THE ROADSIDE CENSUS AS A METHOD OF MEASURING BIRD POPULATIONS

BY JOSEPH C. HOWELL

INTRODUCTION

THE subject of the measurement of bird populations has been extensively treated by Kendeigh (1944). Kendeigh's paper orients the roadside census in relation to other types of censuses. It has been used as a method of determining relative abundance and not absolute or true abundance. In relative abundance the number of birds reported is not the actual total number present in the area censused but an unknown proportion of the actual total, while in absolute or true abundance the number of birds reported is the total number of individuals present per unit of area (preferably given in terms of birds per 100 acres).

The roadside census is an enumeration of the birds contacted along secondary roads, usually from a moving automobile. Nice (1921) used the roadside census to study Oklahoma bird populations in 1920. Since then it has been used by a number of other workers. It has been used to study many species of birds, but usually the individual species chosen have been the more conspicuous ones. Perhaps it has been most widely used to measure population fluctuations of the Ring-necked Pheasant (Fisher, Hiatt, and Bergeson, 1947).

My objective in this study has been to measure population changes and trends in a large area. The area selected was Knox County, Tennessee. The population in an area of this size is too great to be more than sampled. It was the need for a method of securing large population samples over a large area in a limited time that led to the selection of the roadside census. The term population as used in this paper refers to the total number of individuals of both sexes and all ages (other than nestlings) occurring in Knox County.

Knox County lies within about 20 miles of the eastern boundary of Tennessee and is a little nearer to the northern than the southern boundary. Its greatest distance from east to west is about 35 miles and from north to south it is a little over 20 miles. The county has an area of 517 square miles. It lies in the Valley and Ridge Province (Fenneman, 1938), an area lying along the Tennessee River and characterized by many long parallel ridges and intervening valleys. The average elevation is a little less than 1000 feet. Seventy-two per cent of the county is in farms. Ecologically the county is about 60 per

cent within the Yellow Pine-Hardwoods general forest type and 40 per cent Upland Hardwoods.

On each census a recorder was present to make a record of the nature of each contact with a bird. This study would have been impossible without help from numerous volunteer cooperators. I am indebted to a considerable number of persons for occasional assistance, but my greatest gratitude is to my most consistent helpers, my wife Candace, Dr. C. J. Craven of the University of Tennessee Department of Physics, and Mrs. R. A. Monroe.

Dr. George E. Albert, of the University of Tennessee Department of Mathematics, carried out certain statistical treatments of the data and provided technical advice as to how the other data should be treated. Dr. James T. Tanner, of the University of Tennessee Department of Zoology and Entomology, helped in the planning of the problem and also read the manuscript critically.

Sumner A. Dow and Andrew J. Meyerriecks, students at the University of Tennessee, were largely responsible for making the absolute censuses of Areas 1 and 2.

DESIGN OF THE CENSUS

In determining relative abundance it is essential to select a unit of measurement. The three kinds of units available are divisions of time, linear distance, or area. Time was used in this study. Dice (1930) recommends that the hour be used as the time unit for measuring relative abundance. This has important advantages but was not used in this study because the samples secured during intervals of an hour were often small for statistical purposes. It was to secure larger samples that the unit adopted was a period of four hours. These four-hour periods are referred to as trips or censuses. No use is made in this study of units of time shorter than four hours.

The time of day at which each count is made has a pronounced influence on the number of birds enumerated. The hours just after sunrise and shortly before sunset are those of greatest activity. To take advantage of these two peaks in daily activity rhythm it was decided to divide the censuses evenly between mornings and afternoons. The morning censuses were scheduled to begin near sunrise, as soon as the light was strong enough to permit safe sight identifications and evening ones timed to end just before the light failed.

The number of censuses taken each month was set at ten, since that was the largest number that other responsibilities permitted. (Occasionally it was impossible to complete this many censuses and only seven each were taken during August and October, 1947, and eight

each during December, 1947, and January, 1948.) Five censuses in each month were planned for the morning and five for the afternoon.

In this study the following census method was used. An automobile was driven at speeds of five to ten miles-per-hour along secondary roads and every individual bird which was seen or heard was enumerated. At frequent intervals, often when unidentified individuals were encountered, the automobile was stopped and spot counts were made. These stops were of only a few minutes' duration in most cases, but they were important in that the sounds which were masked by the noise of the moving car could then be picked up.

A record was kept for each census on which was placed the nature of the original contact which was established with each individual. The record was kept by a helper, leaving the census taker free to count the birds and drive the car. In recording each contact with a bird a symbol was used to show whether the bird had been initially contacted through its song, its call, or through seeing it. A mimeographed form was used for the record on which were listed all of the common species of birds. The identity of some individuals could not be established, and these were recorded under the headings "unidentified" or "unidentified sparrow."

The choice of routes was made with the primary aim of securing ones that would be representative of the various areas within the county. Five routes were eventually selected which averaged about 25 miles in length and passed through the more important types of environment within the county, excepting only those of the urban and suburban areas of the city of Knoxville. Since the roads tended to follow the valleys and to avoid the ridges, roads were chosen which compensated for this ecologically undesirable situation. In selecting census routes it is necessary to avoid the heavy traffic of highways, and it is desirable to avoid roads with gravel on them for they are noisy. It is important to select roads which are passable at all times and under adverse weather conditions.

In order that a continuing series of roadside censuses may be comparable it is essential that they be as uniform as possible. The individual birds observed by the census taker should be the only ones recorded. The perfect record keeper would take no action that would influence the observer. Binoculars should always be used.

Ideally, censuses should be taken in such a manner that as many factors as possible between groups of censuses will be equal. If they are equal they may be cancelled out since they have the same affect on each group. These censuses were planned to cancel out many such factors. No comparisons are based on units that are smaller than a

month. During each month throughout the year the same five routes were censused, which cancelled out differences in habitat. The lengths of the trips were strictly equal in time and equal, or almost so, in miles travelled. It was assumed that certain inequalities cancelled out during each month. For example, no corrections were applied to compensate for differences in temperature or the amount of wind, precipitation, and sunshine. Personal efficiency and mechanical interference from the automobile were treated as constants.

RELATIVE ABUNDANCE OF INDIVIDUAL SPECIES

The first roadside census of this study was taken on July 13, 1947. Between that date and the end of September, 1947, a total of 15 censuses was completed. On the basis of the experience thus gained certain changes were made in the method of taking censuses. A new series was begun in October, 1947, and was carried through a full year.

Two important characteristics of the data secured from these censuses deserve special mention. The counts obtained from roadside censuses are not directly comparable between species, nor are they comparable for the same species from one season to another. The underlying factors which are responsible for both of these characteristics are many, but they possess one thing in common; they affect the conspicuousness of the birds counted.

Of the many factors which affect the conspicuousness of species the physical characteristics of size, color, and form are important. Of great influence also is the behavior of a species—the duration and frequency of its songs and calls, reproductive pattern, feeding habits, flocking habits, flight characteristics, and wariness. In the case of certain species the environment is the most important single factor affecting conspicuousness. These factors and complexes of factors vary widely from species to species in their importance and most of them vary also with the different seasons.

If it were not for these differences in conspicuousness, it would be possible to count the individuals of each species observed in a certain area and use the totals for the various species to indicate directly their relative abundance. For example, if Killdeers and Meadowlarks are equally conspicuous, then the number of each which we observe while driving along a mile of road on say a morning in late August will correctly reflect their relative abundance. Suppose we count 10 Killdeer and 20 Meadowlarks; then we can accurately state that Meadowlarks are twice as abundant as Killdeer.

Actual examples of species having equal conspicuousness must be relatively unusual. Certain species are many times as conspicuous as

others. If during our drive along the road mentioned above we had observed two Grasshopper Sparrows, we would hardly have been justified in concluding that Meadowlarks were ten times, and Killdeer five times, as abundant as Grasshopper Sparrows. At this season Grasshopper Sparrows are extremely inconspicuous from roads since they have ceased singing and they remain on the ground concealed by the cover which they inhabit. In order to compare the relative abundance of the Grasshopper Sparrow with that of the two more conspicuous species, some allowance must be made for the difference in conspicuousness.

These differences in conspicuousness stand squarely in the path of comparisons between the relative abundance of different species. A number of ornithologists have attempted to weigh these factors of conspicuousness and assign them a definite value known as an index or coefficient of conspicuousness. In conspicuous birds a low value for conspicuousness is assigned, while species which are difficult to find are given high ratings. By the proper application of the conspicuousness ratings the differences in conspicuousness between species are compensated. Colquhoun (1940) equates differences in conspicuousness by means of a coefficient of conspicuousness derived by dividing the number of individuals per acre (determined by an absolute census) by the number of birds actually observed per hour.

The writer used a modification of the Colquhoun method to secure percentages, instead of coefficients, of conspicuousness for two areas in Knox County. The method used was to determine the absolute population (through breeding bird censuses) of a strip extending along 3000 feet of road and back from the road on each side to a distance of 500 feet. Following this, four roadside censuses of four hours each were taken by driving back and forth along these 3000 feet of road. The percentages of conspicuousness for each species were secured in the following manner. The total number of individuals which would have been seen, if every individual of each species known to be within the census strip had actually been encountered on each run along the 3000 feet of road, was determined by multiplying the number of runs made by the known population of the census strip. The total number of individuals of each species actually contacted on all four trips was then divided by this calculated total. The figures thus obtained are the percentages of the absolute population of each species which were found by this set of four roadside censuses. They are a measurement of the conspicuousness of each species, and they are also a measurement of the degree of efficiency of the roadside census for each species.

Two areas were studied in this manner. Area 1 was largely in yellow pines and hardwoods, but had some open areas along the road. It was censused on May 22, 26, 29, and 30, 1949. Area 2 was in farm land which was used for pasture and for the production of hay, corn, oats, and lespedeza. Some of the oat fields had been cut before the roadside censuses were taken. Area 2 was censused on July 28, 30, 31, and August 2, 1949. In both areas roadside censuses were begun just before the absolute censuses were completed, and were finished a few days after the completion of the absolute censuses.

Table 1 contains the data for the species which are thought to be fairly represented. Many species are omitted since they do not remain in their nesting territories to feed, or their territories are so large that they cannot be censused on the small scale of this study. Among the species omitted are the following: Turkey Vulture; Black Vulture, *Coragyps atratus;* Cooper's Hawk, *Accipiter cooperii;* Broad-winged Hawk, *Buteo platypterus;* Sparrow Hawk, *Falco sparverius;* Chimney Swift; Barn Swallow, *Hirundo rustica;* Purple Martin; Common Crow; Starling; and English Sparrow. Some species are omitted since they had ceased to hold territories during the times at which the two studies were made and were feeding or caring for their broods at points outside of their territories.

The number of individuals of each species assigned to each area was determined as follows. A map was made of the territory of each pair of birds. If the territory lay entirely within the study area, two individuals were credited to the proper species. If half of the territory lay within the study area, only one individual was assigned to the species. In some cases fractions of individuals were assigned to a species if only a part of a territory lay within a study area. Where young were known to be present and out of the nest they were included in the total for the species. It was assumed that singing males were mated or that there were an equal number of unmated females.

The percentages of conspicuousness are valuable in proportion to the amount of data on which they are based. No percentages of conspicuousness are given for species represented by fewer than four individuals. In each area the roadside censuses were completed in a period of less than a week. They should be representative of the species for that time and place, but if the time or place is changed it is certain that the percentages of conspicuousness will also change. At different stages in the life history of a species its percentage of conspicuousness will change. Thus only a series of such percentages covering many habitats over a specific interval of time can give really representative values for differences in conspicuousness.

TABLE 1

PERCENTAGES OF CONSPICUOUSNESS AND AVERAGE CONTACT DISTANCES OF CERTAIN BIRDS AS DETERMINED BY ROADSIDE CENSUSES OF AREAS HAVING A KNOWN POPULATION

SPECIES	AREA 1		AREA 2		SPECIES	AREA 1		AREA 2	
	Percentages of Conspicuousness	*Average Distances in feet*	*Percentages of Conspicuousness*	*Average Distances in feet*		*Percentages of Conspicuousness*	*Average Distances in feet*	*Percentages of Conspicuousness*	*Average Distances in feet*
Turkey Vulture *Cathartes aura*	X*	X	X	1550	Blue-gray Gnatcatcher *Polioptila caerulea*	10	150	X	X
Bobwhite *Colinus virginianus*	X	X	12	700	Loggerhead Shrike *Lanius ludovicianus*	X	X	24	200
Killdeer *Charadrius vociferus*	X	X	X	800	Starling *Sturnus vulgaris*	X	X	X	350
Mourning Dove *Zenaidura macroura*	X	X	X	350	White-eyed Vireo *Vireo griseus*	5	250	X	X
Yellow-billed Cuckoo *Coccyzus americanus*	7	400	X	X	Red-eyed Vireo *Vireo olivaceus*	10	350	X	X
Chimney Swift *Chaetura pelagica*	X	550	X	650	Kentucky Warbler *Oporornis formosus*	9	300	X	X
Pileated Woodpecker *Dryocopus pileatus*	X	600	X	X	Yellow-throat *Geothlypis trichas*	8	200	X	X
Phoebe *Sayornis phoebe*	X	200	X	X	Chat *Icteria virens*	13	250	X	X
Wood Pewee *Contopus virens*	X	X	X	800	Hooded Warbler *Wilsonia citrina*	6	250	X	X
Purple Martin *Progne subis*	X	650	X	650	English Sparrow *Passer domesticus*	X	X	X	400
Blue Jay *Cyanocitta cristata*	X	350	X	X	Eastern Meadowlark *Sturnella magna*	X	X	15	350
Crow *Corvus brachyrhynchos*	X	650	X	1000	Red-winged Blackbird *Agelaius phoeniceus*	X	X	11	450
Carolina Chickadee *Parus carolinensis*	13	100	X	X	Summer Tanager *Piranga rubra*	28	250	X	X
Tufted Titmouse *Parus bicolor*	3	X	X	X	Cardinal *Richmondena cardinalis*	14	200	X	650
Carolina Wren *Thryothorus ludovicianus*	9	300	X	700	Indigo Bunting *Passerina cyanea*	12	200	24	350
Mockingbird *Mimus polyglottos*	X	X	19	200	Eastern Goldfinch *Spinus tristis*	X	X	17	300
Brown Thrasher *Toxostoma rufum*	X	X	1	X	Red-eyed Towhee *Pipilo erythrophthalmus*	14	250	X	X
Robin *Turdus migratorius*	10	350	X	X	Grasshopper Sparrow *Ammodramus savannarum*	X	X	10	250
Wood Thrush *Hylocichla mustelina*	3	X	X	X	Field Sparrow *Spizella pusilla*	5	250	10	550
Bluebird *Sialia sialis*	X	X	X	350	Song Sparrow *Melospiza melodia*	X	X	20	400

* X indicates that the available data are too limited to justify the use of a definite figure.

Considering only the species in Area 1 the percentages of conspicuousness range from 3 to 28. The extreme percentages show that the Summer Tanager is more than nine times as conspicuous as the Wood Thrush. At this time the males of the two pairs of Wood Thrushes had virtually stopped singing and presumably had small young in their respective nests. Since neither pair ranged regularly across the road, they remained hidden in the woods on either side of the road. The male Summer Tanagers (there were three), on the other hand, were singing frequently and loudly. Individuals of both sexes scolded at most of the stops. The thrushes were never seen in or flying through the tops of the large trees, whereas the tanagers were usually there and hence easier to contact.

The mean percentage of conspicuousness for the 18 species of Area 1 which were represented by four or more individuals was 10. The Summer Tanager is in a class by itself since its percentage of conspicuousness is twice that of the two next ranking species, the Cardinal and the Towhee. From these percentages it is apparent that in a wooded area it is common for one species to be twice as conspicuous as another. If the two species with the lowest percentage of conspicuousness are omitted, then it is evident that very few species are three times as conspicuous as any others. In the farm lands of Area 2 the range of percentages of conspicuousness is greater than it was in Area 1. Both the Loggerhead Shrike and the Indigo Bunting are 24 times as conspicuous as is the Brown Thrasher. At the time of the year when this set of censuses was taken the Thrasher has ceased singing entirely and rarely leaves the shelter of the thickets or hedgerows, making it a very difficult species to locate. The mean percentage of conspicuousness for the 11 species on Area 2, included in Table 1, is 15.

The effect which percentages of conspicuousness have when they are applied to the observed population indices of various species is shown in Table 2. The population index as used in this study is simply the average number of individuals of a species observed during the censuses taken during a particular time interval. Thus in June, 1949, there was a total of ten censuses taken during which 283 Bluebirds were observed, giving a population index of 28.3.

The population indices in Table 2 are those for the month of May, or June, 1948. The figures for the Cuckoo, Chickadee, Gnatcatcher, Chat, and Bunting are for June, since these population indices are more accurately representative of these species for the period in late May, during which were taken the roadside censuses from which the percentages of conspicuousness were derived, than are the May figures. For example, during early May many Indigo Buntings have not yet

reached this area in their spring migration and others have not yet begun to sing; thus the population index for the entire month of May is lower than it would be for late May. The June figures, like those of late May, sample the population after the completion of the spring migration and after most males have begun to sing. The population

TABLE 2

RELATIVE ABUNDANCE OF CERTAIN BIRDS IN MAY OR JUNE, 1948, IN KNOX COUNTY, TENNESSEE, AS DETERMINED BY ROADSIDE CENSUSES, AND FOLLOWING ADJUSTMENT FOR DIFFERENCES IN CONSPICUOUSNESS

Species	*Observed*		*Adjusted*	
	Rank	*Index*	*Index*	*Rank*
Yellow-billed Cuckoo	13	3.5	5	12
Carolina Chickadee	7	16.3	13	9
Carolina Wren	9	14.3	16	6
Robin	4	34.1	34	3
Blue-gray Gnatcatcher	12	5.9	6	11
Red-eyed Vireo	8	14.8	15	7
Kentucky Warbler	14	1.6	2	14
Yellow-throat	5	20.0	25	5
Chat	10	11.8	9	10
Hooded Warbler	15	0.6	1	15
Summer Tanager	11	11.0	4	13
Cardinal	2	40.8	29	4
Indigo Bunting	1	64.6	54	2
Red-eyed Towhee	6	19.7	14	8
Field Sparrow	3	40.3	81	1

indices for the other species are for May. Each population index has been adjusted for differences in conspicuousness by dividing it by the percentage of conspicuousness for that species. The percentages of conspicuousness used are those found in Table 1 under Area 1. To make comparisons between species easier the decimal point has been moved one place to the right in the adjusted index, and the nearest whole number so produced has been used. The rank of each species is given before and after adjustment for differences in conspicuousness.

Another method of adjusting differences in conspicuousness among various species of birds is described by Kendeigh (1944). This method rests on the assumption that the conspicuousness of a species is directly proportional to the average distance at which an observer becomes aware of the individuals of that species. Each of the average contact distances appearing in Table 1 is the average distance of a number of contacts with individuals of a particular species in which the distance between the observer and the individual was estimated. The presence of numerous markers at distances of 250 and 500 feet from the road helped greatly in obtaining reasonably accurate estimates. The average distances have been rounded off to the nearest

multiple of 50 feet; 50 feet was the limit of accuracy used in making estimates. Table 1 includes a number of these average contact distances; it also includes percentages of conspicuousness for some of the same species. It should be expected that birds with long average contact distances would also have high percentages of conspicuousness since both of these are used as measurements of conspicuousness. However, such is not the case. For example, the Yellow-billed Cuckoo has an average contact distance of 400 feet and a percentage of conspicuousness of 7, whereas for the Carolina Chickadee the average contact distance is only 100 feet, but the percentage of conspicuousness is 13. By one method the Cuckoo is four times as conspicuous as the Chickadee, but by the other method the Chickadee is almost twice as conspicuous as the Cuckoo.

No means was found by which to resolve the differences between the two methods. The field observations on which Kendeigh based his method were carried out during the winter. At this season the factors affecting conspicuousness have entirely different values than they do during the summer. For example, in winter, song and the screening effect of vegetation are much less important than during summer.

It is possible that the two methods may be complementary, the percentage-of-conspicuousness method being indicated during the breeding season and the average-contact-distance method being applicable during the remainder of the year. Thus a method of equating differences in conspicuousness would be available at all seasons.

MONTHLY CHANGES IN ABUNDANCE OF INDIVIDUAL SPECIES

There are population changes occurring during all units of time for most species in an area as large as Knox County. The roadside census should be used to measure only the changes occurring during units of time which are sufficient to permit sampling areas which are large enough to be representative. How large such areas should be can scarcely be objectively determined, and they will usually be dictated by such practical considerations as available personnel, time, and funds. For this study it was impractical to secure the data necessary for determining population changes for time units smaller than months. The individual roadside censuses within any month are not comparable since they differ in either the route taken or the time of day. For each month, however, there is a set of ten censuses which are matched as nearly as possible with sets taken during the other months of this study.

In comparing the numbers observed for a particular species in different months it is well to remember that the numbers observed

may reflect differences other than true population changes. This is particularly true with seasonal changes in conspicuousness. These differences have already been discussed.

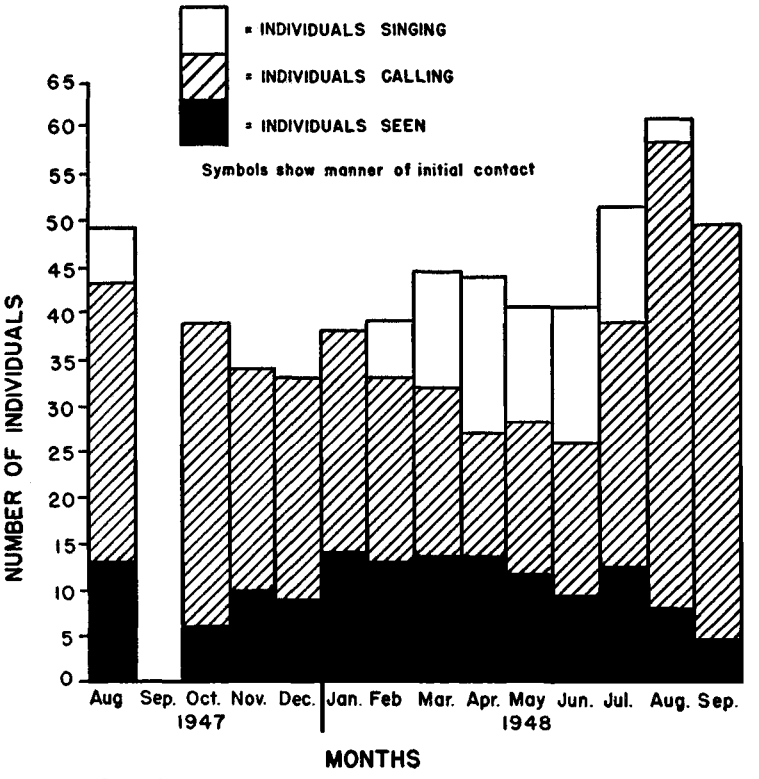

FIGURE 1.—Monthly changes in populations of the Cardinal as determined by a series of roadside censuses.

Figure 1 is a histogram of the monthly population changes of the Cardinal as observed during roadside censuses. Since the species is not migratory, this factor may be ruled out. The population of the Cardinal may be expected to reach a peak during the breeding season and then to fall without interruption until the following breeding season. An examination of the histogram does not show this to be the case. It will be seen that the observed population does drop during October, November, and December, but rises in January. This rise is probably due to some unusually large counts in January, as is indicated by the statistical analysis presented later. In February the observed population rose again. However, a new factor is introduced in February, for the Cardinal begins singing. Prior to February the

individual Cardinals counted were either seen or heard calling. To place the February observed population counts on the same basis as those of the fall and winter, those birds initially found through their songs during February must be omitted. When this is done,

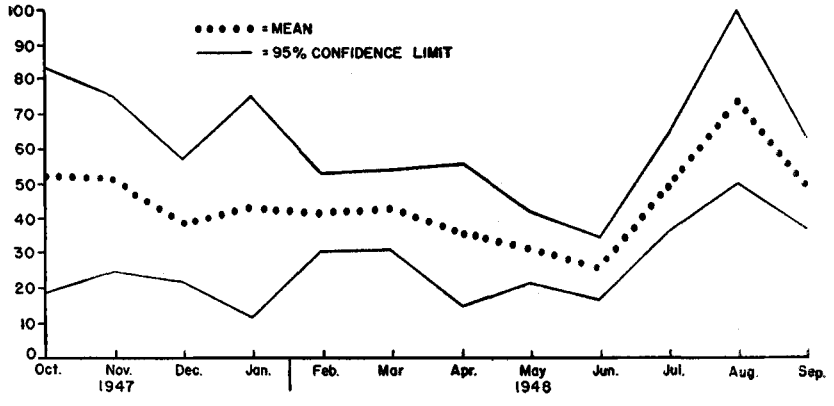

FIGURE 2.—Mean observed monthly populations of the Cardinal as determined by a series of morning roadside censuses.

we find there is an observed population drop as would be expected. In subsequent months also, the individual Cardinals contacted initially through song were omitted in determining the observed population changes.

If the Cardinal data for each month (omitting the individuals initially found through hearing them sing) are treated statistically, the range within which the actual mean lies for such a series of censuses can be determined within certain limits of accuracy. It is essential

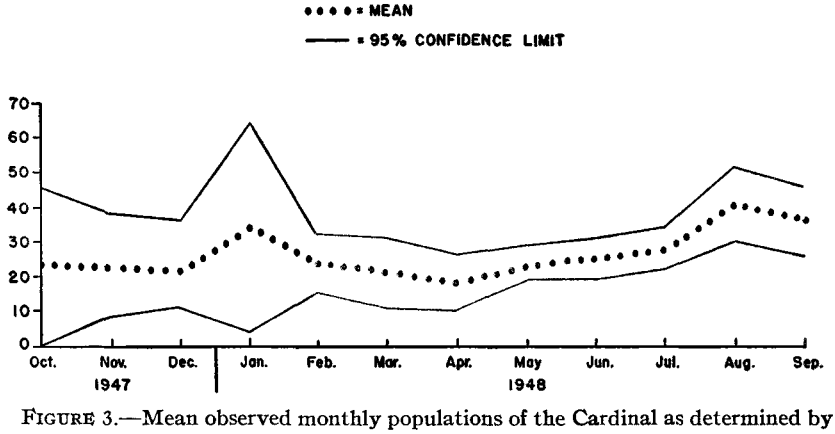

FIGURE 3.—Mean observed monthly populations of the Cardinal as determined by a series of afternoon roadside censuses.

that the morning and afternoon counts be treated separately for, as will be shown later, the morning counts average significantly higher.

In Figure 2 are shown the monthly averages for the censuses taken in the morning. The 95 per cent confidence limits indicate that in 19 of 20 cases it may be expected that the true mean of the population of

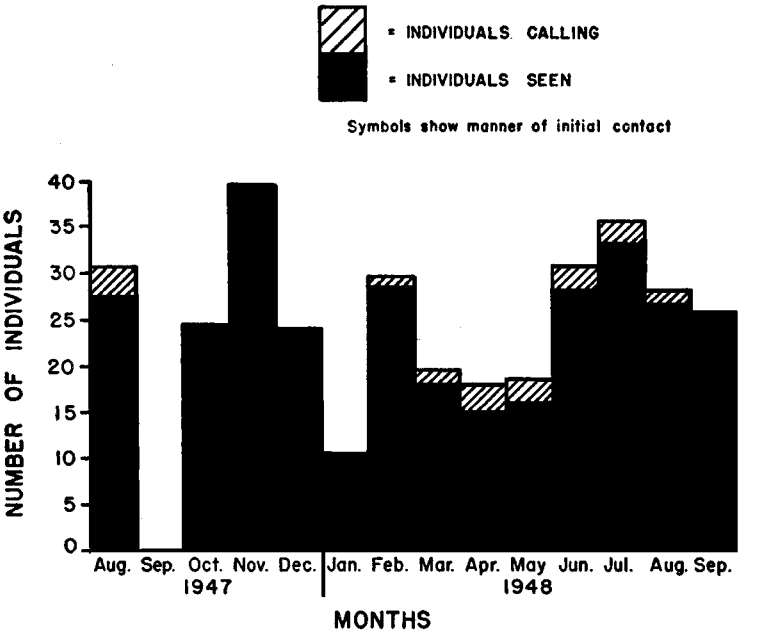

FIGURE 4.—Monthly changes in populations of the Mourning Dove as determined by a series of roadside censuses.

Cardinals sampled falls between the values shown. The population trend is downward for the period from October to June, but in no month has a statistically significant change taken place. However, it can be seen that in July there was a significant increase in population. The afternoon data shown in Figure 3 indicated that no significant monthly population changes took place.

From the fact that a mathematically significant change in numbers took place in only one month it is apparent that the roadside census, as used in this study, is not sufficiently refined to reflect monthly population changes with statistical significance.

On the assumption that the Cardinal might be a species which was unusual in its monthly population changes, a number of other species were studied in the same manner. The Cardinal showed the least month-to-month variation of any of the species studied.

While this type of census is such that the findings do not have statistical significance for *monthly* population changes, some of the findings do provide suggestive and tentative answers to local problems in the midwinter status of certain species. For example, the data on the Mourning Dove indicate that there are fall (November) and late

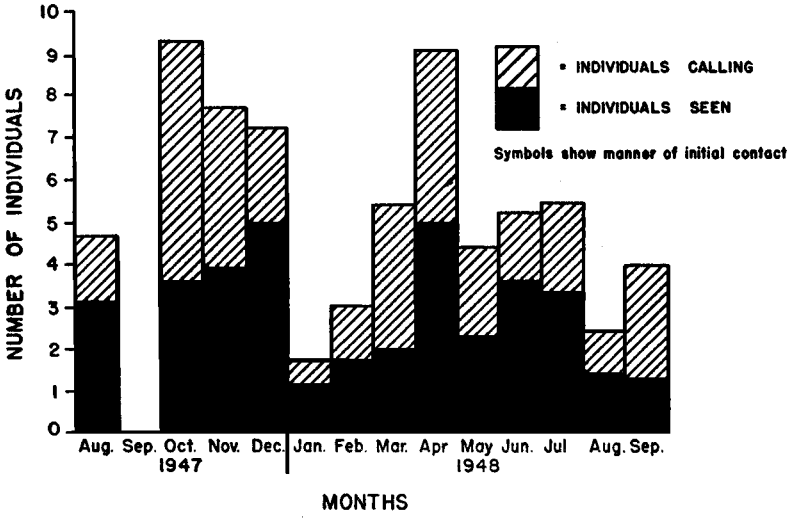

FIGURE 5.—Monthly changes in populations of the Flicker as determined by a series of roadside censuses.

winter (February) population peaks separated by a midwinter (January) low (Fig. 4). These data are those to be expected for species which are more numerous as migrants than as winter residents.

The winter status of the following species is also problematic. The data on the Flicker, *Colaptes auratus* (Fig. 5) show the same population picture as that for the Mourning Dove. For the Blue Jay (Fig. 6) the same may be true, although the spring population peak is a low one. The Bluebird (Fig. 7) has similar population changes. The status of the Crow (Fig. 8) is better known, but the data do provide some indication of the proportion of migrant and resident individuals.

The monthly changes in total bird population as reflected in this roadside census (Fig. 9) point to a greater population of individuals during the late fall months than at any other season. It is of interest to note that there are more birds present in the winter than in the summer. This may be more apparent than real. Yet it is during the winter that the Starling is present in greatest numbers; in fact, half of all the individuals seen during November and on through February were Starlings.

The monthly changes in the number of species observed in this area (Fig. 9) are independent of the monthly changes in the number of individuals observed. These changes are quite regular and show nothing of an unexpected nature.

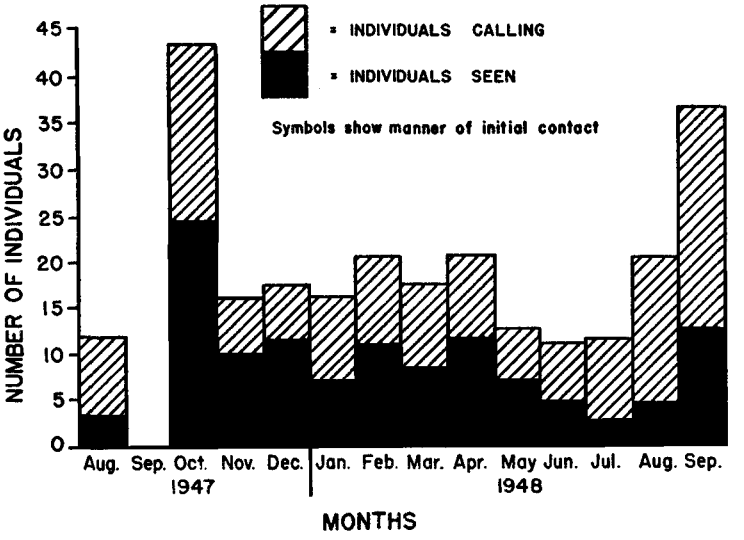

FIGURE 6.—Monthly changes in populations of the Blue Jay as determined by a series of roadside censuses.

ANNUAL CHANGES IN ABUNDANCE

The roadside census may be used to measure population changes from year to year. The design of this set of censuses is well suited to the making of comparisons between different years, or between the same seasons of different years. It is possible to match the censuses of the past very closely when carrying out a new set of censuses.

During the summer of 1949 a series of roadside censuses was taken to secure data on population changes between the summers of 1948 and 1949. Ten censuses were taken in each of the months of June, July, and August, 1948. In 1949 a comparable series of censuses was taken. The 1949 series was matched with that of 1948 in such a way that each census for 1949 was paired with one in 1948 as to the route taken, the time of the month, and the hours of the day. Thus in each summer the total of the hours spent in the field was 120. The sample of birds counted in the summer of 1948 was 32,426 and in 1949 it was 34,830. During both summers over a thousand birds were counted on the average census.

The population level for each species for each month is shown by means of population indices. The population index for each species was secured by simply taking the average number seen per census during a particular month.

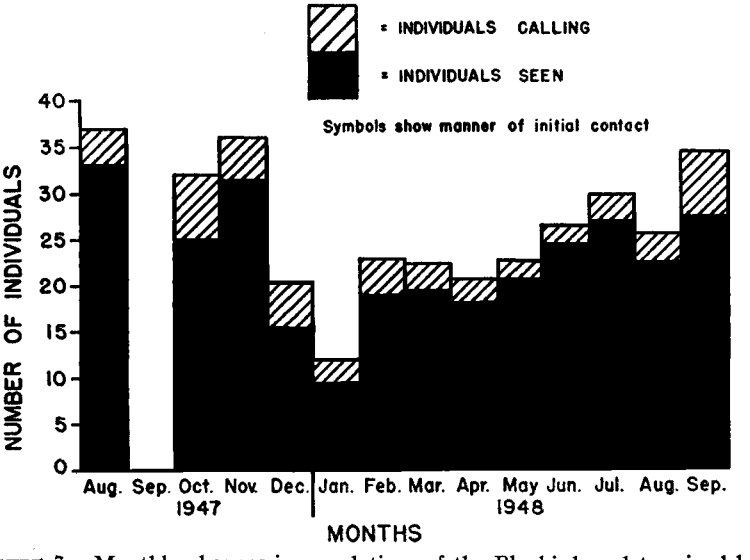

FIGURE 7.—Monthly changes in populations of the Bluebird as determined by a series of roadside censuses.

Such population indices have a complex and changing relationship to the real or absolute population of a species. It is certain that changes in conspicuousness play an important part in this relationship. In this comparison where the individual censuses are matched, it is thought that adequate allowance is made for the major factors of conspicuousness influencing the population indices and that the changes observed between the two summer seasons reflect true fluctuations in population levels. It is assumed, for example, that the factors affecting the availability of the Cardinal to censusing on a morning in early June along a particular route would be the same in 1948 and in 1949. This might not be true if the two seasons were unlike in terms of earliness or lateness.

Determination of the earliness or lateness of a particular season may be done in many ways. In this study the method used was to compare the times at which the volume of song of the various species began to drop. Since the volume of song reflects the stage in the reproductive cycle of many species (particularly at the summer season since few species sing as they molt), it may be used as an index to the earliness or

lateness of the season. The actual system used was to compare the percentages of original contacts which were made through singing birds for the same periods in the same seasons of the two years being compared. For example, 66 per cent of the original contacts estab-

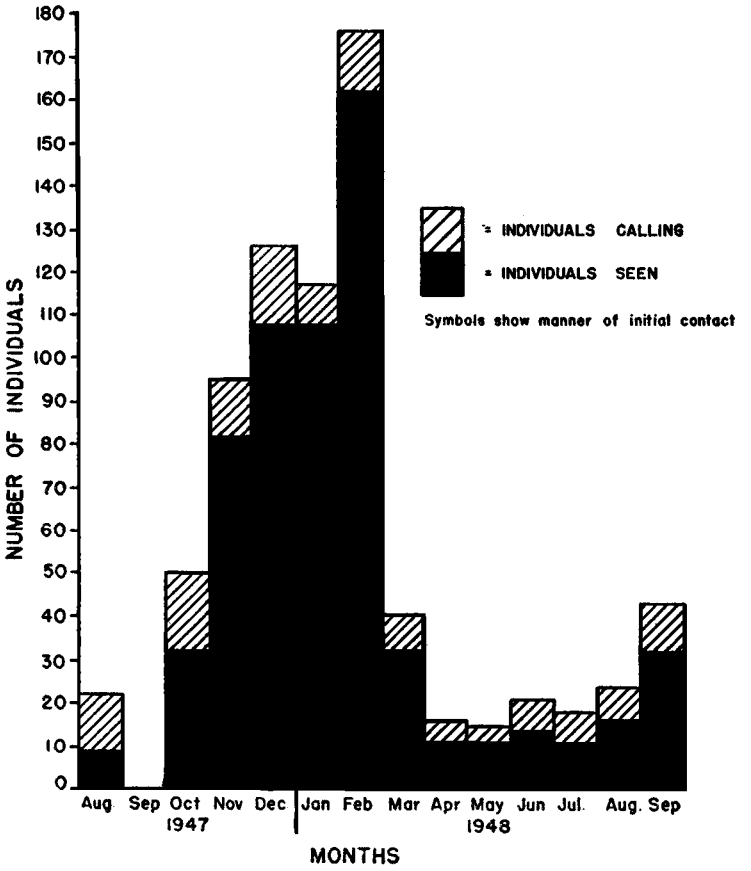

FIGURE 8.—Monthly changes in populations of the Crow as determined by a series of roadside censuses.

lished with Indigo Buntings during four censuses in early July of 1948 were made with singing males. For a matched set of censuses for 1949 the percentage was 76. For a similar set of censuses taken in mid-August of 1948, 15 per cent of the original contacts were with singing males, and 13 per cent were with singing males in 1949. These figures indicate that about the same percentage of birds was at the same stage in the reproductive cycle at the same calendar dates during the two seasons. Therefore, in comparing the summer seasons of

1948 and 1949 no allowance needs to be made for the relative earliness and lateness of the two seasons.

In presenting the data secured for the two summers the monthly levels of total population are shown first. Table 3 presents the total number of individuals seen during the months of June, July, and

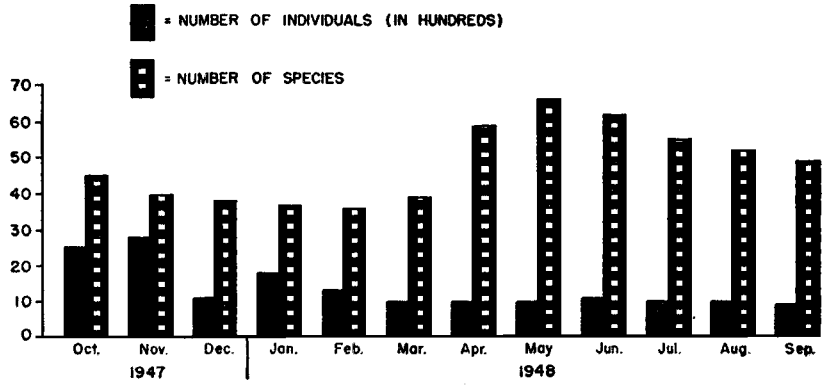

FIGURE 9.—Monthly means of the number of individuals and the number of species observed during a series of roadside censuses.

August for 1948 and 1949. While there was an increase in each of the summer months of 1949 over those of 1948, the increases are relatively small. In terms of percentage the total population for the summer of 1949 was about 7.5 per cent greater than in 1948. This increase in total population is not statistically significant.

TABLE 3

POPULATION INDICES FOR TOTAL POPULATION OF ALL BIRDS IN KNOX COUNTY, TENNESSEE

	June	*July*	*Aug.*	*Average*	*Change*
1948	11,275	10,605	10,546	10,809	
1949	11,574	11,858	11,399	11,610	+801

Table 4 contains the monthly population indices for the 24 species of birds which were the most common during the two summers under consideration. The column headed *Avr.* presents the average number of individuals (average of population indices) seen during each of the 30 trips taken during each of the two summers. The column headed *Chg.* lists the difference in the population index of 1949 from that of 1948 for each species. For example, on the average trip in the summer of 1948 there were 155 Starlings seen, whereas in the summer of 1949 there were 172 Starlings seen. The change therefore

TABLE 4

POPULATION INDICES FOR SOME COMMON BIRDS OF KNOX COUNTY, TENNESSEE

Species	*Year*	*June*	*July*	*Aug.*	*Avr.*	*Chg.*	*Sig.*	*Pct.*
Starling	1948	107	111	247	155			
Sturnus vulgaris	1949	126	129	262	172	+17	NS*	+11
English Sparrow	1948	76	71	83	77			
Passer domesticus	1949	81	102	77	87	+10	NS	+13
Field Sparrow	1948	54	58	57	56			
Spizella pusilla	1949	52	60	56	56	0	NS	0
Indigo Bunting	1948	65	65	35	55			
Passerina cyanea	1949	62	66	32	53	−2	NS	−4
Purple Martin	1948	20	42	83	48			
Progne subis	1949	14	88	77	59	+11	NS	+23
Cardinal	1948	41	52	61	51			
Richmondena cardinalis	1949	47	47	59	51	0	NS	0
Mockingbird	1948	46	39	29	38			
Mimus polyglottos	1949	62	56	35	51	+13	±4.6	+34
Mourning Dove	1948	31	36	28	32			
Zenaidura macroura	1949	35	46	51	44	+12	±10.9	+38
Chipping Sparrow	1948	39	35	27	34			
Spizella passerina	1949	39	32	24	32	−2	NS	−6
Song Sparrow	1948	46	36	10	31			
Melospiza melodia	1949	44	43	15	34	+3	NS	+10
Chimney Swift	1948	36	32	20	29			
Chaetura pelagica	1949	31	36	31	33	+4	NS	+14
Eastern Bluebird	1948	26	30	26	27			
Sialia sialis	1949	28	30	40	33	+6	NS	+22
Robin	1948	41	34	15	30			
Turdus migratorius	1949	38	21	13	24	−6	NS	−20
Red-eyed Towhee	1948	26	28	11	22			
Pipilo erythrophthalmus	1949	27	29	13	23	+1	NS	+4
Crow	1948	21	18	25	21			
Corvus brachyrhynchos	1949	24	16	29	23	+2	NS	+10
Cowbird	1948	10	14	47	27			
Molothrus ater	1949	9	18	31	19	−8	NS	−30
Yellow-throat	1948	26	28	6	20			
Geothlypis trichas	1949	23	27	7	19	−1	NS	−5
Carolina Wren	1948	13	16	21	17			
Thryothorus ludovicianus	1949	15	24	26	22	+5	±2.7	+29
Purple Grackle	1948	31	15	13	20			
Quiscalus quiscula	1949	34	6	15	18	−2	NS	−10

TABLE 4—(*Continued*)

Species	*Year*	*June*	*July*	*Aug.*	*Avr.*	*Chg.*	*Sig.*	*Pct.*
Eastern Meadowlark	1948	29	18	5	17			
Sturnella magna	1949	31	20	10	20	+3	NS	+18
Red-winged Blackbird	1948	22	11	(5)†	17			
Agelaius phoeniceus	1949	26	16	(25)†	21	+4	NS	+24
Carolina Chickadee	1948	16	18	22	19			
Parus carolinensis	1949	16	17	15	16	−3	NS	−16
Blue Jay	1948	11	12	21	15			
Cyanocitta cristata	1949	12	17	22	17	+2	NS	+13
Wood Thrush	1948	17	18	(1)†	18			
Hylocichla mustelina	1949	13	11	(1)†	12	−6	±4.1	−33

* NS indicates that the change was not significant statistically.

† The figures in parentheses were not used in determining the statistical significance.

is listed as + 17 for the year 1949. In the next to the last column headed *Sig.* is indicated whether or not the change for each species is statistically significant. The "Student's t" test (Snedecor, 1938) was used to determine the statistical significance at the five per cent level. For those species which showed a significant change the 95 per cent confidence limits of the change are shown. The final column headed *Pct.* shows the percentage of the change. The percentage of change was obtained by dividing the amount of change (*e. g.* + 17 for the Starling) by the 1948 average number of individuals seen (155 for the Starling). The monthly averages (population indices) for the month of August are not used for the Red-winged Blackbird and the Wood Thrush. In the case of the Blackbird an unusual sample (census count) made the 1949 data unusable. The Wood Thrush figures for August of the two years are comparable, but the species is so retiring (unavailable to censusing) in that month that the figures are radically different from those of June and July and should not be treated statistically with them.

The results indicate that among the common species studied none experienced a truly large fluctuation in population. Considered in terms of percentage of change from the 1948 population, no species underwent a change in population of 50 per cent. The greatest change in population level is the 38 per cent shown by the Mourning Dove. The average population change for these 24 species was 16 per cent. Those population changes which were statistically significant were all close to, or greater than, 30 per cent.

Of the four species which underwent statistically significant changes between the summer of 1948 and that of 1949, two, the Mockingbird and the Carolina Wren, are species which frequently suffer heavy

mortality during severe winters such as that of 1947–1948. The relatively mild winter of 1948–1949 very likely was responsible to a considerable extent for the population rise recorded during the summer of 1949. It seems probable that the same hypothesis would apply in the case of the Mourning Dove. The Wood Thrush, however, since it winters south of the United States, must have suffered population losses during either its migration or its winter residence. It is the only species to show a statistically significant decline in population.

The population changes of certain of the species which did not undergo changes of statistical significance are of interest. Those of the six native fringillids are of interest since they are so slight. Not one of them underwent a population change which was as great, in terms of percentage, as the average for the entire group of 24 species. The average change for the six is about four per cent. The average for the three turdids is 25 per cent, and for the four icterids it is 20.

A study of the monthly population indices in Table 4 shows that there is great variation among the different species in the adequacy of the sample taken. If the trends for each season are similar, it seems reasonable to assume that the sample was adequate. For example, the population of the Starling showed an increase in each summer month in both 1948 and 1949. Also the population index is greater for each month of 1949 than for the corresponding month of 1948. There are no obvious inconsistencies in the samples for this species.

In contrast to the regularity of the samples of the Starling population are the samples taken of the Red-winged Blackbird population. During June and July of the two years the samples are uniform enough in the trend shown for the two years, but the August samples are obviously not in keeping with trends established during June and July. An examination of the individual censuses taken in August makes it clear that the August data are not comparable with those of the earlier months. In August this species is no longer scattered widely among the many wet meadows in which it nested during June and July, but has left these marshy areas for corn fields and other farm lands. Not only does this species change its habitat preference, but it changes its social habits as well to form units which are larger than its relatively small nesting colonies. As a consequence of this organization into flocks of considerable size, it happened that more individuals were observed during one census in August, 1949, than on all of the other censuses of that month and all of those of August, 1948, as well.

Other species which form large flocks that are widely scattered present the same problem. The true population level of the English

Sparrow and of the Purple Martin is masked by their flocking habits. Neither species shows a consistent trend when the monthly population indices are compared. Such species are a special problem. A possible solution might lie in simply prolonging the individual censuses to the extent necessary to insure encountering at least one such large flock on each census. In this connection it is interesting to note that the censuses of the Starling seem quite satisfactory despite the fact that they are similar in their flocking habits. The difference would seem to lie in the fact that there are more flocks of Starlings, and therefore the possibility of overlooking the species entirely is less.

COMPARISON OF MORNING AND AFTERNOON DATA

A by-product of this study was a set of data permitting a comparison of the number of birds seen during the morning censuses with the number seen during the afternoon censuses. The morning censuses were begun as soon as the light was strong enough to permit identification, and the afternoon censuses ended when the light intensity was about the same as that at which the morning censuses were started. Thus the morning and afternoon censuses were matched as to light intensity.

Fifty-five morning censuses taken throughout the year were compared with the same number of afternoon censuses. Each morning census was paired with the afternoon census of the closest date. The routes censused were the same ones in both the morning and afternoon. The difference between the two groups of censuses proved to be statistically significant at the one per cent level. A total of 142,737 individuals was counted during these 110 censuses. Of these 88,302, or 61.8 per cent, were seen during the morning. The morning is, therefore, the better time during which to secure large samples of a bird population.

A check was made to determine whether or not there were any species of birds which were more available to censusing during the afternoon than during the morning. Only one such species was found. The Nighthawk, *Chordeiles minor*, censuses were consistently higher during the afternoons than during the mornings. A number of species were as likely to be found in the afternoon as in the morning.

SUMMARY

1. Relative abundance of individual species was found to differ from absolute abundance chiefly because of differences in conspicuousness.

2. Differences in conspicuousness were measured by determining the percentage of the known absolute population of a species in a certain area which was noted during a set of roadside censuses.

3. These percentages of conspicuousness ranged from 1 to 28.

4. Percentages of conspicuousness were secured only for species which maintained relatively small territories.

5. Percentages of conspicuousness vary with the season of the year, the habitat, and certain other factors.

6. Use of percentages of conspicuousness to adjust interspecific differences in conspicuousness is shown to affect greatly the ranking of species in order of abundance.

7. Monthly changes in population as observed during a set of roadside censuses are shown for the Cardinal in Figure 1; only during the month of July did a statistically significant change occur.

8. Data from roadside censuses are used to show graphically that the Mourning Dove, Flicker, Blue Jay, and Bluebird, while considered resident species, have higher populations during periods of migration than during mid-winter.

9. Data from roadside censuses are used to show graphically the monthly population changes of the Crow, thus providing an indication of the relative sizes of the wintering and resident populations.

10. The observed total bird population was highest in the late fall, and it was higher during the winter (due largely to the number of Starlings) than it was during the summer.

11. The number of species observed was found to vary independently of the number of individuals observed.

12. Thirty censuses taken during June, July, and August, 1948, were matched by a set of 30 censuses taken during the same months of 1949. Certain findings resulted from these two sets of censuses:

a. The total number of individuals observed was 7.5 per cent greater in the summer of 1949—not a statistically significant change.

b. The percentages of increase or decrease from one summer to the next ranged from zero to 38 among 24 common species selected for mathematical study.

c. Only population changes of about 30 per cent, or greater, were found to be mathematically significant; only four species underwent statistically significant changes.

d. The fringillids underwent much less population change than the mean change for the entire group.

e. The data secured on flocking species indicate that these samples are less reliable than are those of non-flocking species.

13. It was found during a series of 110 censuses, half of them taken during mornings and half of them taken during afternoons, that 61.8 per cent of all the individuals were counted during the mornings.

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THE HOUSE WREN BREEDING IN GEORGIA: AN ANALYSIS OF A RANGE EXTENSION

BY EUGENE P. ODUM AND DAVID W. JOHNSTON

To US, the appearance of the House Wren, *Troglodytes aëdon*, as a nesting bird in Georgia has significance beyond the addition of a new species to the list of breeding birds for the state. In the first place, the phenomenon of southward invasion has been a subject of special interest to Georgia bird students for the past ten years. Secondly, the appearance of the House Wren fulfills the last of three predictions ventured by Odum and Burleigh in 1946. Finally, as a result of the work of Kendeigh and his associates at Cleveland, the physiological tolerances of the House Wren to temperature and other factors are known—enabling us to base a discussion of the limiting factors upon something more than pure theory. The writers are indebted to Mr. Chandler Robbins and Dr. John W. Aldrich for checking distribution records and to Dr. S. Charles Kendeigh for reading the manuscript.

The Georgia Record: On June 20, 1950, Odum heard the unmistakable song of the House Wren and was able to observe the bird for several minutes near the Veterinary Clinic Building on the Agricultural Campus of the University of Georgia. The next day, the authors found a pair of birds at this location and watched the female