaks down the stalks, (4) hand-picking from the standing corn stalks, and (5) leaving corn stand through the winter in the field. The last method may be followed by any of the other kinds of harvest, except cutting for ensilage. It is practiced commonly in some parts of the country, the corn being harvested as needed during winter or early the following spring.

Unplowed fields in which a mechanical corn picker was used could be readily identified and were recorded as "machine picked;" any field in which corn stubble remained was listed as "cut;" fields in which standing corn stalks remained and from which corn had been picked were listed as "hand picked;" only one field, of those classified, had corn unharvested on December 27.

Pheasant Counts. Field observation of pheasants had as its major objective verification of the relatively high population density in the New Holland area and the low level in the Quarryville area. It was decided early in the study that actual census would not be made in view of the great difficulty of making a reliable population estimate.

Crowing-Cock Count. The crowing-cock count, as described by Kimball (1949), depends upon two-minute counts of calls heard at one-mile intervals along a census route. Results can be translated into an estimate of actual population density by correcting for percentage of cocks expected to crow during a two-minute interval, the average area that can be covered by auditory range, and the sex ratio of the population.

In the Lancaster area, however, a low population of cocks, the large number of hens per cock, and the noise created by farming operations and poultry flocks, all combine to make the crowing-cock count unreliable. Hence, after three trials the method was abandoned as a census technique.

Roadside Counts. The roadside count, as proposed by Bennett and Hendrickson (1938) was used with some modification as the principal method of estimating populations of pheasants. For the degree of accuracy required in the present study, it was not deemed necessary to flush all broods seen in order to obtain an accurate count. Because of the high humidity in the Lancaster area, fields are wet during the early part of the day, and pheasant broods tend to rest along the edge of corn fields. They slip into standing corn when disturbed, and it is almost impossible to obtain reliable counts by flushing them. Furthermore, because of public relations it was thought inadvisable to enter clover and alfalfa fields in many instances.

Pheasants were counted as accurately as possible from the car, regardless of their distance from the road. Binoculars were used on some counts, but their use was of less value than might have been expected. Pheasants were located while driving, and in most instances could be counted readily without the aid of binoculars.

Experimental

Location of Experiment. Research on the nutritional aspects of the problem was done at the Patuxent Research Refuge, Laurel, Maryland. Advantages in conducting the work there included the use of pens, brooders, incubators, and other essential physical facilities as well as assistance in feeding and care of the birds. Technical facilities of the chemistry section of the Refuge were also available, an indispensable feature in a study of this kind.

Experimental Animals. Experimental stock consisted of eighty pheasants each year which were distributed into four pens at the beginning of the experiment. In the first year these were about equally divided as to sex, an unsatisfactory arrangement since it was necessary to remove most of the cocks after the mating season had started and fighting began. In the second year the experimental groups included 17 hens and 3 cocks each. These birds were obtained from the stock that had been hatched at the Patuxent Research Refuge. They were the offspring of pheasants that had been on various experimental diets, so there was a possibility that they might have differed somewhat in vitality because of differences in carry-over of nutritional factors from the parent through the egg. This was adjusted so far as possible by distributing birds from different stocks about equally in the various groups.

The first year, because of the necessity to set up additional control groups, the number of pheasants in each pen was reduced to five hens and one cock in each of the four experimental pens at the beginning of breeding. In the second year when laying began, the number of hens was reduced to twelve in each pen.

Physical Facilities. At the beginning of the experiment, the pheasants were placed on the ground in pens approximately 20 by 50 feet in dimension. No shelter was available except for a single wooden frame in each pen which offered some protection against rain. Feed was placed in a covered feeder, but only two or three pheasants could enter at any one time. Water was available at all times and was prevented from freezing by means of a kerosene burner.

Because of the possibility that the pheasants might obtain some nutrients from the soil, wire-floored pens were constructed soon after the experiment was started, and the pheasants were moved into them on December 20, 1951. The new pens had no shelter of any kind, so small, cut pine trees were placed on the floor to provide some protection. The pens had board sides about three feet up from the floor, which cut down exposure to winds, and a panel was placed along one side from the floor to the ground in winter to reduce the amount of wind that might sweep up through the wire-mesh floor.

In the second year a shelter was constructed along one side of the pens to provide protection against rain, but it was observed that the pheasants seldom went under it during rainy weather.

Experimental Diets. Experimental diets used were based on natural diets as indicated by various food habit studies made in different parts of the pheasant's range.

Diets tested the first year included corn, 65 percent; wheat, 20 percent; oats, 10 percent; and alfalfa, 5 percent. The two diets were identical except that items for the "A" diet were from the limestone valley whereas those for the "B" diet were from the Piedmont (non-calcareous) area. Materials were purchased in the two areas and were stored at the Patuxent Research Refuge to be ground as used.

Corn and wheat, comprising 85 percent of the diet, were purchased in relatively small lots in an attempt to obtain representative samples from the areas to be compared. Arrangements were made with two feed companies, the J. B. Fritz and Sons Company at Quarryville, and C. P. Wenger and Sons, of Ephrata, Pennsylvania, to save 50 pounds of wheat from each of 8 lots from various farms within the respective areas. Corn was not readily available at the beginning of the experiment and consequently was purchased in small lots from time to time as needed. Thus, over a period of several months corn consumed came from several localities within each of the two areas.

Because amounts of oats and alfalfa to be used were small, it was believed that any differences related to source of these items would be insignificant in the total diet. Therefore, a single purchase of oats and alfalfa was made in each of the two study areas.

It was necessary to modify this diet in mid-February to provide a source of vitamin B_{12}. This was done by adding 5 percent liver meal and 2-1/2 percent APF concentrate which provided 3 mg vitamin B_{12} activity per pound. Thus the concentrate should have added approximately 165 micrograms of the vitamin per kilogram of feed.

The diet was still further modified for the second year's test, after the results from the first year indicated that kind of grit was more important than source of dietary materials in determining success in reproduction. In the second year all birds received the same basic diet, comprised of corn, 75 percent; wheat, 20 percent; and alfalfa, 5 percent. To this was added a supplement of 4.67 percent liver meal and 0.33 percent "Bicon 6 plus," a vitamin-B_{12} concentrate prepared by the Chas. Pfizer Company. The concentrate added approximately 44 micrograms of vitamin B_{12} activity per kilogram of diet.

Feed Preparation and Rationing. Two lots of feed were ground and mixed at the Agricultural Research Center, at Beltsville, Maryland, but because of the small amount ground each time in proportion to the size of the feed mixer, there was a possibility of serious contamination. On one occasion, total weight of ground feed exceeded that of the whole cereals and hay, an indication that mash had remained in the hopper from a previous grinding. Where small lots of about 100 pounds each were ground, such contamination might be significant. Consequently, materials for later small batches were ground at the Patuxent Refuge.

During the first winter, when dry corn was difficult to obtain, about 20 kilograms of each diet was ground at a time. This was stored in galvanized cans labeled A and B, according to the diet held, from which weighed amounts were taken. Four smaller, labeled cans, one for each pen, were used to transport feed to the pens. Weights were recorded as the mash was transferred to the small cans. In February, 1952, enough corn was obtained to prepare about 800 pounds of each diet. This was ground and mixed at the Agricultural Research Center at Beltsville.

Method of Weighing Diets. The amount of mash actually consumed was estimated by subtracting that remaining in the feeders and any left in the small cans from the total recorded weight of mash supplied. This was done periodically to compute the amount of mash consumed to that time.

Capacity of the feeders was approximately 7 kilograms each. These were filled at each feeding and checked daily to make sure that they were operating successfully. One filling usually was sufficient for five or six days.

Analyses of Diets and Grit. Each diet was analyzed by J. V. Derby, Jr., chemist at the Patuxent Research Refuge, for total nitrogen, fat, crude fiber, nitrogen-free extract, calcium and phosphorus.

Crushed limestone was obtained from a quarry about 1-1/2 miles east of Hinklestown, Pennsylvania, to be used as grit in two of the pens. This was also analyzed by Mr. Derby. Since this was taken from good pheasant range, it was considered to be representative of calcareous grit available to pheasants.

Assignment to Pens and Records Taken. Pheasants were placed in experimental pens as follows on November 1, 1951. Pen D-1 received the A diet with limestone grit; pen D-2 received diet A with granite grit; pen D-3 received diet B with limestone; and pen D-4 received diet B with granite. Weights were recorded to the nearest 5 grams about a week before the experimental diets were initiated, and this was taken as the initial weight. Subsequently, pheasants were weighed at approximately 4-week intervals. Records were maintained on food and grit consumption and notes were taken on behavior, general appearance and feathering of the birds.

Collection of Eggs and Incubation. During the laying period, eggs were collected daily and were marked as to date and pen number. They were stored in a cool place and were incubated in separate lots at about 2-week intervals.

Eggs were candled at about 20 days incubation at which time infertile eggs and those that could be identified as having dead embryos were discarded. Others were transferred to another incubator for hatching.

Analyses of Bone Ash. At the end of the laying season in 1952, surviving hens were sacrificed. Tibiae were removed, fleshed and stored in ethyl alcohol for analysis. In 1953, at the beginning of the laying season, surplus hens were sacrificed and tibiae were saved for analysis with the same treatment. Both lots were analyzed by Mr. Derby for bone ash content.

RESULTS

Field Observations

Agricultural Patterns. It can be observed in table 1 that the two experimental areas agree reasonably well in percentages of basic crops. Careful examination, however, reveals slight differences that agree with soil fertility differences of the two areas. These include the higher percentage of tobacco and potatoes in the New Holland area, and the larger percentage of buildings in this area, an indication of smaller farms, which reflects higher fertility. The slightly lower fertility of the Quarryville area is also indicated by the larger amount of land in pasture and waste areas.

Corn Harvest. Results of the corn harvest survey of 75 fields are as follows:

Machine Picked		Cut		Hand Picked		Not Harvested		Total	
No.	%	No.	%	No.	%	No.	%	No.	%
35	46.7	31	41.3	8	10.7	1	1.3	75	100

Distribution of Pheasants. Total number of pheasants seen in the New Holland area and adjacent limestone areas on 18 field trips was 1,214. In contrast, no pheasants were observed in the non-calcareous Quarryville area on eight field trips made under the conditions that proved successful in the New Holland area.

Mr. Wallace Woodring, game protector at Ephrata, who assisted on several field trips, believes that pheasants from the New Holland area migrate in winter into the more heavily wooded lands north and east of Ephrata. This point was checked in December while there was snow in

Table 1. Land-use of the New Holland and Quarryville areas as estimated from roadside surveys.

Type	New Holland		Quarryville	
	Miles	Percent	Miles	Percent
Corn	10.16	22.3	6.31	22.0
Wheat	6.97	15.3	4.74	16.5
Hay	9.04	19.8	5.97	20.9
Pasture	4.59	10.1	4.42	15.4
Tobacco	6.09	13.4	1.59	5.5
Buildings	4.34	9.5	1.80	6.3
Potatoes	2.28	5.0	0.69	2.4
Garden	0.80	1.8	0.35	1.2
Orchard	0.67	1.4	0.21	0.7
Oats	0.32	0.7	0.24	0.8
Beans	--	--	1.11	3.9
Tomatoes	--	--	0.36	1.3
Waste and Woods	0.34	0.7	0.86	3.0
Totals	45.60	100.0	28.65	99.9

Fig. 4. Farming Land in the New Holland Area.

Fig. 5. Farming Land in the Quarryville Area.

Fig. 6. Farming Land in the New Holland Area.

Fig. 7. Farming Land in the Quarryville Area.

the area and evidently is not correct. Flocks of from 4 or 5 to as many as 26 hens were observed in the open farmland seeking shelter in small patches of weeds or brambles that seemed to offer a bare minimum of protection. A total of 85 pheasants (3 males, 82 females) was seen on December 27, 1951. This seems to indicate that there is little, if any, movement of pheasants from the farmland in winter.

Hunting Pressure. It is evident that the relatively high population of pheasants in the New Holland area is not a result of low hunting pressure. Situated in an area of dense human population, this resource is harvested about as heavily as is any pheasant population in North America. Under game laws which restrict the kill to male pheasants, sex ratio at the close of the open season probably is near 10 males to 100 females. Counts of adult birds made along roadsides in summer gave an impression of fewer cocks than this. For example, in July 1951, 5 cocks, 80 hens, and 232 young pheasants were counted. Despite the fact that cocks during summer may be less readily observed than hens, the observed sex ratio of 1 cock to 16 hens is an indication that the population is heavily hunted.

Furthermore, as pointed out by Dale (1951), a sex ratio as unbalanced as 1 to 10 can be expected only where there is a combination of high pheasant population and heavy hunting pressure. Areas in which pheasants are relatively scarce seldom have a sex ratio more unbalanced than 1 cock to 2 or 3 hens.

Predation. Foxes, both red and gray, seem to be relatively abundant in the New Holland area. Mr. Woodring was engaged in fox trapping during the winter months for the purpose of predator control, evidently with good success. Undoubtedly, from observations made elsewhere, foxes can be considered fairly important pheasant predators, but their presence in the Lancaster area seemed to be of little relative significance to the pheasant population.

Experimental

Although the outdoor pen provided approximately 50 square feet of area per bird, there was more than average feather-picking and some cannibalism among the pheasants. The tendency to occupy areas adjacent to the fence caused considerable crowding, and it is likely that this fact contributed about as much to feather-picking as did deficiency in the diet. Despite the fact that the birds looked rough because of the severe feather-picking, fairly adequate gains were made during the first month on the experimental diets.

Analyses of Diets. Chemical analyses of the experimental diets indicated that they were of poor quality as compared with standard poultry diets (Titus, 1939). Protein was increased in the 1953 diet, undoubtedly by the addition of the liver meal, and although the A and B diets were not analyzed after liver meal was added in February, it is likely that these diets would have been about as high as the 1953 diet in protein.

Calcium and phosphorus both were low in all diets. The ratio of calcium to phosphorus was much lower in the B diet (from the non-calcareous area) than in the A diet (0.46:1, as compared with 0.71:1). In the 1953 diet the ratio of calcium to phosphorus was about the same as in the A diet, but both elements were increased. Probably a similar change was made in the A and B diets with the addition of liver meal and the APF supplement.

Table 2. Chemical analyses of experimental diets expressed as percentage of dry weight.

Diet	Protein Dry Basis	Ash	Fat	Fiber	N.F.E.	Ca	P.
A	10.75	2.33	3.91	4.37	78.64	.223	.313
B	10.07	2.30	3.66	4.36	79.61	.200	.431
1953	12.33	2.24	5.13	3.08	77.22	.251	.357

Deficiency of Vitamin B_{12}. Most of the birds lost weight when they were placed in the wire-floored pens. By January 16 this loss was approximately 2 percent of their weight and by the next time of weighing, on February 13, it amounted to about 150 grams per hen or nearly 15 percent of the December weights. Two hens that died were plucked of practically all feathers and were partly eviscerated in a short time (see figure 8). It seemed apparent that some severe deficiency existed and that unless a change in diet was made, heavy mortality would soon result. Consequently, it was decided that original feeding plans would have to be modified in an attempt to identify the deficiency.

Animal protein factor was suspected, since weight losses seemed to coincide with transfer of birds to the wire-floored pens. It was realized, however, that any other deficiency in the diet might not become apparent for one or two months and that weight loss at the time of transfer to the new pens might have been coincidental.

To test these possibilities, 4 control pens were set up as follows:

Fig. 8. Dead Pheasant Plucked and Partly Eaten by Mates During Deficiency of Vitamin B_{12}.

C-1 (negative control) in which 5 hens and 1 cock were removed to another wire-floored pen and were continued on the original experimental diet.

C-2. Four hens and 1 cock were returned to a pen on the ground without other change of diet.

C-3. Four hens and 1 cock were placed in a wire-floored pen and were given the A diet with a supplement of 5 percent liver meal.

C-4. Four hens and 1 cock were placed in a wire-floored pen and were given the A diet with a supplement of 2.5 percent APF, a vitamin B_{12} concentrate prepared by the Chas. Pfizer Company.

In order to set up these controls, it was necessary to reduce the number of birds in the experimental pens to 5 hens and 1 cock each. These birds were given their original diets with a supplement of 5 percent liver meal plus 2-1/2 percent APF. Birds were placed in the control pens on February 18. In C-1, the negative control pen, one of the 5 hens gained 90 grams by March 12. Two died on March 8 and 9, respectively, and the other two lost 15 and 20 grams, respectively. The cock in that pen lost 5 grams. No further mortality was experienced in this pen but the 3 hens that survived until June weighed an average of only 670 grams by that time.

In pen C-2 it was evident that the birds actively sought some nutrient from the soil. They scratched heavily and after a few days the surface of the pen had the appearance of being lightly cultivated. Whatever factor the pheasants were seeking evidently was available since the 4 hens gained an average of 108 grams each by March 12. Since it was demonstrated by Stephenson, _et al_ (1948) that the soil contains a growth factor for chicks, which now appears to be vitamin

B_{12}, it seems probable that this vitamin was being obtained from the soil in the ground pens. Coprophagy was also observed and there was no accumulation of droppings in the pen. This is added evidence that vitamin B_{12} was the deficiency factor (Lindstrom, et al, 1949; Holbrook, et al, 1950).

Results in pen C-3 indicated that liver meal at the 5 percent level did not provide sufficient vitamin B_{12} to make up the deficiency. Weight losses continued in this pen and 2 birds died in the second month.

In pen C-4, however, there was rapid growth response to the APF supplement. This supplement was Pfizer's "Bicon APF 3 plus" which has a potency of 3 milligrams B_{12} activity per pound. Thus the 2-1/2 percent supplement should have supplied about 165 micrograms B_{12} activity per kilogram of feed.

Table 3. Average weights in grams of female pheasants in control pens, February 13 to May 21, 1952.

Pen	Number of Birds	Feb.	Mar.	Apr.	May
C-1	5	794	813	828	732
C-2	4	796	904	1076	919
C-3	4	805	782	814	845
C-4	4	812	931	1092	855

It seemed apparent, however, from subsequent variations in weight that there must have been deficiencies other than vitamin B_{12}. Birds in pen C-4 were down to near starvation condition by June, whereas weights of experimental birds were considerably higher. Thus, it seems that the liver meal must have provided either an additional growth factor or an amino acid that was deficient in the original diet.

Responses to Experimental Diets. Despite the fact that feather-picking continued to be a serious problem throughout the first laying season and the birds evidently were on less than an optimum diet, weight losses were generally restored by early April and it was possible to test the diets and the effectiveness of limestone on the experimental birds.

During the winter months, no difference was observed in responses of birds to the varied diets. There was considerable variation in weight in each pen and actually the greatest average gain in weight was observed in pen D-4 but this difference was not significant. Birds in this pen were slightly larger at the initiation of the experiment.

Table 4. Average weights in grams of male pheasants October 24, 1951 to February 13, 1952.

Pen	Number of Birds	Oct.	Nov.	Dec.	Jan.	Feb.
D-1	10	1324	1367	1393	1427	1284
D-2	10	1346	1453	1493	1489	1315
D-3	10	1339	1455	1538	1490	1381
D-4	10	1372	1485	1508	1540	1448
Average		1345	1440	1483	1486	1357

In April, however, differences could be observed in behavior of the pheasants. Those in pens D-1 and D-3 were more alert and it was noted that when an observer approached the pens, these pheasants stood erect in an alert pose with necks extended (see figure 9). In contrast, pheasants in pens D-2 and D-4 characteristically kept the head low, seemed much more sluggish, and at times exhibited tremors (see figure 10).

In mid-April birds in pen D-4 reached a serious condition and 3 of the 5 hens died between April 17 and 27. The 2 surviving hens lost weight from an average of 1195 grams in April to 977 grams in May. In pen D-2 there was a similar loss of weight from an average of 1188 to 1026 grams. Nevertheless, there was no mortality in this pen.

Table 5. Average weights in grams of female pheasants October 24, 1951 to February 13, 1952.

Pen	Number of Birds	Oct.	Nov.	Dec.	Jan.	Feb.
D-1	10	941	973	1015	981	843
D-2	10	918	1021	1016	973	850
D-3	10	936	1097	1120	1048	904
D-4	10	918	1006	1030	997	880
Average		928	1024	1043	1000	894

Weights are reported in separate tables for the periods October to February, 1952, and February to May, 1952. Table 5 includes all females with which the test was started, whereas table 6 includes only those left after the control pens were set up.

As a result of modifications in diets and techniques, the birds made considerably better weight gains the second year than in the first year and also were prevented from feather-picking. There was

Fig. 9. Pheasant from pen D-3, with limestone grit.
Note erect posture.

Fig. 10. Pheasant from pen D-4, with granite grit.
Illustrates typical drooping posture.

no recurrence of the losses in weight observed in January and February, 1952.

Table 6. Average weights in grams of female pheasants in experimental pens February 13 to May 21, 1952.

Pen	Number of Birds	Feb.	Mar.	Apr.	May
D-1	5	915	1030	1225	999
D-2	5	930	1025	1188	1026
D-3	5	975	1040	1202	1062
D-4	5	908	995	1172	977
Average		932	1022	1197	1016

Table 7. Average weights in grams of female pheasants in experimental pens October 28, 1952 to March 19, 1953.

Pen	Number of Birds	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
D-1	17	895	959	1018	1057	1113	1208
D-2	17	870	982	1067	1103	1138	1213
D-3	17	873	944	1001	1047	1101	1184
D-4	17	866	928	987	1027	1118	1232

Consumption of Food. Consumption of food was checked for the first time on January 16 at which time it was found to range from 56.8 to 63 grams per bird per day (average 59.8). This estimate may have been high since there was no way to recover food scratched from the feeders. General observation, however, indicated that relatively little was wasted.

From January 16 to February 13, consumption dropped off to an average of 37.6 grams per bird per day (34.8 to 39.9). This was the period during which greatest losses of weight were experienced and it seemed evident that lack of vitamin B_{12} resulted in loss of appetite.

Records of consumption of food during the period February 13 to 28 were not kept. During this period, there was considerable change in setting up control diets and in obtaining liver meal and the APF concentrate. In making the dietary changes there was some confusion as to residues in the feeders. From February 28 to March 11, however, consumption increased to an average of about 90 grams per bird per day (82.0 to 105.2) and remained at a high level throughout the laying period.

Table 8. Food consumption in grams per bird per day, November 1, 1951 to March 11, 1952.

	D-1	D-2	D-3	D-4
Nov. 1 to Jan. 16	63.0	56.8	59.1	60.3
Jan. 16 to Feb. 13	39.9	35.5	34.8	39.2
Feb. 28 to Mar. 11	105.2	82.0	86.1	87.5

Consumption of Grit. Consumption of grit was difficult to measure accurately. The grit was placed in a small box in each pen and birds did not consume all that was taken from the boxes. Large metal sheets were placed below the boxes in an attempt to recover grit through the wire netting but not all was salvaged. It was apparent as the laying season progressed that the amount of wastage increased. Consequently, attempts to estimate consumption of grit were discontinued.

On February 7, however, 2 kilograms each of crushed limestone was put into pens D-1 and D-3, and 2 kilograms of granite was put in pens D-2 and D-4. Residues on February 20 in these pens including what was salvaged from that dropped through the wire were as follows: limestone, pen D-1, 1.9 kilograms; pen D-3, 1.85 kilograms; granite, pen D-2, 1.5 kilograms; pen D-4, 1.5 kilograms. From this it was computed that maximum consumption of limestone was at a rate of 0.46 grams per bird per day in D-1 and 0.60 grams per bird per day in D-3. Granite consumption was 2.03 grams per bird per day in D-2 and 2.47 grams per bird per day in D-4.

This consumption increased throughout the laying period although consumption of limestone remained well below that of granite. In pens D-2 and D-4 consumption of granite plus wastage between April 1 and April 9 amounted to from 20 to 25 grams per bird per day. Limestone consumption, although not measured, was estimated to be far less than this.

Table 9. Grit consumption in grams per bird per day, February 7 to February 20.

Pen	Type	Gm.
D-1	Limestone	0.46
D-2	Granite	2.03
D-3	Limestone	0.60
D-4	Granite	2.47

Production of Eggs. Production of eggs evidently was delayed by the poor condition of the birds, since the first egg was collected in the experimental pens on April 12, 1952, in contrast to April 1 as the date of first egg collection from pheasants on other experimental diets at the Refuge.

Eggs were numbered and dated when collected and were stored in a cool place pending accumulation of enough for incubation. They were placed in incubators on April 25, May 9 and 23, June 6, 20 and 23. Total collection in 1952 was as follows:

D-1	71
D-3	49
D-2	4
D-4	9

The pheasants in 1952-53 received liver meal and vitamin supplement from the beginning of the experimental diet and consequently approached the laying season in much better physical condition than in the previous year. This was reflected in earlier production of eggs and in a greater number produced by hens receiving limestone. The first egg was recovered on March 23, 1953, approximately 15 days earlier than in the previous year. Nevertheless, despite their apparently good physical condition, hens in pens D-3 and D-4, which received granite grit, produced few eggs. By April 24, hens in the pens receiving limestone grit had produced 201 eggs, whereas those in pens D-3 and D-4 had produced only 17.

By April 21, it was apparent that the pheasants without supplemental limestone would not survive the breeding season. Their condition seemed even worse than that observed the previous year, and several birds died in pens D-3 and D-4. Consequently, it was decided to provide a supplement of powdered calcium carbonate in the diet for these birds. Fifty grams of powdered calcium carbonate was added per kilogram of diet on April 21 in pens D-3 and D-4. Previous to this, in pen D-3 one soft-shelled egg had been obtained on April 20, an imperfect egg on April 12, and an apparently normal egg on April 11. Ovaries taken from several hens that died prior to April 21 in granite grit pens all contained apparently fully developed eggs but there were few ovulated follicles. Approximately 24 hours after the addition of calcium carbonate, 2 normal eggs were obtained from pen D-3. Production increased rapidly as follows: on April 23, 3 eggs; April 24, 4; April 25, 7. By May 8, 75 eggs were collected from pen D-3.

Eating of Eggs. Considerable difficulty was experienced with pheasants eating their eggs. This was especially noticeable in pens D-2 and D-4. Eggs were collected several times daily and an attempt was made to discourage eating of eggs by the use of quassin, an intensely bitter chemical, which was sprinkled on broken eggs and left in the pen. This was found to be of some value but did not prevent birds from eating an undetermined number of their eggs.

Fertility and Hatchability. Fertility and hatchability were low in all pens, probably partly because of dietary deficiencies other than calcium. The incubator used was of a forced-draft type which gives good results with eggs of the bob-white, but it has been unsatisfactory for eggs of the pheasant. Eggs were not tested for fertility except by candling at about the eighteenth day, at which time it is practically impossible to identify embryos that died during the first few days. As a consequence it is likely that many eggs listed as "infertile" were actually eggs in which early death of embryo occurred.

For these reasons, as well as because of the low number of eggs received from hens on the granite diet, it was not possible to draw reliable conclusions as to fertility of eggs. Nevertheless, fertility was not found to be significantly lower in eggs from birds on granite than in those from hens on limestone.

Table 10. Fertility and hatchability of eggs from experimental pens in 1952.

Pen No.	Eggs Set	Number Fertile	Number Hatched	Percent Fertile	Percent Hatched
D-1	60	51	16	85.0	31.3
D-2	4	3	0	75.0	0
D-3	49	26	20	53.1	76.9
D-4	6	6	0	100	0

In the second year's study, power failure several times during the period of incubation may have contributed to the low rate of hatchability.

Table 11. Fertility and hatchability of eggs from experimental pens to April 24, 1953.

Pen No.	Eggs Set	Number Fertile	Number Hatched	Percent Fertile	Percent Hatched
D-1	112	63	8	56.2	12.7
D-2	89	33	4	37.1	12.1
D-3	17	5	1	29.4	20.0
D-4	0	0	0	--	--

Bone Ash Analyses. At the end of the laying period in 1952, 27 females were sacrificed and tibiae were saved for analysis of bone ash. In the second year's study, 16 surplus females were sacrificed on March 19, just before the first egg was laid. Because of the slight difference observed in these samples, it was decided that nothing could be gained from analysis of additional tibiae after the 1953 laying season.

Table 12. Results of pheasant tibiae bone-ash analyses in percent ash.

1952 (Post-laying season)

Pen	Average	Range
D-1	58.64	53.87 - 61.95
D-2	58.52	54.71 - 60.92
D-3	60.42	58.68 - 62.85
D-4	59.74	54.89 - 62.74
Control*	62.90	60.30 - 65.07

1953 (Pre-laying season)

Pen	Average	Range
D-1	59.00	58.48 - 59.32
D-2	58.43	56.92 - 60.63
D-3	57.07	56.62 - 59.68
D-4	58.47	57.16 - 59.58
Control*	64.14	59.89 - 67.77

*Controls were female pheasants from standard diets sacrificed at comparable periods in studies conducted by Dr. J. B. DeWitt.

DISCUSSION

Field Observations

Roadside counts of pheasants in the New Holland and Quarryville areas confirmed the fact that the former area supports a relatively high population and that the Quarryville area has few if any pheasants. Randall and Bennett (1939) attempted to establish standards for interpreting roadside counts of pheasants in southeastern Pennsylvania. They concluded that where the population was about one pheasant to two acres, the average count in the morning would be about six to eight birds per mile. Where the population was estimated to be approximately one pheasant to four acres, the average count was about two to three birds per mile of road. If these estimates can be assumed to hold for the New Holland area, the population of pheasants must have approached a pheasant per two acres. The average count on five morning trips was 108 pheasants for approximately 20 miles, an average of about 5.04 pheasants per mile.

Even in areas where the pheasant population was as low as a bird to 18 or 20 acres, Randall and Bennett counted an average of from 0.25 to 0.60 birds per mile of road. Therefore, the fact that no pheasants were seen on eight trips through the Quarryville area seems to indicate that pheasants are almost if not quite absent from this area.

The close similarity in percentages of crops in the two areas seems to offer no explanation for the difference in pheasant population. As a matter of fact, it is doubtful that two counts within the same area would give average crop percentage figures more nearly comparable than those taken for these two areas. It is believed that the greater acreage of tobacco in the New Holland area is of little value to the pheasant, since none were seen in tobacco fields until late in summer. Other differences appear to favor the Quarryville area rather than New Holland, such as the greater amount of waste areas and pasture in the Quarryville area.

The observations on method of corn harvest were made because Randall (1940) found that most of the corn in the Pennsylvania area studied by him was picked from standing stalks, so that there was a large amount of standing corn stalks left in winter for cover. He concluded from his studies that first-class range for pheasants in Pennsylvania was largely a matter of the production and method of harvesting of corn. It was Randall's belief that first-class pheasant range should have about 10 percent of the land in standing corn in winter, and that a minimum of about 4 percent is essential. Since only about 22 percent of the New Holland area is in corn, and since only about 12 percent of this is either picked by hand or not harvested until late in winter, it seems that the New Holland area produces a high population of pheasants with no more than about 2.6 percent of its land left in standing corn through the winter.

Observations on pheasants in winter in open farm areas demonstrated the small amount of cover required for this species when other conditions are suitable. This substantiates an opinion based upon observations of this bird in Michigan, Colorado, California, and South Dakota that the pheasant may respond to good cover conditions, but that cover alone does not compensate for some other factor in the habitat that is not readily discernible. The relationship in

Lancaster County between distribution of pheasants and availability of calcium seems to be an example of cause and effect. This conclusion was given further weight by the experimental evidence derived from the nutrition experiment.

Experimental

Adequacy of Experimental Diet. Interpretation of results from the experimental diet depends upon an assumption that it was comparable to that of the pheasant in the wild. It is apparent that this diet was far below the quality of modern poultry feeds. Protein level was well below the 15 to 20 percent required for chickens for growth and egg production, according to Ewing (1951). It is not known, however, what level of protein is essential for the pheasant, nor has it been established that the wild pheasant can obtain anywhere near the high quality diet provided the domestic chicken. The experimental diet was planned to be as near that of the wild pheasant in nutritive quality as feasible.

Cottam (1929) reported that 33 crops and gizzards of pheasants collected in Utah from October to March, inclusive, contained 96.1 percent vegetable and 3.9 percent animal matter. Grain made up 62.5 percent of the vegetable matter in October but dropped off in relation to weed seeds as the winter progressed.

Swenk (1930), reporting on 100 crops of pheasants from Nebraska, found vegetable matter to comprise 89.09 percent by weight. Corn was the most important single item, forming 67.09 percent of the total food for the period studied. In January, corn comprised 96.41 percent of the food in crops examined. Animal matter, chiefly insects, was taken principally in spring and early summer.

Hiatt (1947) gave an analysis of 500 pheasant crops collected throughout the year in Montana, where corn is less important than in the Midwest. Vegetable matter comprised 88.4 percent, by weight, of the annual diet, and cultivated crops made up 77.4 percent of the total food. Wheat and barley were considerably more important than corn, which was reduced to 10.2 percent of the total food.

Dalke (1937) computed percentages of component foods in 352 Michigan pheasant crops from weights of oven-dried materials. His method has the advantage that a rough estimate can be made of the percentages of major chemical constituents in the total diet. Vegetable matter comprised 94 percent of the annual diet as indicated by this study.

A more recent study of pheasant food-habits is that by Trautman (1952) in South Dakota, covering crop contents of 1,679 birds. Trautman's technique was to air-dry the crop contents for a minimum of 6 days before weighing. This method permitted more rapid analysis. Results were as follows: farm crops, 82 percent; weed seeds 7 percent; insects, 5 percent; plant foliage, 5 percent; and minerals (grit), 1 percent.

Thus, it appears that the experimental diet, when supplemented with liver meal and the APF concentrate, was roughly comparable to that of the wild pheasant. It is believed that any deficiencies in this diet would have little bearing on the requirement for calcium.

The grit provided was dolomitic. This is believed to have little if any significance, since Randoin, et al (1950) found that calcium carbonate and calciferous dolomite gave practically identical results in tests on rats. That is, the presence of magnesium had no effect on metabolic results of calcium carbonate.

Vitamin B_{12}. Results observed from vitamin B_{12} deficiency indicate that the pheasant has a relatively high requirement for this vitamin as compared with that observed for poultry. The rapid development of symptoms when pheasants were placed in wire-floored pens contrasts with conditions observed in poultry where the chief effect of vitamin B_{12} deficiency on adults seems to be noted in decreased production of eggs or more especially in loss of fertility (Carver and McGinnis, 1950; Petersen, et al, 1950). This factor, however, was not given further study because of the small likelihood of its being significant in wild flocks. There seems to be no reason to suspect that deficiency of vitamin B_{12} exists in any one area more than in another. Consequently, vitamin B_{12} is considered as playing a relatively minor role, if any, in influencing distribution of pheasants.

Calcium Requirement. Pheasant diets may be classified as growth, maintenance and reproductive diets. The essential level of calcium for each diet has not been definitely established for the pheasant, although probably this does not differ markedly from that of domestic poultry which has been studied rather intensively. Evidently, requirements for calcium are highest during growth and reproductive periods. During the growth period, the young animal requires considerable calcium for the formation of skeleton, whereas in the reproductive stage, birds have a high requirement of calcium for the formation of egg shells.

Bethke, et al (1929) show that in poultry either calcium or phosphorus can be limiting in determining rate of growth. They believe that "within limits" the ratio of calcium to phosphorus in the diet is more important than actual levels of either element. In the natural diet of the pheasant, however, phosphorus is not likely to be deficient since this element is more abundant in cultivated grains than is calcium. In that study, it was found that increased calcium gave beneficial results until the ratio of calcium to phosphorus reached 3.5:1.

Evans, et al (1945) found, however, that actual level of calcium was important. They maintain that the levels of calcium and phosphorus are of greater importance than the ratio. A level of 1.8 percent calcium was required in poultry where the level of vitamin D was moderate. Yet, with high vitamin D levels, as low as .6 percent calcium was sufficient.

Wheeler (1919) found in poultry that several diets deficient in calcium were adequate for maintenance of mature hens for long periods without apparent harm, but that they would not sustain or induce reproduction. He also noted that chemical analysis of egg shells varied but slightly as the calcium level of the diet was modified, whereas the amount of egg shell produced was directly related to the calcium level of the diet. Hens on low calcium diets were able to withdraw calcium from bone to meet the added requirement for egg production.

Tyler (1945) tested calcium requirements of Rhode Island red pullets and found that hens on a level of .18 percent calcium soon ceased laying. One experimental hen lost the use of her legs on this low level diet but recovered when given additional calcium. One hen on a level of 3.37 percent calcium laid soft-shelled eggs, but none of the birds on low calcium diet produced any soft shells. Thus, apparently, lack of calcium does not necessarily produce soft shells but rather prevents ovulation.

In the present study, birds were placed on experimental diets on November 1, when they were approximately 12 to 15 weeks of age. They were practically of adult size and skeletons were well formed. Consequently, no information was obtained as to calcium requirements of the pheasant growth diet. The experimental diets appeared adequate for winter maintenance even with granite grit, although bone ash level was low on all experimental birds. It is not clear why there was no difference between level of bone-ash of pheasants on the granite and limestone grit. However, it is possible that this may be a function of other dietary factors such as proteins or vitamins.

McCance, et al (1942) demonstrated that humans absorbed more calcium as the protein of the diet was increased. A higher percentage of dietary calcium was absorbed from the gut with high protein levels and the amount excreted increased with higher dietary protein levels.

Pheasants on other diets in experiments conducted by DeWitt at Patuxent Refuge had higher bone ash than pheasants in the experiment here reported (unpublished). Nevertheless, DeWitt's birds were on diets with both higher protein and calcium levels.

Despite the ability of the low calcium diets to maintain pheasants through the winter, it was apparent that they were inadequate during the laying season for either maintenance or ovulation. Hens receiving granite grit were in poor condition and mortality was high during the laying season despite the fact that they laid few eggs. The poor condition of hens that laid no more than one or two eggs and the relatively rapid recovery when calcium carbonate was added to the diet indicates that pheasants could not be maintained throughout the year on this low calcium level even though they did not produce eggs.

No studies of blood calcium level were made in this experiment, and the relationship between calcium level and production of gonadotrophins was not investigated. It has been shown, however (Tyler, 1948), that the blood calcium level is increased from about 7 to 9 mg. per 100 g. whole blood in the non-laying pullet to about 16 to 24 mg. in the laying hen. This increase evidently is under control of sex hormones, since it has been shown by Baldini and Zarrow (1947) that an increase of blood calcium can be caused in the bob-white by injection of estrogens. Others have found similar responses to estrogenic substances injected into hens. Under the influence of estrogen, the animal's absorption of calcium from the intestine is greater, and where adequate calcium is not available in the food it can be withdrawn from skeletal reserves for this purpose.

The precise role of calcium in egg production was not established in this study. It was apparent, however, from examination of ovaries of pheasants on low calcium levels that ova are developed about as readily as in pheasants on the higher calcium level. Failure of birds on granite grit to ovulate seemed to be in some way related to calcium levels and probably reflected calcium level of the blood. The relatively rapid response to calcium carbonate added to the diet of pheasants on granite grit seems to suggest that calcium level operates in some manner through hormone control.

The bone calcium level of pheasants on the experimental diets must have been too low for calcium to be withdrawn to an appreciable degree. It is, of course, possible that a more nearly adequate diet, such as one with higher levels of protein, might have permitted greater storage of calcium in bones so that some ovulation might have occurred. Nevertheless, it is doubtful that pheasants on any diet with the low calcium level studied here could ovulate sufficiently to reproduce in the wild.

Buss, et al (1951) estimated from studies of ovulated follicles that wild pheasants produce an average of about 30 eggs annually. It was found in that study that pheasants normally drop several eggs at random and that they usually desert one or two nests before they start incubation. Furthermore, pheasants whose early nests are destroyed normally attempt to re-nest until late July or until they are successful in bringing off a brood. Thus, it is doubtful that wild pheasants would be successful in reproducing on levels of calcium similar to those tested in the present study.

Sources of Calcium. Calcium deficiency in the pheasant could be expected to result from the dependence of this bird upon cultivated grains. In eastern United States, corn is the staple item in the wild pheasant's diet, and corn is of all common food sources the poorest in calcium, with an average analysis of only 0.01 percent. Other cultivated grains also are low, the average being about 0.06 percent. Thus, the average calcium level of grains eaten by the pheasant can hardly exceed 0.04 percent. Calcium levels are taken from Ewing (1951).

The present study gives no indication of the minimum level of calcium required by the pheasant but from comparison with needs of chickens and quail it seems reasonable to assume that levels lower than 1 percent might be dangerously low.

If the minimum requirement for calcium be assumed to be no lower than 0.5 gram per 100 grams of diet, and 75 percent of the diet is cultivated grains, then the calcium from grains would be no more than .03 gram, and the deficit of at least .47 gram would need to be provided by only 25 percent of the bird's diet. The richest calcium source for this part of the diet is alfalfa, which has a level of 1.3 to 1.7 percent. No study has shown alfalfa to comprise as much as 10 percent of the pheasant's diet, so no more than about .15 gram per 100 could be expected from this source. Thus with 85 percent of the diet providing no more than .18 gram of calcium, the pheasant would need an additional .32 gram to be provided by no more than 15 percent of the diet. Not all seeds and fruits have been analyzed chemically, but the average calcium level appears to be no higher than about .5 percent for both seeds and fruits (King and McClure, 1944). From this evidence it seems that the calcium level of the natural pheasant diet in eastern United States would be only about half as high as necessary to support reproduction.

Possibly such factors as amount of sunshine, which influences vitamin D levels, natural sources of vitamin D, or protein level of the diet might operate to lessen this calcium deficiency, yet it is clear that the margin of safety must be low in most instances. If so, then distribution of pheasants can be expected to be related to natural sources of limestone or to calcium levels of the soil, as well as to food sources high in calcium.

Biologists have differed in opinion as to the value of alfalfa to the pheasant since heavy losses of pheasant nests usually are occasioned by early mowing of this crop. For example, Ball (1952) reported on one small alfalfa field on Pelee Island in which the density of pheasant nests was about 8 per acre, all of which were destroyed when the field was mowed. Nevertheless, it seems that the ability of pheasants to maintain high populations in the face of such heavy destruction must imply that alfalfa makes some significant contribution to the welfare of the birds. Possibly in the absence of alfalfa and with high dependence on cultivated grains, the pheasant finds it almost impossible to maintain an adequate calcium balance.

Weed seeds vary in calcium level, apparently not only according to species but also according to the soil on which they are produced. Unfortunately, there are relatively few published analyses of weed seeds. However, King and McClure (1944) analyzed 54 samples of various seeds which ranged from .08 percent calcium for paspalum grass to 1.23 percent for the seeds of rabbitfoot clover. Ragweed seeds (*Ambrosia aptera*) from Texas had .71 percent calcium whereas *A. artemisiifolia* from Ithaca, New York tested .36 percent calcium. From this series of results, it seems that weed seeds in general have considerably higher calcium levels than do cultivated grains.

Mast crops, such as acorns and chestnuts, also are considerably higher in calcium than are cultivated grains. For example, King and McClure found levels of calcium to vary from .10 for the kernel only of willow oak acorn from Arkansas to a high of .43 for Spanish oak from Mississippi. Fruits were found to vary from .08 percent for skunk-bush (Rhus canadensis) from Oklahoma to .95 percent for the fruits of swamp rose (Rosa palustis) from Virginia. From these data, it appears that the pheasant might partly compensate for the low calcium level of cultivated grains by proper selection of wild seeds, fruits, and mast crops, but there is no evidence that these foods make up an appreciable part of the pheasant diet.

Calcium in Relation to Other Factors. Calcium is only one ecological factor influencing distribution of the pheasant. Consequently, although the importance of calcium as a distributional factor may explain in part the failure of this species in noncalcareous areas, nevertheless it cannot be expected that pheasants will be abundant in all areas with adequate calcium. Because of its dependence on cultivated grains, the pheasant is restricted to farming areas and generally to grain producing localities. For this reason, the northern tip of Michigan's lower peninsula, although relatively rich in calcium, cannot be expected to produce pheasants.

Pheasants in southwestern United States appear to require free water during summer, a characteristic which has not been noted in eastern United States where dew appears to provide an adequate supply. John Chattin, then game biologist, California Division of Fish and Game (in personal communication, 1951) stated that pheasants in the Central Valley of California are found in summer clustered around pools of standing water and that they do not exist far from free water. Consequently, pheasants cannot be expected to survive in many parts of the Southwest except along streams or in irrigated areas.

Temperature and humidity appear to play a part in the viability of pheasant eggs (Yeatter, 1950). It is believed that this fact as well as requirement for calcium operates to prevent the pheasant from becoming established in southeastern United States. Mountainous areas and wooded sections do not have pheasants because of their lack of food-producing plants suitable for this species. This fact mitigates against the establishment of pheasants throughout large areas of northeastern United States as well as in mountains of the West. Thus, it is clear that calcium is only one of many ecological factors which must be considered in determining the suitability of an area for pheasants. Nevertheless, it appears to be a major factor.

Distribution of Other Species. Probably the slowness of biologists to accept the suggestion of Leopold (1931) that distribution of the pheasant might be controlled by a nutritional factor stems from the fact that other species exist in fair numbers within areas not suited to pheasants. Game biologists reasoned that if bob-white quail or ruffed grouse could exist, then it would be difficult to rule out the pheasant on a strictly nutritional basis.

It is evident, of course, that this is faulty reasoning since, although all animals must meet a nutritional requirement for calcium, modification which would enable an animal to exist in areas low in calcium might be of two kinds: (1) The animal might through more efficient use of calcium either by improved absorption through the digestive tract or by more efficient use of the element in metabolism reduce the dietary level required for maintenance. (2) More efficient modification perhaps would be in an adjustment of the diet so as to select foods richer in calcium. Turkeys and grouse, for example, are largely mast eaters or budders, while the bob-white subsists largely on wild weed seeds, acorns, and leaves of plants. The pheasant is the only American game species which normally utilizes cultivated grains to the extent of more than 50 percent of its diet. Thus, it is apparent that calcium deficiency, although it may be an important factor in influencing the distribution of the pheasant, may be of relatively little significance in the distribution of other species.

Calcium in Soils. It has been demonstrated repeatedly that calcium level of the soil may have an important bearing upon the animal life as well as the plants of an area. As long ago as 1861 von Gohren (1861) reported on a disease in the bones of cattle in Germany in dry years which apparently was related to scarcities in inorganic elements in feed. The disease was cured by feeding bone meal. Lewite (1907) related an outbreak of bone disease in Germany to the greater ratio of calcium to phosphorus in oats in dry years. Taylor (1930) associated sheep sickness in New Zealand with deficiency of minerals in soils derived from volcanic ash over porous sandstones or loose sands. In France, Maume and Monteil (1938) noted that some soils that had developed from gneiss, mica schists, or granite produced plants deficient in calcium and phosphorus. They also observed animal diseases in areas where these soils occurred and related them to the mineral deficiency.

If survival of pheasants is influenced by availability of calcium, then this relationship should be discernible in the national pattern of distribution of the species. Unfortunately, it is not possible to make an exact comparison, since not all areas have been analyzed for this element. Inferences can be drawn, however, from factors that in themselves control calcium level of the soil. Such a comparison gives considerable additional evidence that availability of calcium is a major factor in the welfare of the pheasant.

Calcium level of the soil is a function of the parent material from which the soil was developed, depth of soil, its age, amount of annual rainfall, texture of soil, agricultural practices, and such geological events as glaciation and subsequent history.

Even soils that have been derived from limestone tend, in humid areas, to lose calcium from surface layers by the process of leaching. Calcium, although relatively insoluble in pure water, is readily soluble in dilute carbonic acid. Carbon dioxide of the air combines with water to form an acid solution which rapidly leaches calcium from the surface. The rate at which this is accomplished depends upon amount of rainfall and rate of percolation of water through soil.

As rainfall diminishes, leaching is less severe, and in areas of low rainfall the process is reversed. During dry periods, water rises to the surface by capillary action and as it evaporates its load of minerals is deposited.

The calcium content of soils is highly variable, with local factors playing an important role in some areas. Hence, it is seldom possible to be sure that soils in any place are entirely devoid of this element. Nevertheless, there are large areas which are deficient in calcium.

Soil classification is complex and does not account for any one factor, such as level of calcium. Nevertheless, it is possible to define some characteristics of the great soils groups that give evidence on the relationship investigated in this study. Byers, et al

(1938) and Baldwin, et al (1938) have provided the principal sources for the following discussion of soils.

Figure 11 shows the distribution of the great soil groups of midwestern and northeastern United States. Calcium levels of these soils vary within each group, yet there are some generalizations that can be made. Podzols and red-yellow podzolic soils are almost always deficient in calcium. The chernozem and the chestnut and brown soils nearly always have a relatively high amount of calcium in surface layers. Gray-brown podzolic soils are variable, depending upon amount of rainfall, glaciation, and length of time since glaciation. Bog soils and wiesenboden, or half-bog soils, generally are relatively rich in calcium. Prairie soils, like the gray-brown podzolic soils, are variable, but they tend to be richer in calcium than the podzolic soils. The chief reason for this difference seems to be that the prairie soils lie within a region of lower rainfall than the gray-brown podzolic soils.

Pedalfers and pedocals. One major soil classification which expresses the effect of climate on the mineral content divides soils into pedalfers, with a low concentration of calcium and a high concentration of aluminum and iron, and pedocals with high content of calcium in surface layers. Most soils in the western half of the United States, beginning with the chernozem, are pedocals.

Glaciation. Glaciation, by the redistribution of calcium through the soil and by transportation of limestone from northern areas and dropping it upon the surface, has increased the calcium content of most soils in the glaciated areas. The amount of calcium available in surface layers of glaciated soils depends largely upon the length of

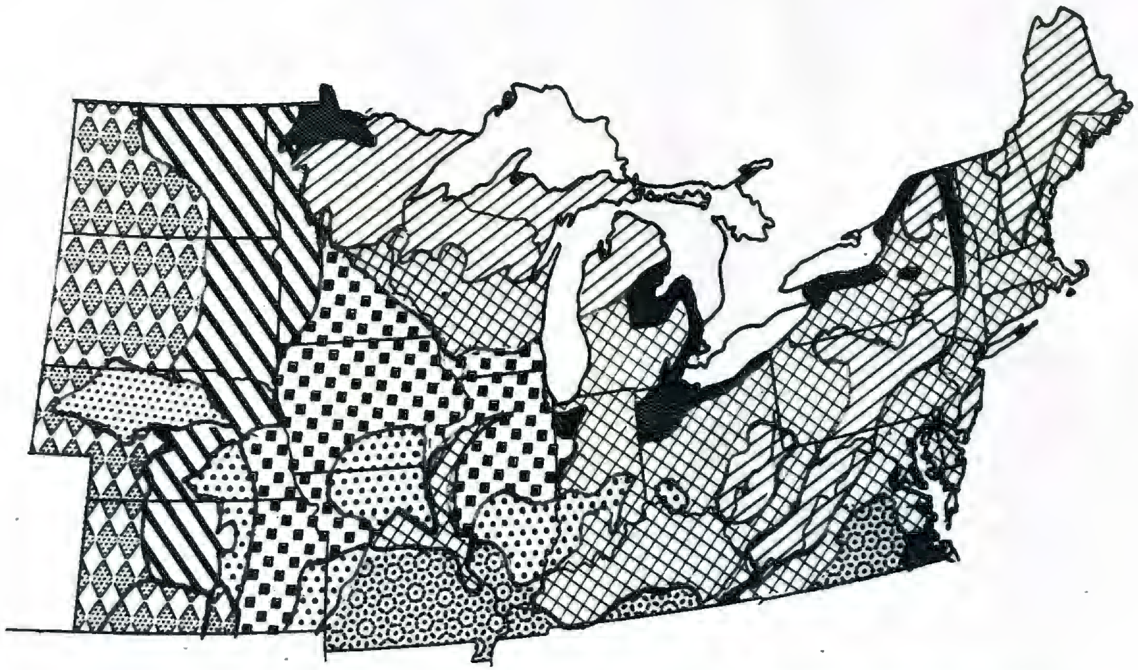


Fig. 11. General pattern of great soil groups of north central and northeastern United States, generalized after Kellogg (1951).

Podzols

Brown and gray-brown podzolic soils

Red and yellow podzolic soils

Wiesenboden and half-bog soils

Prairie soils

The chernozem

Planosols

Sands

Chestnut and brown soils

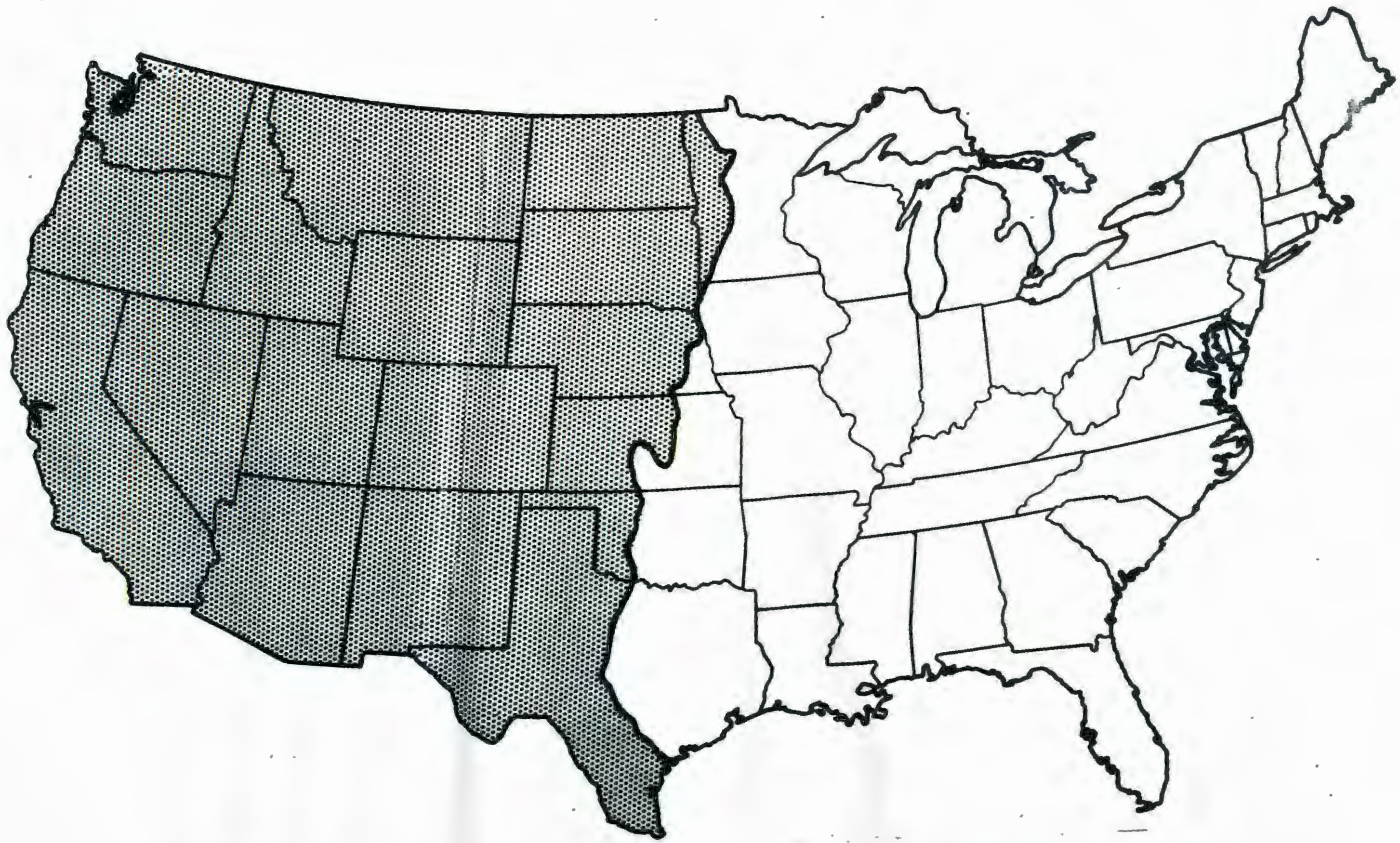


Fig. 12. Calcium availability of soils of the United States, after Shorey (1940).

Legend:

Soils inherently rich in calcium

Soils high to poor in calcium supply depending upon drainage and history time since the glacier retreated and the amount of rainfall in the area.

Loess. Loessial soils are common in parts of the Midwest. These soils tend to reflect climatic conditions as well as parent materials from which they were derived (Smith, 1942). In Iowa, for example, it is assumed that the loessial soils were derived from calcareous materials left by glaciers. These materials were transported by wind into their present locations, forming beds as great as 100 or more feet in depth. Subsequently there has been leaching of the calcium from the surface in some areas and erosion of the surface layers so that these loess deposits differ markedly in the calcium level of surface soils. Still further west the loess has developed into chernozem with a high level of calcium.

Pheasant Distribution. West of the lime line, that is within the pedocals, pheasants are found wherever crop conditions provide suitable habitat (Sharp and McClure, 1945; Rasmussen and McKean, 1945). Along the eastern part of this region is to be found the most favorable pheasant range of the United States. To the westward pheasants tend to be restricted to river valleys and irrigated lands, but there are few such irrigated valleys without pheasants. East of the lime line, however, pheasants seem to be highly responsive to calcium levels of the soil.

Iowa. Iowa was covered by five ice sheets in the Pleistocene period (Brown, 1936). These are designated as the Nebraskan, Kansan, Illinoian, Iowan, and Wisconsin. Coverage of some of these areas by loessial soils from three sources and various degrees of leaching result in a somewhat complex pattern of availability of calcium in the State. In general, however, the Wisconsin drift and the Missouri Loess areas are richest in this element. Calcium is most available in northern and western counties, and least available in the southeast.

Comparison of figures 13 and 14 shows that there is a relatively high degree of correlation between calcium availability of soils and population of pheasants, although there are few pheasants in southwestern Iowa in an area with fairly high availability of calcium.

Wisconsin. Soils of Wisconsin reflect a variety of geological conditions, including parent materials of soils, glaciation, and subsequent history (Martin, 1932; Whitson, 1927; Muckenhirn and Dahlstrand, 1946). Although Martin divides the State into five geographical provinces, from the standpoint of calcium availability and distribution of pheasants only three regions need be considered. The eastern ridges and lowlands, which occur in the southeastern quarter of the State, are richest in calcium. This area combines underlying limestone with glacial deposits that are rich in calcium. It is in this region that Wisconsin's highest populations of pheasants occur. Northern areas have been glaciated, yet the glacial drift is thin and overlies non-calcareous rocks. Vegetation since the glacial period has been principally coniferous forest, so that most of the soils are podzols. Calcium supplies in surface layers of soil are meager; pheasants are almost non-existent in this northern area.

Soils in western Wisconsin include those of the "driftless area," a region which was not touched by glaciers, yet which has limestone as the basic material from which soils have been derived. In addition, there are some areas which have been covered by glaciers, and which have not been leached as strongly as some eastern soils. Southwestern

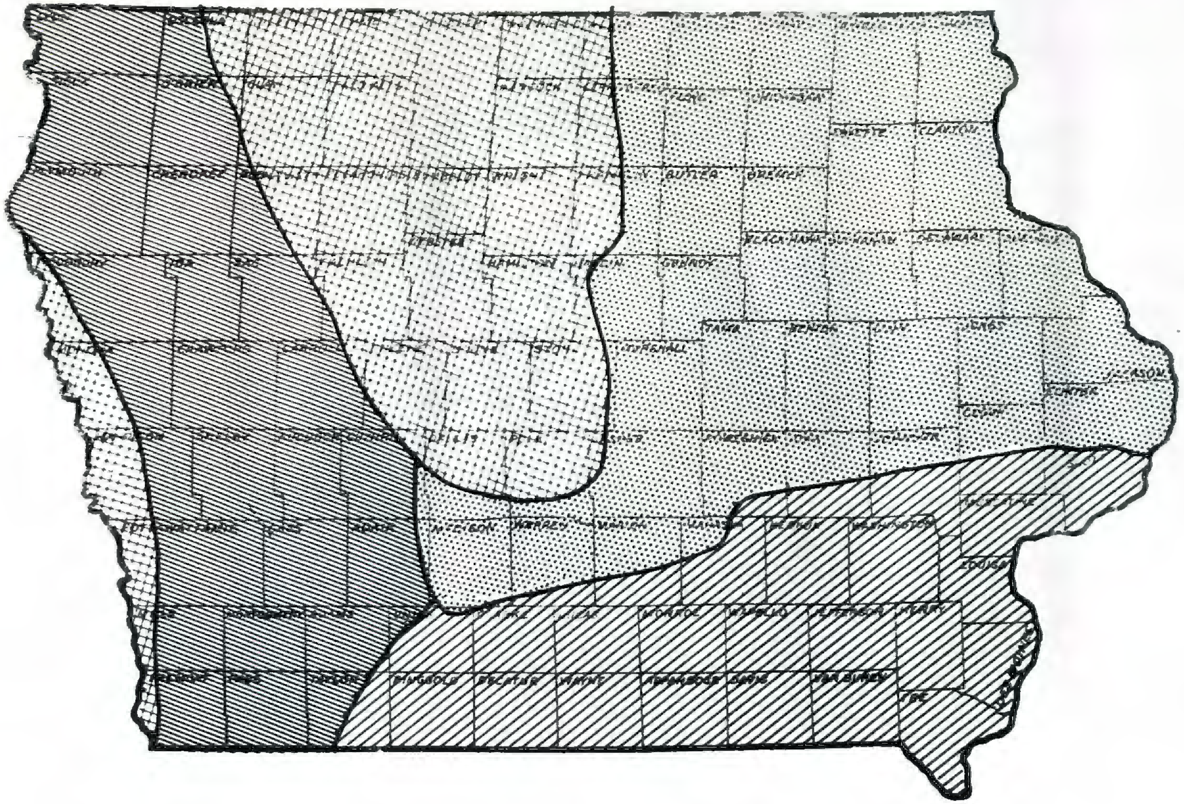


Fig. 13. Availability of calcium in Iowa soils, after Shorey (1940).

Legend:

- Soils fairly rich in calcium
- Soils high to medium in calcium
- Soils acid but calcium within reach of deep-rooted plants
- Soils medium to low in calcium

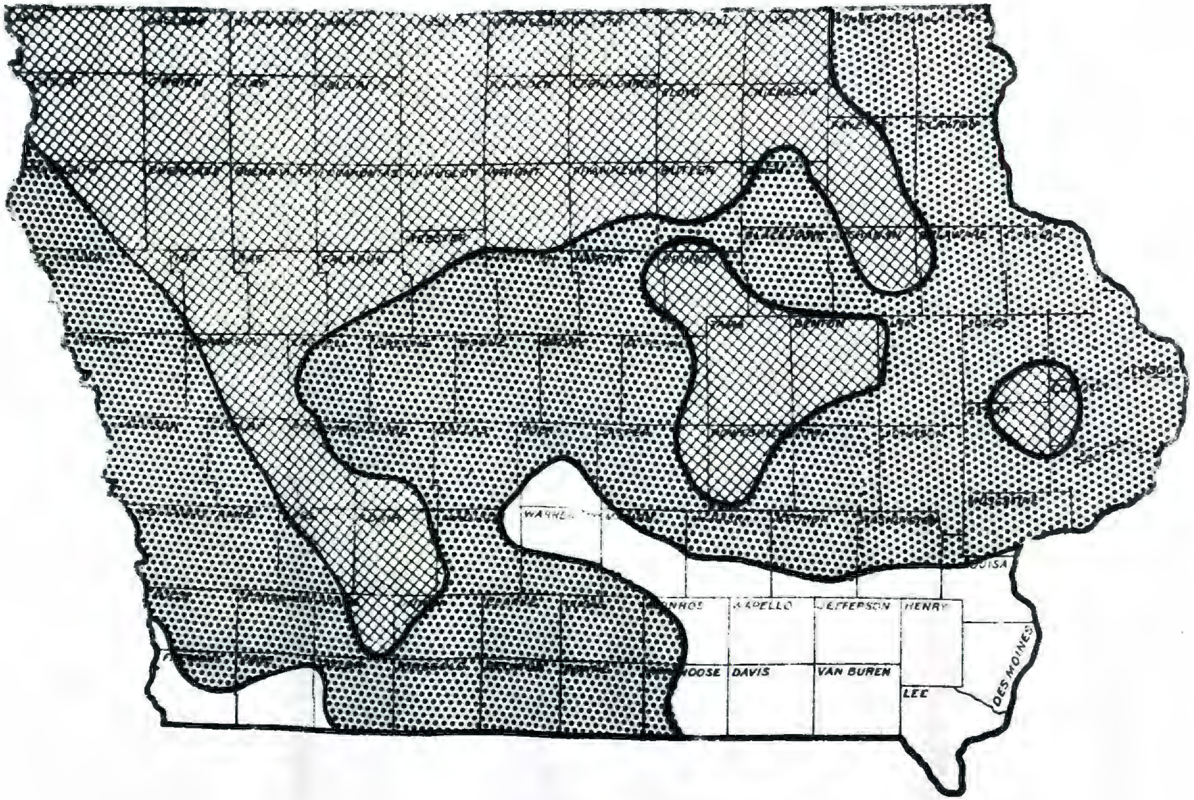


Fig. 14. Iowa pheasant distribution based on 1953 crowing cock counts. Information furnished by R. C. Nomsen, Game Biologist, Iowa Conservation Commission.

Legend:

- More than 10 calls per 2-minute stop
- 1 to 9 calls per 2-minute stop
- Less than 1 call average per 2-minute stop

Wisconsin has less available calcium in its soils than the southeastern part of the State and also has a lower population of pheasants (see figures 15 and 16).

Michigan. Distribution of pheasants in Michigan illustrates both their dependence upon agricultural crops and an apparent relationship with availability of calcium in soils. Northern Michigan has relatively high calcium in soils, according to Millar (1940), yet there is little farming. Pheasants have never been successfully established in this part of the State. Pheasant populations of high density are found only within the southern farm area. Within this agricultural region, however, there is considerable variation in both fertility of soil and production of pheasants. Soils around Saginaw Bay and southward around the eastern boundary of the State are classed as wiesenbodens. Poorly-drained before they were placed under cultivation, these soils have not lost as much of their mineral store as have other soils of this region. Consequently, they have produced excellent crop yields when properly managed, and they also produce the highest populations of pheasants of the State. To the west from the poorly-drained soils lies a block of glacial till, a considerable part of which is similar to soils of southeastern Wisconsin. Miami is the predominant soil series, and according to Millar (1940) a good percentage of this area has enough calcium to permit growing of alfalfa without the addition of agricultural lime (see figure 17). This area of fairly high calcium level is also good for the production of pheasants.

Southwestern Michigan has soils largely derived from glacial outwash. They generally are sandy and low in calcium. Some places

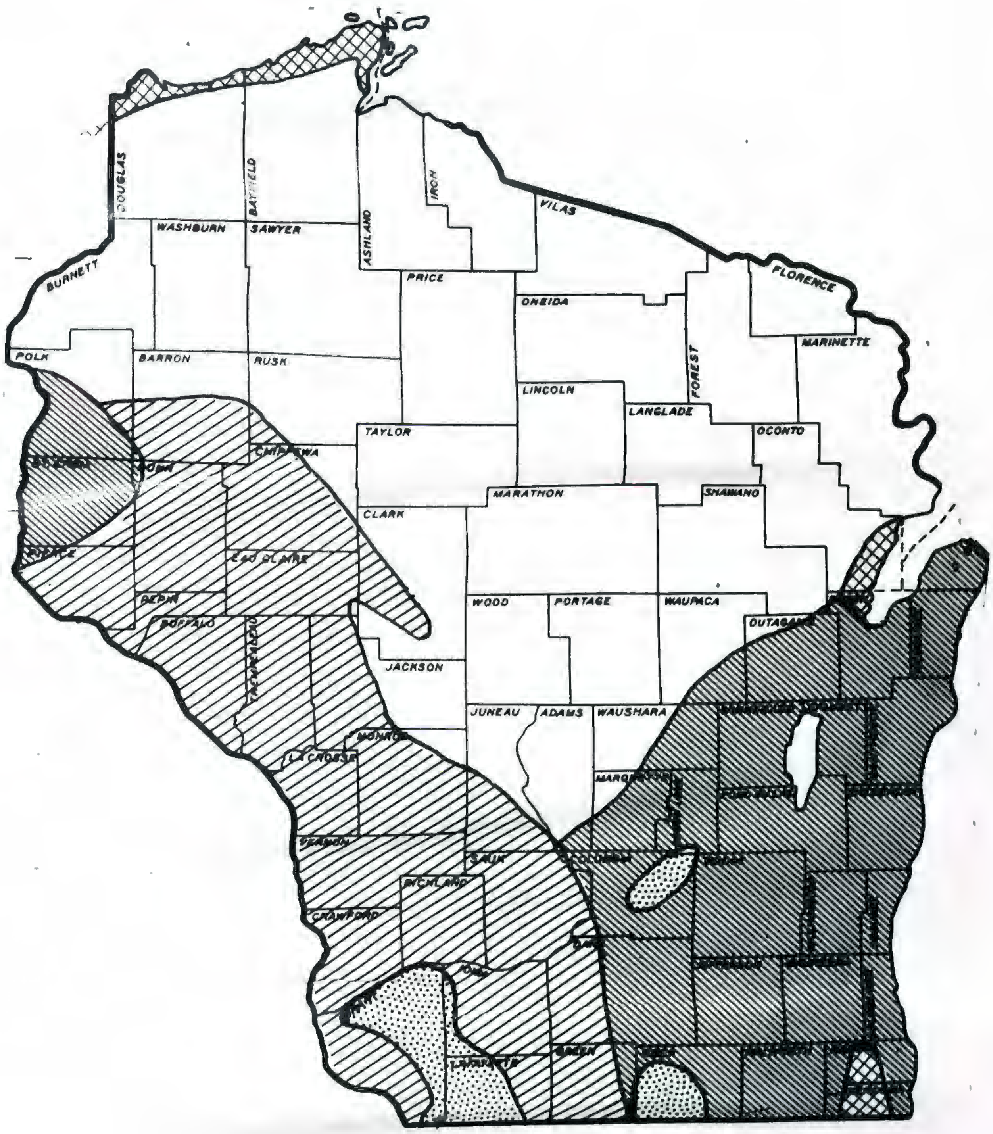


Fig. 15. Distribution of calcium in Wisconsin soils, after Shorey (1940).

Legend:

- Soils fairly rich in calcium
- Soils high to medium in calcium
- Soils acid, but calcium within reach of deep-rooted plants
- Soils medium to low in calcium
- Soils poor in calcium

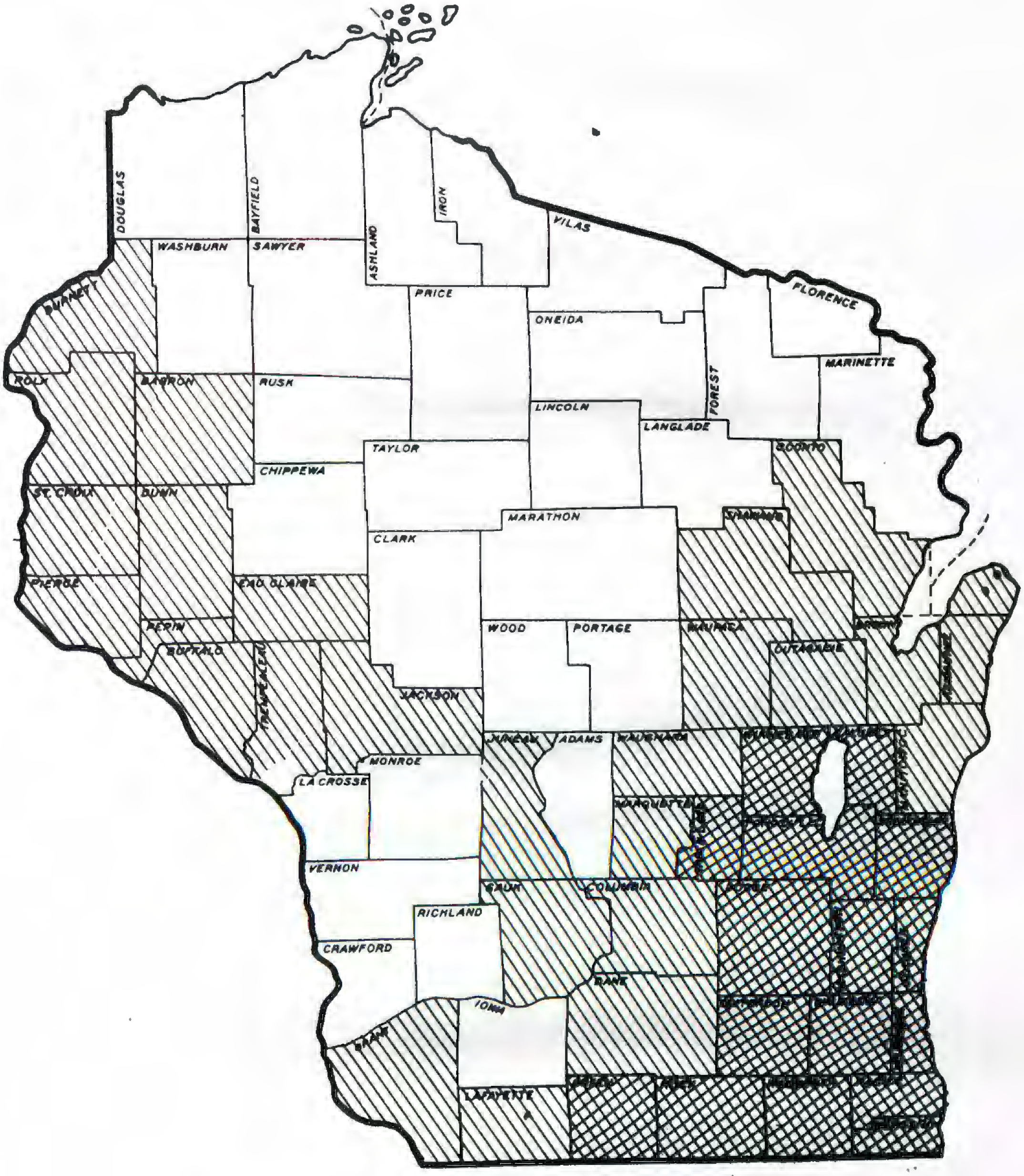


Fig. 16. Wisconsin pheasant distribution, after Buss (undated).

Legend:

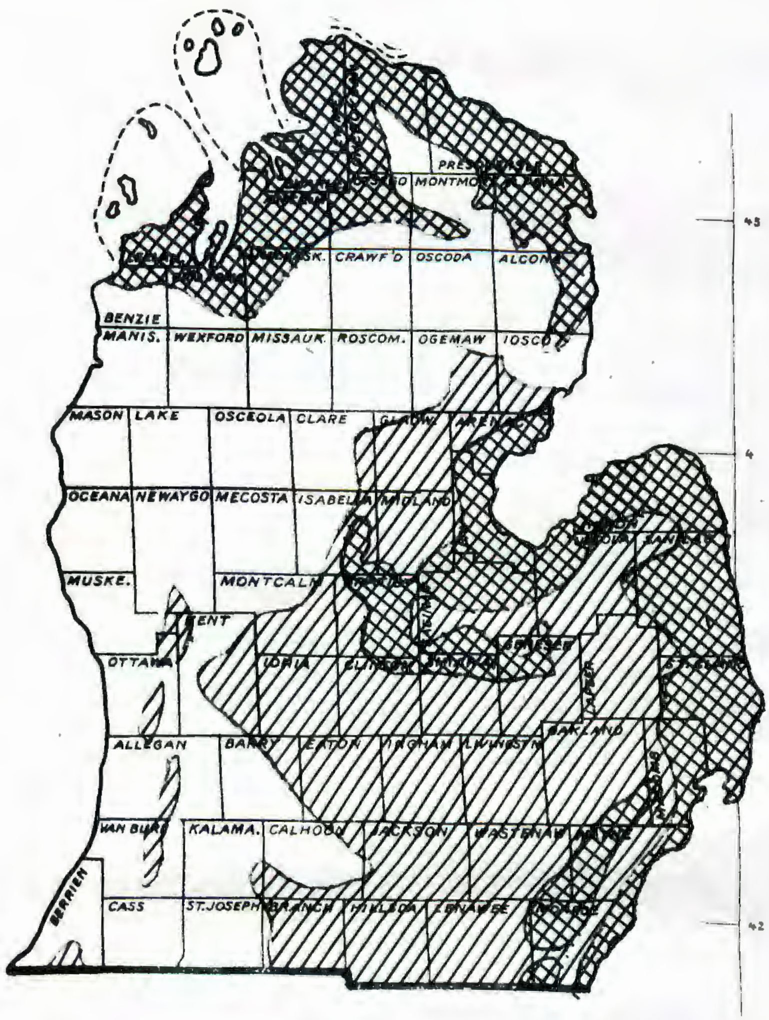
1942 kill more than 6 per 100 acres

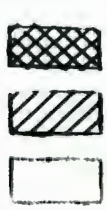
1942 kill 1 to 5 per 100 acres

1942 kill less than 1 per 100 acres

Fig. 17. Percentages of southern Michigan soils that will produce alfalfa without additional lime.

Information from Millar (1940).



Legend:  70 to 90 percent.

40 to 60 percent.

Less than 30 percent.

in this part of the State are sufficiently fertile to grow good crops, but even in these places pheasants are scarce. The only questionable part of southern Michigan in the apparent relationship between calcium availability and distribution of pheasants is in part of Kent and Ottawa counties, where good populations of pheasants exist in areas not listed as high in lime. Nevertheless, even in this area there are marl pits in some poorly-drained localities, and it is possible that calcium levels there are higher than in other parts of southwestern Michigan.

Ohio. Like Michigan, Ohio has its best populations of pheasants in the area of wiesenboden soils. Wood County, in northwestern Ohio, has one of the highest populations of pheasants in the Great Lakes region, and this county is noted for its heavy-textured soils relatively high in lime. Populations drop off rapidly to the south and east of this area (Leedy and Hendershot, 1947).

Pennsylvania. In addition to the correlation demonstrated between limestone outcroppings of Lancaster County and pheasant distribution, Pennsylvania shows a general relationship in its pheasant populations with the availability of calcium (Gerstell, 1937). Soils of the western counties are variable in calcium level, but all areas with populations of pheasants sufficient to provide good hunting are either glaciated or have outcrops of limestone. In the Susquehanna Valley near the northern boundary of the State is a small pheasant population in an area of glaciated limestone. Southeastern pheasant distribution has been shown to coincide with limestone outcroppings. Some valleys of Pennsylvania have limestone but no pheasants, but there are no heavy populations of pheasants in the absence of calcium.

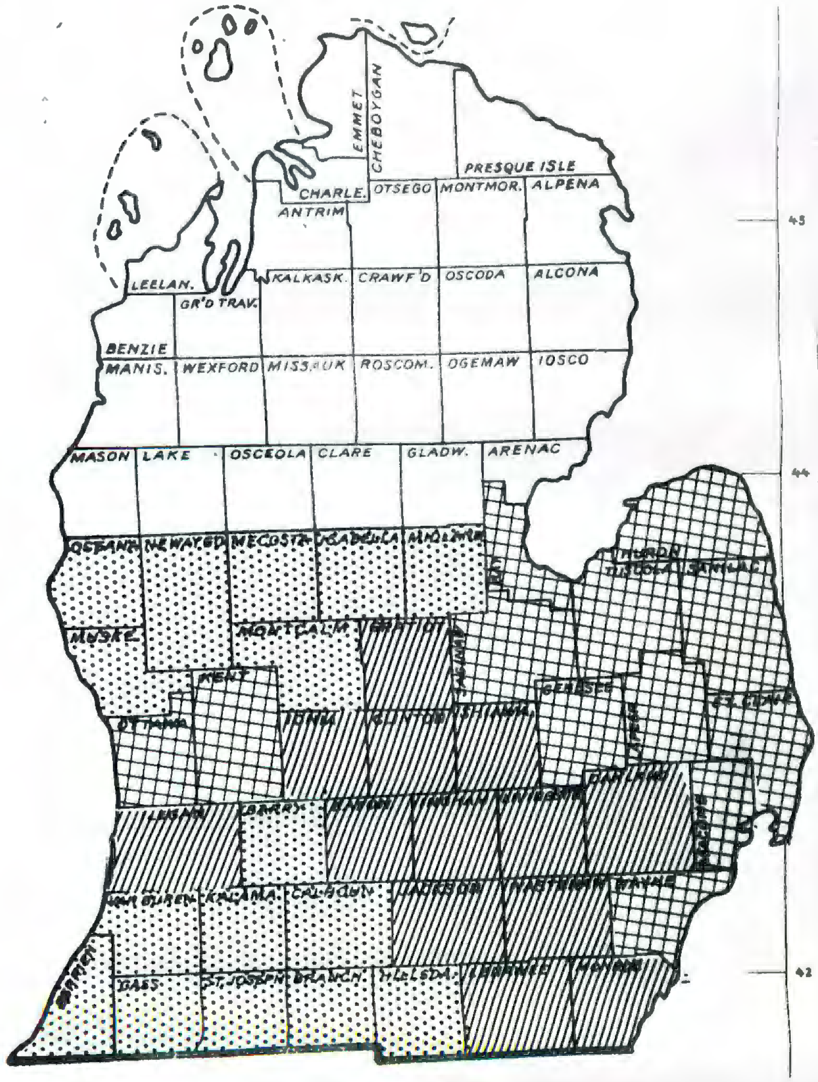


Fig. 18. Distribution of pheasants by counties in Michigan computed from official state release, May 14, 1943.

Legend:

Kill greater than 10 cocks per 100 acres

Kill between 5 and 10 cocks per 100 acres

Kill less than 5 cocks per 100 acres

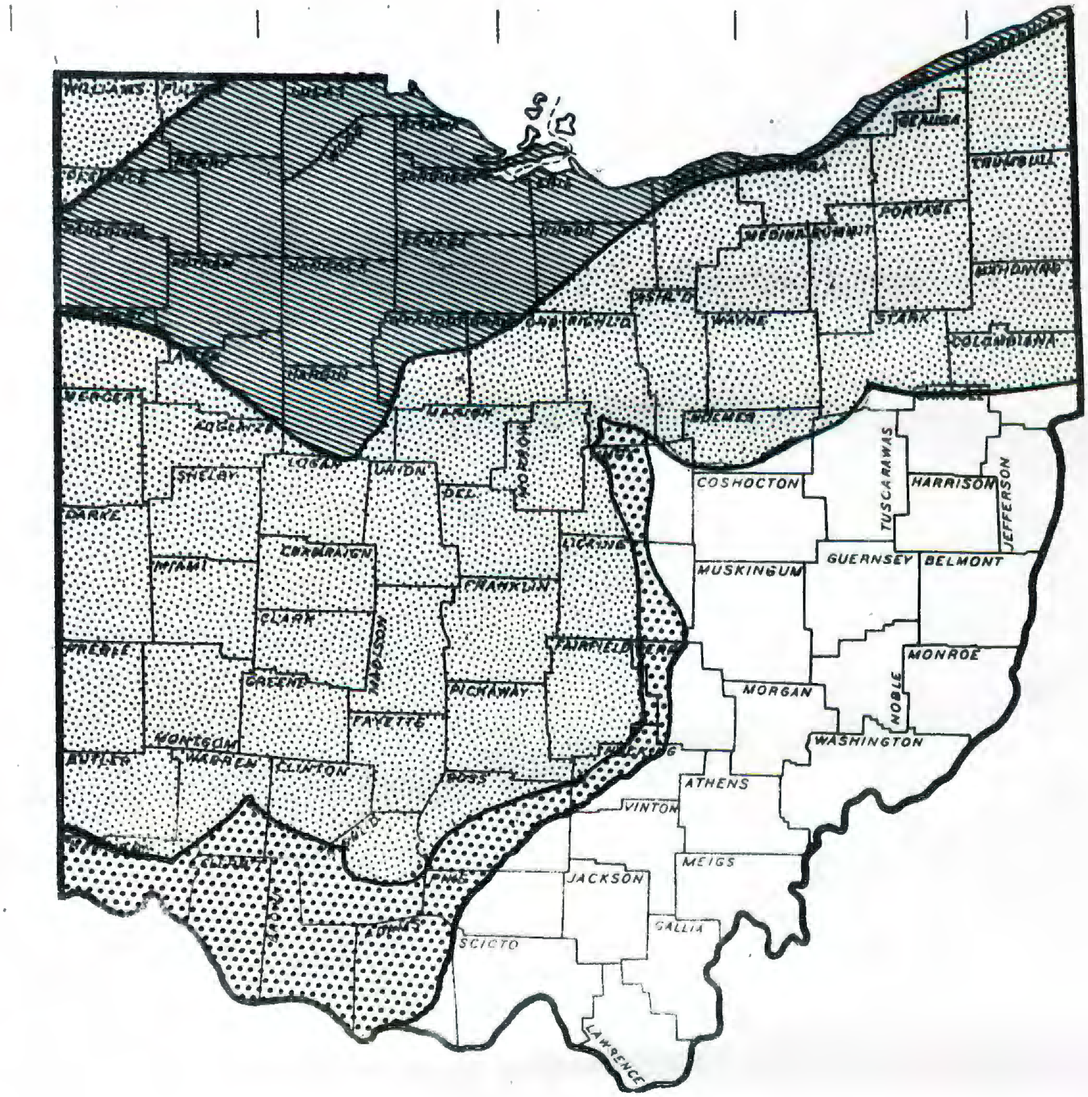


Fig. 19. Calcium availability of Chio soils, after Shorey (1940) and Geological Society of America (1949).

Legend:

Soils high to medium in calcium

Wisconsin glaciated area, high to low in calcium

Illinoian glaciated area, soils generally lower in calcium

Unglaciated area, soils generally poor in calcium

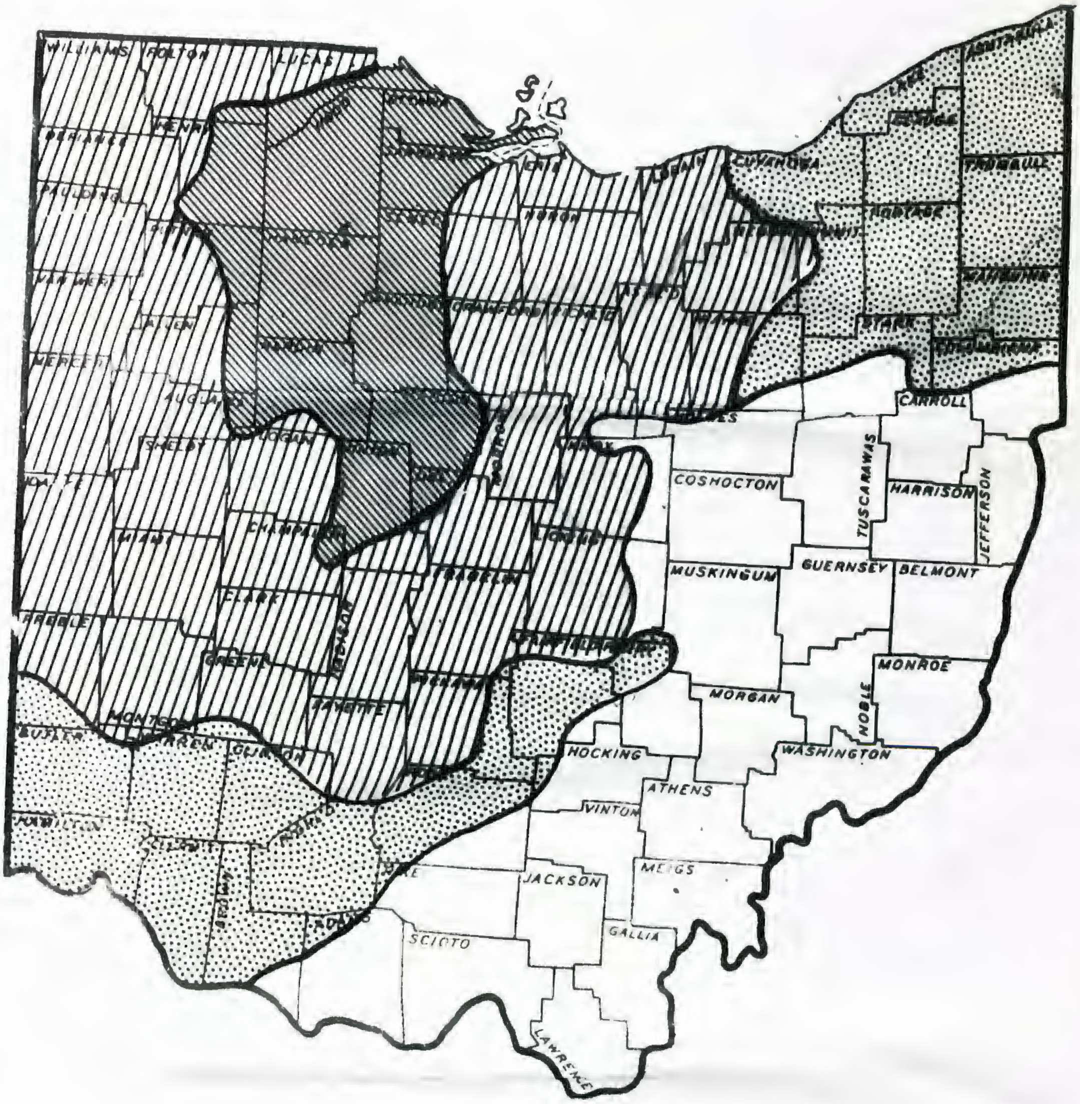


Fig. 20. Distribution of Pheasants in Ohio, after Leedy and Hendershot (1947).

Legend:

- Pheasants relatively abundant
- Pheasants scarce to common
- Pheasants rare to scarce
- Pheasants rare or absent

SUMMARY AND CONCLUSIONS

Studies reported here have involved field observations and controlled nutrition experiments to learn to what extent calcium availability influences production of the ring-necked pheasant. Results have been discussed in relation to nationwide distribution of pheasants in an attempt to apply theoretical results in the field.

Two areas in Lancaster County, Pennsylvania, were compared. One of these, the New Holland area, has soils of limestone origin and has small bits of limestone available to the pheasant in the form of grit. The Quarryville area has soils of non-calcareous origin. Grit available there is granite, sandstone, or quartzite. The two areas are generally similar as to crop patterns and soil fertility, although the New Holland area is slightly superior in fertility. From close observations, it appears that the primary difference between the two areas involves source of soil and the availability of limestone in the New Holland area.

Pheasant populations were estimated by means of roadside counts and were found to correspond rather closely to availability of limestone. A high population exists in the New Holland area, whereas pheasants are scarce or absent in the Quarryville area. Hunting is heavy and the New Holland population is harvested about as thoroughly as feasible. Thus, there is no indication that the high population within the New Holland area is in any way related to special protection of the birds there. Likewise, there is a high population of foxes in the New Holland area and it is believed unlikely that predation could in any way account for the difference in population.

From these observations, a tentative conclusion was drawn that the most likely factor influencing population of pheasants in the New Holland area was presence of a rich source of calcium.

To test this hypothesis, an experiment was set up at the Patuxent Research Refuge to learn the effect of a supplement of calcium in the form of grit in connection with a diet thought to be comparable to the natural diet of the pheasant. Pheasants were found to be highly sensitive to vitamin B_{12} and it was necessary to provide a supplement of this vitamin in order to maintain the birds in wire-floored pens. Nevertheless, it is not believed likely that deficiency of vitamin B_{12} plays an important role in distribution of pheasants since wild pheasants should have adequate natural sources.

The level of calcium in the experimental diet was adequate for maintenance in winter without calcareous grit but was inadequate to maintain hens through the breeding season even with low production of eggs.

Pheasant hens with a supplement of granite laid very few eggs. Only one of those obtained in two years hatched. Hens receiving limestone produced more eggs and, although hatchability was low, production still was considered satisfactory in view of the low level of protein in the experimental diet and the inadequate incubator used.

A supplement of powdered calcium carbonate added to the diet served to increase production of eggs by hens on granite, indicating that deficiency of calcium was the factor influencing production of eggs. Eggs developed within the ovary in hens on granite but were not ovulated normally without a supplement of calcium.

There was no significant difference in levels of bone-ash in birds on calcium or granite. It is believed that some other factor such as level of proteins or vitamins may function in this relationship as well as availability of calcium.

Nationwide distribution of pheasants gives additional evidence of the importance of calcium. On the pedocal soils of western United States, populations of pheasants seem to be directly related to agricultural practices. On pedalfers of eastern United States, there is a close relationship between size of population and availability of calcium.

Alfalfa is believed to be an important source of calcium for pheasants. It seems likely that this crop may make it possible in many areas otherwise deficient in calcium for the pheasant to obtain minimum levels of this element. Thus, despite high losses in the mowing of alfalfa, it is believed that the net results of this crop are beneficial.

Corn is an important food but is deficient in calcium. Pheasants are scarce in the corn belt except for those localities where general farming is practiced.

Rotation of crops provides a varied source of food that permits year-around supply where calcium is adequate. In addition, it is believed that in general farming areas there are likely to be more crops rich in calcium than in some single-crop areas.

From these various sources of evidence, it seems apparent that level of calcium is an important factor in influencing distribution of the pheasant. If this is correct, then such practices as manipulation of habitat or stocking of game-farm pheasants in areas deficient in calcium have little chance of success unless the level of calcium can be increased. Possibly this can be accomplished to some extent by wider use of agricultural lime and by increased production of alfalfa. At any rate, continued large expenditures aimed at increasing populations of pheasants in lime-deficient areas seems unwise.

LITERATURE CITED

Albrecht, Wm. A. and G. E. Smith. 1941. Biological assays of soil fertility. Soil Sci. Soc. Amer. Proc., 6:252-258.

Allen, D. L. 1950. Problems and needs in pheasant research. Jour. Wildl. Mgt., 14:105-114.

American Ornithologists' Union. 1931. Check-list of North American birds. 4th Ed. Amer. Ornithologists' Union, Lancaster, Pennsylvania. xix + 526 p.

Baldini, J. T. and M. X. Zarrow. 1952. Estrogen and serum calcium levels in the bobwhite quail. Poultry Sci., 31:800-804.

Baldwin, Mark, Charles E. Kellogg and James Thorp. 1938. Soil classification. In Soils and men, USDA Yrbk. Agric. :979-1001.

Ball, K. E. 1952. Nesting of the ring-necked pheasant on Pelee Island, Ontario. Canadian Field-Nat., 66(3):71-81.

Barnes, William B. 1950. Indiana's 1949 game harvest. Outdoor Indiana, 17(11):18-19.

Bennett, Logan J. and G. O. Hendrickson. 1938. Censusing the ring-neck pheasant in Iowa. Trans. Third N. Amer. Wildl. Conf. : 719-723.

Bennitt, Rudolf and H. V. Terrill. 1940. Possible temperature factors in north central pheasant distribution. Trans. Fifth N. Amer. Wildl. Conf. :428-432.

Bethke, R. M., D. C. Kennard, C. H. Kick and G. Zinzalian. 1929. The calcium-phosphorus relationship in the nutrition of the growing chick. Poultry Sci., 8:257-265.

Black, D. J. G. 1946. A comparison of some methods of supplying calcium to intensively kept chicks. Jour. Agric. Sci., 36: 199-206.

Bliss, George S. 1941. Climate of Pennsylvania. In Climate and man, USDA Yrbk. Agric. :1087-1098.

Brown, P. E. 1936. Soils of Iowa. Agric. Exp. Sta., Iowa State Coll. Agric. and Mech. Arts, Spec. Rept. No. 3, Ames.

Buss, Irven O. Undated. Wisconsin pheasant populations. Wisconsin Cons. Dept. Publ. 326, A-46, 184 p.

__________, Roland K. Meyer and Cyril Kabat. 1951. Wisconsin pheasant reproduction studies based on ovulated follicle technique. Jour. Wildl. Mgt., 15:32-46.

Byers, H. G., Charles E. Kellogg, M. S. Anderson and James Thorp. 1938. Formation of soil. In Soils and men, USDA Yrbk. Agric. : 948-978.

Cahn, A. R. 1938. A climographic analysis of the problem of introducing three exotic game birds into the Tennessee Valley and vicinity. Proc. Third. N. Amer. Wildl. Conf. :807-817.

Carver, J. S. and J. McGinnis. 1950. Effect of an "animal protein factor" fermentation product on hatchability of chicken eggs. Poultry Sci., 29:307-309.

Clarke, C. H. D. 1949. The management of the ring-necked pheasant in Canada. Internat. Ass'n. Game, Fish, & Cons. Comm., 39th Conv. Trans. :58-64.

Cottam, Clarence. 1929. The status of the ring-necked pheasant in Utah. Condor, 31:117-123.

Crawford, Bill T. 1950. Some specific relationships between soils and wildlife. Jour. Wildl. Mgt., 14:115-123.

Dale, Fred H. 1951. The refuge in pheasant management. Jour. Wildl. Mgt., 15:337-346.

__________. In press. Pheasants and pheasant populations. In Allen, D. L., Pheasants on the land. Amer. Wildl. Inst., Washington, D. C.

Dalke, Paul D. 1937. Food habits of adult pheasants in Michigan based on crop analysis method. Ecology, 18:199-213.

__________, A. Starker Leopold and David L. Spencer. 1946. The ecology and management of the wild turkey in Missouri. Missouri Cons. Comm. Tech. Bull., 1:1-86.

Delacour, Jean. 1945. Classification and distribution of the game, or true, pheasant. In McAtee, W. L., The ring-necked pheasant and its management in North America. Amer. Wildl. Inst. :6-10.

Denny, Arthur H. 1944. Wildlife relationships to soil types. Trans. Ninth N. Amer. Wildl. Conf. :316-323.

Dustman, Eugene H. 1949. The 1948 Ohio game kill. Ohio State Univ., Release 200 (mimeo) :1-8.

English, P. F. 1941. Hatchability of pheasant eggs in relation to some known temperatures. Jour. Wildl. Mgt., 5:213-215.

Errington, Paul L. 1945. The pheasant in the northern prairie states. In McAtee, W. L., The ring-necked pheasant and its management in North America. Amer. Wildl. Inst. :190-202.

Evans, Robert John and A. Wade Brant. 1945. Calcium, phosphorus, and vitamin D interrelationships in turkey poult nutrition. Poultry Sci., 24:404-407.

Ewing, W. Ray. 1951. Poultry nutrition. W. Ray Ewing, South Pasadena, California, 4th Ed. (Rev.) : xiv + 1518.

Faber, Lester F. 1948. The effect of farm crops on the production of the ring-necked pheasant in Iowa. Proc. Iowa Acad. Sci., 55: 109-113.

Geological Society of North America. 1945. Glacial map of North America. Spec. Papers, 60(1), Eastern Half.

Gerstell, Richard. 1937. The status of the ringneck pheasant in Pennsylvania. Trans. Second N. Amer. Wildl. Conf. :505-509.

Glading, Ben. 1946. Upland game birds in relation to California agriculture. Trans. Eleventh N. Amer. Wildl. Conf. :168-175.

Gohren, Theodor von. 1861. Ueber eine Beigabe von Knochenerde zum Futter der Theire nebst einem physiologisch-chemischen Versuch ueber deren Verdaulichkeit. Landw. Vers. Sta., 3:161-178.

Graham, Samuel A. and Gene Hesterberg. 1948. The influence of climate on the ring-necked pheasant. Jour. Wildl. Mgt., 12: 9-14.

Greenhalgh, Clifton M. 1949. Pheasant strains vary throughout state. Utah Fish and Game Bull., 7(2):1-2.

Halbrook, E. R., Fay Cords, A. R. Winter and T. S. Sutton. 1950. Vitamin B_{12} production by microorganisms isolated from poultry house litter and droppings. Jour. Nutrition, 41:555-563.

Hawkins, Arthur S. 1937. Winter feeding at Faville Grove, 1935-1937. Jour. Wildl. Mgt., 1:62-69.

Hiatt, Robert W. 1947. The relation of pheasants to agriculture in the Yellowstone and Big Horn river valleys of Montana. Montana State Fish & Game Comm., Wildl. Restor. Div. 72 p.

Kellogg, C. E. 1951. General pattern of great soil groups. Map 2136 prepared for USDA, Soil Conservation Service, Beltsville, Maryland.

Kimball, James W. 1949. The crowing count pheasant census. Jour. Wildl. Mgt., 13:101-120.

King, Thomas R. and Harold E. McClure. 1944. Chemical composition of some American wild feedstuffs. Jour. Agric. Research, 69:33-46.

Knopf, Eleanora Bliss and Anna I. Jonas. 1929. Geology of the McCalls Ferry-Quarryville district, Pennsylvania. U. S. Geol. Surv. Bull., 799: xiii + 156.

Kozlik, Frank and Cyril Kabat. 1949. Why do pheasant populations remain low? Wisconsin Cons. Bull., 14(10):7-10.

Laskowski, Bernard R. 1941. Climate of South Dakota. In Climate and man, USDA Yrbk. Agric. :1109-1118.

Ledin, Donald H. and Gerald T. Bue. 1953. Pheasant population trends. Cons. Volunteer, 16(95):8-12.

Leedy, Daniel L. 1948. Some wildlife and land use relationships in Ohio. Ohio Jour. Sci., 48(4):151-160.

_________. 1949. Hunting statistics in the United States, 1936 vs. 1946. Trans. Fourteenth N. Amer. Wildl. Conf. :410-423.

_________ and Eugene H. Dustman. 1947. The pheasant decline and land-use trends. Trans. Twelfth N. Amer. Wildl. Conf. :479-490.

_________ and William B. Hendershot. 1947. The ring-necked pheasant and its management in Ohio. Ohio Div. Cons. & Nat. Resources, Wildl. Cons. Bull., 1:1-16.

_________ and Lawrence E. Hicks. 1945. The pheasants in Ohio. In McAtee, W. L., The ring-necked pheasant and its management in North America. Amer. Wildl. Inst. :57-130.

Leopold, Aldo. 1931. Report on a game survey of the north central states. Madison, Wisconsin :3-299.

Lewite, Maxim. 1907. Zur Frage des Zusammenhanges zwischen Wetter, Mineralstoffgehalt der Futterpflanzen und Knochenbrüchigkeit des Rindes. Landw. Inst. Leipzig Mitt., 8:69-112.

Lindstrom, Russell G., Charlie F. Petersen, A. C. Wiese and P. R. Moore. 1949. Effect on hatchability of fish meal fed to hens deficient in the unidentified hatchability factor. Poultry Sci., 28:552-555.

McCance, R. A., E. M. Widdowson and H. Lehmann. 1942. The effect of protein intake on the absorption of calcium and magnesium. Biochem. Jour., 36:686-691.

McCann, Lester J. 1939. Studies of the grit requirements of certain upland game birds. Jour. Wildl. Mgt., 3:31-41.

Marshall, William H. 1953. A survey of farm-game habitat restoration programs in fifteen states. Trans. Eighteenth N. Amer. Wildl. Conf. :390-412.

Martin, Lawrence. 1932. The physical geography of Wisconsin. Wisconsin Geol. & Nat. Hist. Surv. Bull., 36, Edu. Series 4: xxiii + 608.

Maume, L. and L. Monteil. 1938. Déficience minérale des fourrages en combraille bourbonnaise. Acad. d'Agr. de France Compt. Rend., 24:45-52.

Michigan Department of Conservation. 1950. Pheasant kill by county computed from hunters kill reports 1937-1949. Map prepared by Game Division.

Millar, C. E. 1940. Soils of Michigan. Michigan State Coll. Agric. Exp. Sta. Circ. Bull., 176:1-20.

Muckenhirn, R. J. and N. P. Dahlstrand. 1947. Soils of Wisconsin. Leaflet issued by Soil Survey Div., Wisconsin Geol. & Nat. Hist. Survey & Agric. Exp. Sta., Univ. Wisconsin.

Nelson, Bernard A. 1946. Population characteristics of South Dakota pheasants. Eighth Midwest Wildl. Conf., Columbia, Missouri (mimeo). 3 p.

Nomsen, Richard C. 1953. Unpublished map prepared for Iowa State Game Commission.

Pennsylvania Game Commission. 1949. Hunting is big business (Hunting season regulations announcement).

Petersen, C. F., A. C. Wiese, C. E. Lampman and R. V. Dahlstrom. 1950. Role of crystalline vitamin B_{12} for hatchability. Poultry Sci., 29:618-619.

Randall, Pierce E. 1940. The ecology and management of the ring-necked pheasant in Pennsylvania. Unpubl. MS thesis, Pennsylvania State Coll., Grad. School, Dept. Zool. & Entomol. 141 p.

__________ and Logan J. Bennett. 1939. Censusing ringneck pheasants in Pennsylvania. Trans. Fourth N. Amer. Wildl. Conf. :431-436.

Randoin, L., D. Hugot, J. Causeret and G. Morel. 1950. Utilisation physiologique comparée du calcium des calcaires dolomitiques et du calcium du carbonate de chaux. Bull. Soc. Chim. biol., 32: 807-814.

Rasmussen, D. Irwin and William T. McKean. 1945. The pheasant in the intermountain irrigated region. In McAtee, W. L., The ring-necked pheasant and its management in North America. Amer. Wildl. Inst. :234-253.

Rowan, W. 1948. The ten-year cycle. Dept. of Extension, Univ. Alberta, Edmonton, Alberta. 16 p.

Sharp, Ward M. and H. Elliott McClure. 1945. The pheasant in the Sandhill region of Nebraska. In McAtee, W. L., The ring-necked pheasant and its management in North America. Amer. Wildl. Inst. :203-233.

Shaw, Charles F. 1914. The soils of Pennsylvania. Pennsylvania State Coll. Agric. Exp. Sta. Bull., 132:205-242.

Shorey, Edmund C. 1940. The liming of soils. USDA, Farmers' Bull., 1845:1-26.

Smith, Guy D. 1942. Illinois loess-- variations in its properties and distribution: a pedologic interpretation. Univ. Illinois Agric. Exp. Sta. Bull., 490:139-184.

Smith, J. Russell and M. Ogden Phillips. 1942. North America, its people and the resources, development, and prospects of the continent as the home of man. Harcourt, Brace & Co. : xiii + 1016.

Sprague, Malcolm. 1941. Climate of California. In Climate and man, USDA Yrbk. Agric. :783-797.

Stephenson, E. L., J. McGinnis, W. D. Graham and J. S. Carver. 1948. Effect of soil on chick growth. Poultry Sci., 27:827-828.

Swenk, M. H. 1930. The food habits of the ring-necked pheasant in central Nebraska. Univ. Nebraska Agric. Exp. Sta. Res. Bull., 50:1-33.

Taylor, N. H. 1930. The relation of geology to sheep sickness in Mairoa District. New Zealand Jour. Sci. & Technol., 12:1-10.

Titus, Harry W. 1939. Practical nutritive requirements of poultry. In Food and life, USDA Yrbk. Agric. :787-818.

Trautman, Carl G. 1952. Pheasant food habits in South Dakota and their economic significance to agriculture. South Dakota Dept. Game, Fish & Parks, Tech. Bull., 1:1-89.

Tyler, Cyril. 1945. The porosity of egg shells, and the influence of different levels of dietary calcium upon porosity. Jour. Agric. Sci., 35:168-176.

__________. 1948. The mineral requirements and metabolism of poultry. Calcium and phosphorus. Part I. Nutrition Absts. and Reviews, 18:261-274.

Walcott, Frederic C. 1945. Historical introduction. In McAtee, W. L., The ring-necked pheasant and its management in North America. Amer. Wildl. Inst. :1-5.

Wheeler, W. P. 1919. Some studies relating to calcium metabolism. New York Agric. Exp. Sta. Bull., 468, 43 p.

Whitson, A. R. 1927. Soils of Wisconsin. Wisconsin Geol. & Nat. Hist. Surv., Bull. 68, Soil Series 49: x + 270.

Wight, Howard M. 1950. Nesting loss-- the pheasant bottleneck. Pennsylvania Game News, 20(12):10-11, 25, 28.

Yeatter, Ralph E. 1950. Effects of different preincubation temperatures on the hatchability of pheasant eggs. Science, 112: 529-530.