A STUDY OF HOUSE SPARROW POPULATIONS AND THEIR MOVEMENTS IN THE VICINITY OF STILLWATER, OKLAHOMA

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CHAPTER I

INTRODUCTION

The house sparrow (Passer d. domesticus L.) spread westward at a rapid rate after being introduced into North America in 1853 (Barrows, 1889). The general outline of its range was essentially established by 1893, and by 1913 the birds were permanent residents of every large city in the United States (Kalmbach, 1940; Wing, 1943). House sparrows were first reported in Oklahoma in 1886 (Nice, 1931). Presently the house sparrow is one of the most numerous and widely distributed birds in North America.

This species is usually found in close association with man, and the evacuation of an area by him has often been followed by the disappearance of the sparrow (Summers-Smith, 1963). Flocks have been sighted 20 miles or more from the nearest house (Cottam, 1929). However, reports of house sparrows existing in the absence of man are extremely rare.

Most house sparrows spend their lifetime within a very limited area and are considered to be a sedentary species by many authorities (Southern, 1945; Gersdorf, 1955; Summers-Smith, 1956; Preiser, 1957; Fallet, 1958b). In Europe a few individuals have been recovered more than a hundred miles from their banding site (Rademacher, 1951; Summers-Smith, 1956; Preiser, 1957), but such long distance movements appear to be rare. There have been reports of limited migrations in Western

Europe (Elder, 1949; Lack, 1952; Bub and Prakelt, 1952) and in North America (Criddle, 1909; Wood, 1911), but seasonal house sparrow migrations occur regularly only in Asia (Southern, 1945; Summers-Smith, 1963).

As a sedentary species the house sparrow offers opportunities for population studies not generally feasible with migratory birds. Summers-Smith (1959) remarked: "The House Sparrow is a good species for population studies because of its sedentary behavior and conspicuousness."

Several authors admit the need for population studies involving sedentary species of birds. Davis (1951) remarked: "Although banding has been used to study the migration of birds, relatively little use has been made of color bands to study local movements." Lack (1950) stated that, in order to determine seasonal population changes (in birds), research with a color-marked population of a sedentary species was needed.

The literature contains frequent references to the amount and kinds of damage caused by the house sparrow as well as to methods for its control. However, specific population studies of this bird are few. Hickey (1943) stated: "One of the most surprising blanks in bird study concerns the size of the area in which birds forage for food." Dexter (1949) notes that " . . . little is known about behavior, movements, longevity, etc., of this common bird (Passer domesticus) of considerable economic importance." Thus, it seems apparent that studies of sedentary bird populations in general and of house sparrows in particular should be initiated.

If only for more effective control of these birds, additional information is needed concerning the daily movements and seasonal distribution of the house sparrow. For example, flocks of sparrows often have been observed feeding in grain fields outside towns and cities (Weaver, 1939; Kalmbach, 1940; Hammer, 1948; Mansfeld, 1950; Griffin, 1960). Although there has been considerable speculation as to the origin and age composition of these flocks (Summers-Smith, 1963), no definite conclusions have been reached. Some authors believe that these birds come from the parts of towns and cities closest to the fields (Summers-Smith, 1956; Preiser, 1957), whereas others think that the entire city serves as a reservoir for field flocks (Fallet, 1958a and b). Although it is generally agreed that most of these birds are immature, the age ratios of field-flocks have not been determined.

A general study of house sparrows and other pest species has been in progress at Oklahoma State University since 1958. Large numbers of sparrows fed at the university agronomy farms causing considerable damage to experimental grain plots (Griffin, 1960; North, 1963). However, no comprehensive study has been made concerning the numbers, movements, and distribution of sparrows congregating in this area.

The purposes of this study are to determine size and composition of populations, changes in the seasonal distribution, and daily movements of house sparrows. These objectives were accomplished by means of trapping programs in which the birds were banded and color marked. Information was obtained through continual retrapping, recovery of dead birds, and regular observations of marked birds. The behavior of trapped birds, effects of marking systems, sexing and aging techniques, and the effectiveness of trapping techniques were investigated. During

the study, information was also collected concerning other activities of this bird such as nesting, roosting, and feeding.

Dr. Fred M. Baumgartner, Dr. Adolph M. Stebler, and Dr. Roy W. Jones served as major advisers. Dr. Robert I. Smith, Dr. Troy C. Dorris, Dr. Bryan P. Glass, Dr. William A. Drew, and Dr. David S. Berkeley served on the advisory committee and criticized the manuscript. Mr. Veryl Board helped with the field work. Mr. Earnest Ables allowed the use of his notes on nesting house sparrows. The assistance of these people is sincerely appreciated.

CHAPTER II

DESCRIPTION OF STUDY AREAS

The study areas were located in Payne County in the vicinity of Stillwater, Oklahoma. This city, with a population of 26,000, encompasses an area of approximately 6 1/2 square miles. The Oklahoma State University campus is located on the west side of Stillwater.

The physiography of north central Oklahoma, consisting of gently rolling hills, was depicted by Curtis and Ham (1957). The vegetation of this region has been classified by Bruner (1931), Blair and Hubbell (1938), and Duck and Fletcher (1943) as postoak-blackjack woodlands and tall-grass prairies.

The principal grain crops are winter wheat which ripens in the late spring, and grain sorghum ripening in late summer and early fall.

Primary Study Area

Oklahoma State University maintains agronomy and livestock farms that extend westward from the campus proper and the city of Stillwater. Some of these farms formed the primary study area. This area, referred to hereafter as "study area," includes 1.03 square miles or 661 acres on the west side of Stillwater between the Oklahoma State University campus on the east and Cow Creek on the west (Figure 1). The farm areas were classified as "feedlot," "pasture," and "cultivated." The

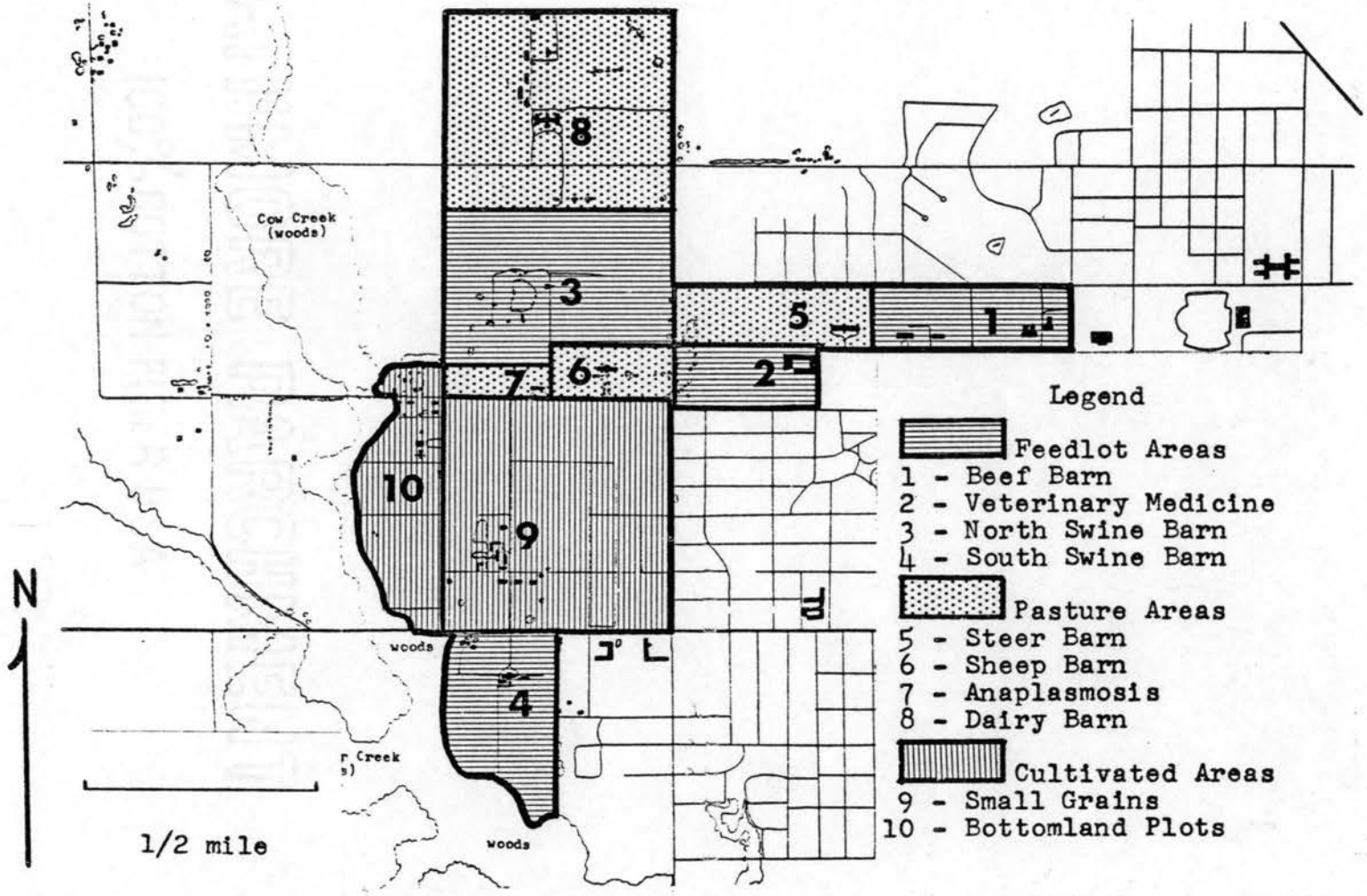

Figure 1. Divisions of the Primary Study Area

size and classification of the farms within the study area are shown in Table I.

TABLE I

SIZE AND CLASSIFICATION OF FARMS WITHIN THE PRIMARY STUDY AREA

Feedlot Areas	Acres	Pasture Areas	Acres	Cultivated Areas	Acres
*Beef Barn	41	Steer Barn	34	*Small Grains	158
*Vet. Medicine	34	Sheep Barn	28	*Bottomland Plots	73
*North Swine Barn	80	Anaplasmosis Laboratory	13		
*South Swine Barn	61	*Dairy Barn	138		
	216		213		231

*Banding locations

Feedlot Areas

Farms on which stock animals were confined in relatively small enclosures were considered feedlot areas (Figure 1). The animals were fed grain daily, and water troughs were located in each lot. Buildings, bordered by shrubs and bushes, as well as a few larger trees, were present on each of these farms. The presence of food, water, and cover provided an attractive feeding situation for house sparrows. Feedlot-type farms comprised 34% (216 acres) of the primary study area (Table I).

Pasture Areas

The locations of experimental farms used primarily for pasturing livestock are shown in Figure 1. Some buildings and a few stock pens

and lots were present, but supplementary feeding was mainly with hay and silage. The ground cover in pasture areas was mainly Bermuda grass. Shrubbery, trees, and other cover were limited. Little grain was available to sparrows, and large concentrations of birds were seldom observed. Pasture areas occupied 31% (213 acres) of the primary study area (Table I).

Cultivated Areas

Crops consisting of winter wheat and grain sorghum with smaller plots of rye, barley, and sunflowers were raised on several of the experimental farms shown in Figure 1. The winter wheat commonly ripened in late May and June, and the grain sorghum matured in August and September. Since some of the land was irrigated, water was usually available. Cover in the form of red cedars, deciduous trees, bushes, and hedges was restricted to the vicinity of buildings and along creeks. When standing grain was available, large flocks of house sparrows fed in these areas. However, relatively small breeding and wintering populations were present. The cultivated areas made up 37% (238 acres) of the primary study area (Table I).

Secondary Study Areas

In order to supplement data collected on the primary study area, selected farms west of town as well as feeding, roosting, and nesting sites of house sparrows within the city were included in the study.

Most of the isolated farms supported permanent sparrow populations and were separated from neighboring farms with resident sparrow populations by at least a half mile (Table II).

TABLE II

ISOLATED FARMS ON WHICH HOUSE SPARROW POPULATIONS WERE OBSERVED

	Direction and Distance From Town	Observed Population Types[1]
Graham Farm	2 miles W	FRN
Focht Farm	2½ miles W	FRN
Fowler Farm	3 miles NW	FN
Swart Farm	3½ miles NW	F
Friedeman Farm	3 miles NNW	F
Rogers Farm	2 miles N	FR
Stewart Farm	2 miles NW	F
Flesner Farm	1½ miles W	F
Weathers Farm	4½ miles W	F

[1] F - Feeding; R - Roosting; N - Nesting

Studies also were carried out within the city of Stillwater on areas which were principally feeding, nesting, and roosting sites. Aggregations of house sparrows were studied in several selected feeding sites commonly frequented by large numbers of birds. Adequate cover and nearby sources of water were available in addition to an abundance of food. Studies were carried out at the Stillwater Mill, Ahrberg's Mill, and the Payne County Courthouse (where a bird feeder and bath were present). Ivy on the sides of buildings provided nesting sites for sparrows. A colony of about 70 nests at Murray Hall was observed regularly in 1965. Other colonies were inspected occasionally during the study. In residential districts on the west side of Stillwater, several large roosts were studied. Cottonwood, oak, sycamore, elm, and maple

trees at least twenty feet tall were utilized as roosting sites during the spring, summer, and fall.

CHAPTER III

METHODS

The primary study area, in which most of the data were collected, was chosen because a large number of sparrows congregated there during certain months. The presence of large populations permitted the capture of a large number of birds. The boundaries of this study area were basically the boundaries of the Oklahoma State University farms--particularly those farms adjacent to the campus and the city containing livestock or cultivated small grain crops (Figure 1). Because of extensive damage to grain crops and possible spread of livestock diseases by house sparrows, information concerning the movements of these birds was of considerable importance.

Birds feeding at the agronomy farms did not spend all their time in the primary study area; and, during some months, few birds visited the farms. Observations outside the study area were necessary, and certain secondary study areas were used.

Table III shows the numbers of birds banded and collared at each trapping site from June 2, 1964 to October 28, 1965. The banded birds were released at their respective trapping sites. All but 244 of the birds that were banded were trapped within the primary study area. Outside the primary study area, 43 nestlings were banded at Murray Hall on the Oklahoma State University campus and 14 at the former residence of

TABLE III

NUMBERS OF HOUSE SPARROWS MARKED, COLOR AND TYPE OF MARKERS, AND LOCATION OF BANDING SITES DURING 1964 AND 1965

Area	Collar		Number Collared	Number Not Collared	Total Banded
	Color	Type			
Beef Barn	red	b	759	759	1,518
South Swine Barn	blue	b	317	317	634
Veterinary Medicine	yellow	b, t	514	513	1,027
North Swine Barn	green	b	80	80	160
North Bottom Plot	none	----	0	36*	36*
	orange	b, t	439	438	877
Small Grains	blue	t	95	95	190
Dairy Barn	white	b, t	119+	0	119+
Graham Farm	lt. green	t	136+	0	136+
Burdick Street	none	----	0	51*	51*
Murray Hall	none	----	0	43*	43*
Baumgartner's Former Residence	none	----	0	14*	14*
Total			2,459	2,346	4,805

*None of the birds were collared

+All birds were collared

[b] neck band

[t] neck tie

F. M. Baumgartner on West Lakeview Drive; 51 adult birds were mist-netted at 201 South Burdick Street; and 136 sparrows were taken on the Graham farm two miles west of town.

Fledged sparrows were captured by means of funnel traps, a modified crow trap, and mist nets. Ten double-funneled "government" house sparrow traps (Lincoln and Baldwin, 1929; Kalmbach, 1940) were employed. These traps were 4 feet long, 2 feet wide, and 15 inches high. Sites protected from livestock were selected in areas with large house sparrow populations. The traps were placed on bare, flat ground and baited with grain sorghum. Funnel traps, while effective in taking young sparrows, caught very few adults or older immatures and were not used later than September. A Norwegian crow trap (Bickle, 1951) was modified for smaller birds. The trap was 8 feet long, 6 feet wide, and 6 feet high with entrance slots 24 inches long and 1 3/4 inches wide. The trap was most effective with five or more decoy birds. It could be used in feed lots and pastures containing livestock. The crow trap became unproductive by late October. Mist nets were employed in the fall, winter, and early spring when funnel and crow traps were ineffective. These small-mesh, black, nylon nets were 7 feet high and 30 or 42 feet long. They were strung between iron poles and placed in front of bushes used for cover by sparrows. As many as 3 nets were used simultaneously. Descriptions and methods of use have been summarized by Given (1960), Spencer (1962), North (1963), and Taber and Cowan (1963). Unfortunately, mist nets were not effective in high winds. In addition, they required constant attention while in operation.

Aluminum leg bands (size 1A) were supplied by the U.S. Fish and Wildlife Service. Trapped birds were banded on the right leg and

released at the trapping site. In addition to banding, every second bird banded was marked with a colored plastic collar. The rate and extent of mortality of collared birds was determined from band recovery data. The colors of the collars represented the different trapping sites. Collars and bands were placed on all sparrows caught at Graham's farm and at the Dairy Barn. Birds taken as nestlings, those trapped at Burdick Street, and 36 of the sparrows caught at the North Bottom Plot were banded but not collared. This resulted in 2,459 birds being banded and collared while 2,346 were banded only (Table III).

Two types of collars, "neck bands" and "neck ties," were employed during the study. A neck band consisted of a strip of thin, colored, plastic about 3/8 inch in width. The strip was fitted around the bird's neck, and the two ends were fastened together by means of a light-weight aluminum rivet. The method was devised by Griffin (1960). Collars of this type were very durable and were usually easily visible. Corrugated, semi-corrugated, and thin plastic material was used for this type of collar. Neck bands made from corrugated plastic were fairly heavy and stiff. This material had been used in previous years with success (Griffin, 1960). A sparrow wearing such a corrugated neck band was recovered in good condition 547 days after having been marked. The semi-corrugated material, which was lighter and more flexible, was thickened along the two edges only. Thin sheets of vinyl plastic were cut into narrow strips and used as neck bands. This was the lightest and most flexible material from which neck bands were made.

Neck ties, which were developed by the investigator for this study, were made from colored plastic lacing fastened around the neck by a size #0B steel-plated paper fastener. The two loose ends were cut off about

1 inch from the fastener. Although lighter in weight, neck ties were not as durable or as easily visible as the neck bands. The two loose ends sometimes wore off, leaving the remaining parts inconspicuous.

During the study each farm within the study area was censused two to three times per week between 1:00 p.m. and 4:00 p.m. The farms were always visited in the same order so that each farm was censused at approximately the same time each day. The observer walked through each farm area using a specific route and counting all the house sparrows that he could locate. Some birds present in the area probably were not seen, and some probably were counted twice. However, this type of census presented an estimate of the numbers of birds present in the study area at one specific time of day and was used as an index to the total population size.

The sexes of immature birds prior to the post-juvenal molt were difficult to determine. Summers-Smith (1963) stated that no accurate method for determining the sex of immature house sparrows had been developed. In order to develop such a method, slight differences in the color of the head and throat plumage were used during the study. Birds with orange-brown feathers on the sides of their heads, white eye-lines or spots, and slightly darkened throats were said to be males. Birds with light throat color, buff or brown eye-lines or none, and no orange head color were called females. The accuracy of this sexing technique was evaluated according to recoveries of previously-sexed birds after their post-juvenal molt when adult sexual dimorphism was apparent.

As the post-juvenal molt proceeded, additional sexual differences in the plumage became apparent. Chestnut shoulders seemed to be the first conspicuous adult male plumage feature to appear. In the males,

a few reddish-brown head feathers, as well as black throat feathers, also were visible early. With the appearance of adult plumage, positive sex determination was possible. The growth and plumage changes of immature house sparrows are described by Nichols (1935) and by Weaver (1942).

Banded birds were aged only as immature or adult. Until the post-juvenal molt occurred, immature males could be distinguished from adult males by plumage differences. Plumage of immature birds of both sexes and that of adult females were similar; and, before the post-juvenal molt, feather wear was the principal method of differentiation. Davis (1953) stated: "There is no plumage character that will consistently separate adults from immatures [house sparrows] when both are in fresh plumage." After the molt, first-year birds were differentiated by examination of the stage of cranial ossification. Age determination in house sparrows according to the stage of cranial ossification has been described and evaluated by Nero (1951), Norris (1961), and Perdeck (1962).

Counts were made to determine the ratio of collared to uncollared birds. All birds whose throats, collared or uncollared, were clearly visible, were recorded. Binoculars (7x50) were utilized at all times. Data concerning the proportions of collared birds in the population were used in making estimations of population sizes.

In conjunction with the observations of marked versus unmarked birds, information concerning the sex and age composition of house sparrow flocks was obtained. Through the use of binoculars (7x50), adult males could be easily identified in the field during the spring and summer. During the late fall, winter, and early spring when all birds

had adult plumage, similar counts were used to determine the proportions of males to females. Sex and age ratio counts were made from December, 1964 to January, 1966.

Nesting colonies were visited during the spring and summer of 1965. Nests in the vines to a height of 20 feet on the north side of Murray Hall were marked with numbered tags. Records were kept of the number of active nests, with clutch size, the hatching time, and the time of nest-leaving. In addition to information collected during 1965, data taken by Ables (1960) concerning nesting house sparrows within the present primary study area have been incorporated.

During the summer and fall, house sparrows established large communal roosts in trees within the city. Several such roosts on the west side of town were studied in 1965. Counts were made of the numbers of birds using particular roosts, and the times and directions of arrival in the evening were recorded. Frequent observations were made of the routes sparrows used in moving to and from particular feeding and roosting sites.

Public cooperation in the observation of marked birds was solicited by means of newspaper articles with photographs of collared sparrows. The publicity was helpful in obtaining reports and recoveries of collared and banded birds. These data provided information concerning the distribution, foraging ranges, and flight routes of the sparrows.

Most band recoveries were obtained by retrapping and population control programs. In addition, some birds were found dead due to other causes. Birds were retrapped by the three trapping methods described previously. A number of dead banded birds were recovered during population control programs on the experimental farms. Techniques used in

these control programs were described by Goodhue and Baumgartner (1965). Information obtained from band recoveries and collar sightings was used in making calculations of population size, as well as in determination of house sparrow movements and foraging ranges.

CHAPTER IV

RESULTS

Trapping Success and Band Recoveries

During the study period, 4,805 house sparrows were trapped, banded, and released at the respective capture sites (Table IV). Funnel traps accounted for 42.5% of these birds, 16.8% were taken in the crow trap, and 39.5% were captured with mist nets. Fifty-seven nestlings also were banded.

Of the birds banded, 721 (15%) were recovered. Any banded bird which was recaptured or found dead subsequent to the original banding date was considered a recovery. Approximately half of the recoveries (51.2%) were made within two weeks of the original banding dates, and 36.3% were retaken within the first week.

The recovered birds were either retrapped (71.2%) or found dead (28.8%). Since 9.3% of the retrapped birds died in the traps, a total of 272 (37.7%) of the recoveries were dead, whereas 449 (62.3%) were retaken alive and released.

Frequent repeats occurred seldom during trapping operations. Only one bird was retaken as many as five times, 7 were recovered four times, 22 were retaken three times, and 97 were recovered twice. Sparrows recovered two or more times made up a small percentage (13.5%) of the total recoveries (Table V).

TABLE IV

NUMBERS OF HOUSE SPARROWS BANDED AND RELEASED IN 1964 AND 1965

Month	Numbers of Birds Banded		
	1964	1965	Total
January	0	184	184
February	0	12	12
March	0	28	28
April	0	18	18
May	0	428	428
June	200	888	1,088
July	0*	530	530
August	99	364	463
September	417	410	827
October	458	365	823
November	109	0	109
December	295	0	295
Total	1,578	3,227	4,805

*Bands not available

TABLE V

NUMBER OF RECOVERIES OBTAINED BY EACH METHOD OF RECOVERY

Recovery Method	Number of Times Birds Were Retaken 1X	2X	3X	4X	5X	Total
Funnel Trap	259	46	13	6	1	325
Crow Trap	67	10	3	1	0	81
Mist Net	187	19	1	0	0	207
Found Dead	208	22	5	0	0	235
Total	721	97	22	7	1	848
Percent	15.0	2.0	0.45	0.14	0.02	17.6

The birds which were retrapped three or more times were recently fledged immatures which were recaught at short intervals. For example, #103-141534, an immature female, was originally trapped on June 7, 1965. It was subsequently recaptured in funnel traps on June 9, 10, 11, 12, and 15.

Effects of Marking on Survival

Observations of newly collared birds suggested that the marking methods would probably reduce the survival rate. When released, some marked birds landed nearby on the ground and struggled for several minutes trying to rid themselves of the collar before flying away. Others immediately flew to a perch where, unaccumstomed to the presence of the collar, they sometimes hung by their feet with the head downward and occasionally even fell to the ground. One bird, when released, flew into the side of a barn killing itself. Collars also appeared to cause, in some instances, a stoppage of food in the esophagus. At least three

birds were found dead with quantities of grain forming a large protrusion above the collar. Thus, an investigation of the additional mortality caused by collars was of considerable interest.

Of 4,376 banded birds, exactly half of which were collared, 670 (15.3%) were recovered. These recoveries included 297 (44.3%) collared and 373 (55.7%) were uncollared birds. About 1.5 times as many uncollared as collared birds were retrapped alive, while 1.2 times more collared birds were recovered dead. Of these dead birds, 1.2 times more collared birds were found dead in traps while 1.6 times more uncollared birds were found dead after control programs. Of all birds found dead due to other causes, about 80% were collared. The probability of recovering collared birds in relation to uncollared birds by each recovery method is shown in Table VI. These data suggest that differential mortality due to the presence of collars did occur.

TABLE VI

THE INFLUENCE OF THE PRESENCE OF COLLARS ON RECOVERIES OF BANDED BIRDS

Recovery Method	Uncollared Birds Percent	Collared Birds Percent	Probability of Recapture Relative to Uncollared Birds
Retrapped Alive	59.9	40.1	0.66
Retaken Dead	45.6	54.4	1.19
in traps	45.0	55.0	1.22
control programs	61.7	39.3	0.64
other	20.8	79.2	3.81
Total Recoveries	55.7	44.3	0.80

Variations in the percentage of recoveries of marked and unmarked birds according to collar types are shown in Table VII. When the number of collared recoveries most nearly equaled the number of uncollared (banded) recoveries, the mortality caused by collars was said to have been the least. Nearly as many birds with thin collars (48.3%) were recovered as uncollared (banded) birds (51.7%). Thin collars were therefore considered to have caused the least mortality. Of all the recovered birds, 44.3% were collared and 55.7% were uncollared. According to these data, an uncollared bird was 1.25 times more likely to be recovered than a collared bird.

TABLE VII

BAND RECOVERIES ACCORDING TO COLLAR TYPES AND THE ABSENCE OF COLLARS

Collar Type	Banded Sample Size*	Recoveries of Banded Birds				
		% Collared	% of Total	% Non-Collared	Total Recoveries	% of Total Banded
Corrugated	1,398*	4.6	(45.1)	5.6	142	(10.2)
Semi-Corrugated	298*	11.8	(38.3)	19.0	89	(30.8)
Thin	1,624*	8.4	(48.3)	9.0	282	(17.4)
Tie	1,065*	5.8	(39.2)	9.0	158	(14.8)
Total	4,376*	6.8	(44.3)	8.5	671	(15.3)
Percent		(44.3)		(55.7)	(100.0)	

*1/2 of banded sample birds were not collared

During the first week after banding, 251 of the 4,376 birds (37.5% of the recoveries) were retaken, of which 54.2% were collared and 45.8% were uncollared. At the end of the second week after banding, a total

of 346 birds (51.6% of the recoveries) were retaken, of which 52% were collared and 48% uncollared. The percentage of collared recoveries kept decreasing with time until the final collared to uncollared ratio of 44.3% to 55.7% shown in Table VI was reached.

In spite of the fact that over 50% of the sparrows recovered were retaken within two weeks, the average length of time from the original banding until the first recovery was 44.2 days. Collared birds were recovered an average of 31.6 days after banding while uncollared sparrows averaged 49.9 days.

After control programs on the study area from July to December, 1965, a large number of house sparrows were found dead (Table VIII). Of these, 24.2% were adults (9.4% banded) and 75.8% were immatures (16.4% banded). Of the 162 banded recoveries, 62 (38.3%) were collared, and 100 (61.7%) were uncollared. The numbers (62 and 100) are significantly different at the 99% level. This suggests that the rate of mortality for the banded and collared sparrows was approximately 1.6 times greater than that of the banded but uncollared birds.

Sex and Age Compositions of Populations

Of the immature birds tentatively sexed prior to the post-juvenal molt, 171 were later recovered with sufficient adult plumage for positive sex identification. Only 16 (9.4%) of the 171 recoveries had been incorrectly sexed. Consequently, the proposed sexing method was considered reliable in approximately 90% of the cases. Most of the incorrectly sexed birds were males mistaken for females.

After the characteristic adult plumage was visible, accurate sexing of immature house sparrows was relatively easy. Adult plumage was

TABLE VIII

HOUSE SPARROWS FOUND DEAD ON THE STUDY AREA DURING CONTROL PROGRAMS IN 1965
(JUNE-DECEMBER)

Age	Banded Recoveries						Non-Banded Recoveries		Total
	Collared	(%)	Not Collared	(%)	Total	(%)	No.	(%)	
Adult	6	2.3	19	7.1	25	9.4	242	90.6	267
Percent	24.0		76.0		100.0		---	---	24.2
Immature	56	6.7	81	9.7	137	16.4	701	83.6	838
Percent	40.9		59.1		100.0				75.8
Total	62	5.6	100	9.1	162	14.7	943	85.3	1,105
Percent	38.3		61.7		100.0				

visible on most immature sparrows by late September and October.

Sex ratios of house sparrow populations in different parts of the study area are shown in Table IX. The observations were made when all the birds were in adult plumage. Males made up 51.4% and females 48.6% of the populations, a ratio of 1.06:1.

TABLE IX

SEX RATIOS OF HOUSE SPARROWS IN THE STUDY AREA DURING FALL AND WINTER (1964-1965)

Method	General Location	Sample Size	Males		Females	
			No.	Percent	No.	Percent
Observed	Primary Study Area (Field Areas and Edge of Town)	350	179	51.1%	171	48.9%
Trapped	Field Areas	678	340	50.1%	338	49.9%
Found Dead	Edge of Town	232	129	55.6%	103	44.4%
Total		1,260	648	51.4%	612	48.6%
				1.06	:	1

The differences in the observed proportions of adult males at feeding sites at each type of sample area are shown in Table X. From May 10 to August 31, 1965, an average of 25.1% adult males were found in house sparrow populations in the center of town, 14.4% on the edge of town, and 3.7% in the fields.

TABLE X

OBSERVED PROPORTIONS OF ADULT MALES IN THREE DIFFERENT POPULATIONS DURING THE BREEDING SEASON IN 1965

Month	Sample Size	Center of Town	Edge of Town	Fields
May	3,450	30.0	21.5	------
June	6,850	26.5	8.0	1.7
July	5,700	27.7	12.4	7.1
August	4,600	13.3	18.9	4.5
Total	20,600	25.1	14.4	3.7

Utilizing the above data and employing the average percentage of females (48.6%) shown in Table IX, the proportions of immature birds in the populations were calculated. Populations in three different locations in relation to the city of Stillwater showed the following percentages of immatures: (1) center of town - 51.2%, (2) edge of town - 71.7%, and (3) fields - 92.5%. A general movement of young birds toward the edge of town and fields seems to have occurred. Of the 20,600 sparrows observed during these four months, 33.8% were adults and 66.2% were immatures (Table XI).

TABLE XI

PERCENTAGES OF IMMATURE BIRDS IN POPULATIONS AT THREE LOCATIONS IN 1965 (MAY-AUGUST)

Month	Center of Town	Edge of Town	Field Areas	Total Average
May	40.8	57.7	-----	46.7
June	47.8	84.2	96.6	73.1
July	48.2	75.6	84.5	63.9
August	73.8	62.7	91.1	70.0
Average % Immatures	51.2	71.7	92.5	66.2
Average % Adults	48.8	28.3	7.5	33.8

Population Sizes

The house sparrow census (actual count), which was made two to three times per week during 1964-65, was used as an index to the actual number of birds using the study area. These daily counts were averaged on a monthly basis for 1964 and 1965 (Table XII). Asterisks indicate months in which house sparrow control programs were in effect. During both years, the sparrow population was smallest in April and largest in September. Flocks containing as many as 2,000 sparrows were observed feeding on grain sorghum in the Bottomland Plots in September, 1965. The average number of sparrows counted daily on the study area was 930 in 1964 and 1,099 in 1965.

TABLE XII

AVERAGE DAILY COUNTS OF HOUSE SPARROW NUMBERS ON THE PRIMARY STUDY AREA FOR EACH MONTH (1964-1965)

Month	Average Daily Population Size 1964	1965
January	149	576
February	155	613
March	139	354
April	80	318
May	273	499
June	1,169*	1,151*
July	1,129*	1,203*
August	2,532*	1,279*
September	2,921*	3,051
October	1,137*	2,333
November	666	1,183*
December	802	631

*House Sparrow control operations in effect

In 1965, field observations were made of the ratio of collared to uncollared birds in each division of the primary study area. The monthly percentages of collared birds on the Beef Barn area are presented in Table XIII. Sparrows in this area were banded from June, 1964 until September, 1965. Accordingly, the percentage of marked birds increased each month until the maximum was reached in September, 1965. Average daily counts of birds present during each month showed population trends in the Beef Barn area. The population size dropped from

TABLE XIII

POPULATION TRENDS AND PERCENTAGES OF COLLARED BIRDS AT THE BEEF BARN

Month	Average Daily Counts (Census Data)	Collared Birds Present in Population		
		Sample Size*	No. With Collars	% With Collars
(1964)				
December	361	400	9	2.3
(1965)				
January	222	---	---	---
February	87	200	6	3.0
March	62	950	40	4.2
April	91	---	---	---
May	169	---	---	---
June	263	650	54	8.3
July	239	1,100	80	7.3
August	341	1,750	202	11.5
September	350	250	30	12.0
October	750	1,000	76	7.6
November	867	600	38	6.3
December	467	2,200	196	8.9
(1966)				
January	---	300	36	12.0
February	---	600	46	7.7
Total		10,000	813	8.13

*Total number of birds observed

222 birds in January, 1965 to 87 birds in February. This may have been due to breeding activities which were centered outside the area. At least, the numbers of birds at the Beef Barn remained low until May when young birds were fledged. The number of birds then increased gradually until October when the average daily count jumped from 350 to 750 birds. In October the percentage of collared birds showed a marked decrease. An ingress of large numbers of sparrows, a smaller percentage of which were collared, must have occurred. The incoming birds may have been recruited from the field flocks which began to break up in October. As the numbers of birds using the Beef Barn area declined in December, the percentage of collared birds increased (Table XIII).

The percentages of collared birds observed on each of the farms in 1965 are shown in Table XIV. The Beef Barn, Veterinary Medicine area, and the North Swine Barn showed the highest percentages of marked birds. Sparrows were trapped and banded continuously at the Beef Barn and Veterinary Medicine areas during 1965, and many of the collared sparrows observed at the North Swine Barn came from these two areas. The South Swine Barn, where no sparrows were banded during 1965, showed a fairly high percentage of collared birds primarily due to recruitment from other areas. Collared birds from several banding sites were found at the South Swine Barn. As the field flocks broke up in October and November, the percentage of marked birds at the South Swine Barn increased from 1.0% in September to 3.1% in October and 5.2% in November. The percentage of collared house sparrows using the entire study area during 1965 (4.93%) was calculated by weighting the percentage of collared birds observed by the average number of sparrows censused daily on each division of the study area (Table XIV). Since approximately

TABLE XIV

PERCENTAGES OF POPULATIONS MARKED WITH COLLARS BASED ON OBSERVATIONS ON THE PRIMARY STUDY AREA IN 1965

	Beef Barn	South Swine Barn	Small Grains	Veterinary Medicine	South Bottom Plots	North Swine Barn	Dairy Barn	
Number of Observations	10,000	4,800	1,185	2,150	1,650	1,500	595	
Number Collared Birds Seen	813	161	18	108	43	84	24	
Percent Collared	8.1	3.4	1.5	5.0	2.6	5.6	4.0	(4.93)*
Average Daily Population Size	326	242	160	119	86	144	21	

*Weighted Average for Primary Study Area

1.6 times as many banded but uncollared birds were present, this suggested that about 13% of the total population using the study area was banded.

The population size was estimated by the method shown in Table XV. The marked-unmarked ratios based on observations of live birds on the study area during the period of maximum house sparrow use (July, August, September, and October) were weighted by the population index census data for the same period. By correcting the calculated percentage of collared house sparrows (4.64%) present on the study area during this period for mortality due to collars (1.6 x 4.64) and by doubling the resulting figure, the average percentage of banded sparrows on the study area (14.84%) was obtained. Dividing one hundred by this percentage gave the number of times (6.7) that the proportion of unbanded birds exceeded the proportion of banded birds in the population. The number of birds banded in 1965 (3,056) was multiplied by 6.7, which resulted in a total population size of 20,475 or approximately 30 birds per acre (Table XV).

Breeding and Nesting Studies

Instances of house sparrows, males in particular, carrying nesting materials were recorded during every month of the year. These materials commonly consisted of dry Bermuda grass or feathers.

During fall and winter of 1965-1966, from October through February, records were kept of observations of copulation or attempted copulation by house sparrows (Table XVI). Prior to January 14, the only observed instances of mating occurred on November 8 when two observations were made. During the latter part of January, copulation was observed twice;

TABLE XV

CALCULATION OF THE TOTAL NUMBER OF HOUSE SPARROWS USING THE STUDY AREA IN 1965

Area	Total Number Observations for 4 Months	Collared Sparrows %		Proportion of Total Population From Census Data		Weighted Percent Collared
Beef Barn	4,100	9.5	x	.214	=	2.033
Veterinary Medicine	750	6.9	x	.065	=	.449
North Swine Barn	1,400	5.6	x	.191	=	1.070
South Swine Barn	2,650	1.9	x	.282	=	.536
Small Grains	250	0.4	x	.108	=	.043
Bottom Plots	975	3.7	x	.130	=	.481
Dairy Barn	300	2.3	x	.010	=	.023
Total	10,425			1.000		4.635%

$\frac{100}{62}$ (uncollared) ÷ (collared) = 1.6 (mortality factor caused by collars)

4.64 (% collared birds) x 1.6 = 7.42 x 2 = 14.84 (% banded birds that should be present in the population)

100 ÷ 14.84 = 6.7 (number of times the unbanded population exceeded banded population in size)

3,056 (banded birds) x 6.7 = 20,475 (total population size)

and in February, seven instances were observed. By March, mating occurred so frequently that no further records were kept. Similar observations of house sparrow mating activities were made by Daanje (1941) and by Summers-Smith (1963).

TABLE XVI

FREQUENCY OF MATING ATTEMPTS BY HOUSE SPARROWS DURING FALL AND WINTER (1965-1966)

	October	November	December	January	February
Number of Observations	0	2	0	2	7

Newly built nests were discovered as early as February 17. By March 15, ten nests in different stages of completion were found under the eaves of a shed in the small grains area. On March 27, twenty-one nests, many of which were only partially completed, were counted in the vines on Murray Hall. None of the nests contained eggs when discovered.

The first nest containing eggs was found on April 9. However, Ables (1960) observed nests with eggs as early as April 4. An immature sparrow capable of flight was observed on April 20. In this case, egg-laying must have begun by the middle of March.

Clutch size at the Murray Hall colony in 1965 averaged 4.3 eggs per nest (Table XVII). However, with the inclusion of Able's observations, an average clutch size of 4.5 was calculated (Table XVII). Clutch sizes varied from two to seven with four or five eggs being most common (Table XVIII). Similar conclusions concerning clutch sizes were reported by Barrows (1889), Niethammer (1937), Weaver (1943), Bösenberg (1958), and Pfeifer and Keil (1962).

TABLE XVII

HOUSE SPARROW BREEDING SUCCESS DURING 1960 AND 1965

Nesting Area	No. Nests	Eggs Laid		Eggs Hatched		Young Leaving Nest	
		No.	(Av. Per Nest)	No.	(Av. Per Nest)	No.	(Av. Per Nest)
South Swine Barn* (Noncolonial-1960)	27	138	5.1	61	2.3	41	1.5
Dairy Barn* (Colonial-1960)	20	81	4.1	50	2.5	31	1.6
Total (1960)*	47	219	4.7	111	2.4	72	1.5
Murray Hall (Colonial-1965)	50	215	4.3	107	2.1	--	---
Grand Total (1960 and 1965)	97	434	4.5	218	2.2	72	1.5

*Data collected by Ables in 1960

TABLE XVIII

FREQUENCY DISTRIBUTION OF CLUTCH SIZES IN 1960 AND 1965

2 Eggs	3 Eggs	4 Eggs	5 Eggs	6 Eggs	7 Eggs	Total Nests
1	9	27	30	12	1	80

In 30 house sparrow nests located in the primary study area (Ables, 1960), 8 to 13 days were required from clutch-completion to hatching. The average time from the laying of the first egg to hatching was 14.4 days (Table XIX).

During April and May in 1960, Ables observed twenty nests containing young birds. In most cases the nestlings were fledged in 14 to 15 days after hatching. However, when disturbed, young birds would leave the next after only 12 days. In 1960 the average time from hatching to fledging was 13.9 days, and it varied from 12 to 18 days (Table XIX). Since some nestlings left the nest early because of disturbance by the observer, the average fledging time (13.9 days) was probably slightly shorter than under undisturbed conditions.

The total number of days required from the laying of the first egg until fledging varied from 28 to 32 with an average of 29.4 days (Table XIX).

To determine the breeding success, a total of 97 nests containing 434 eggs (an average of 4.5 eggs per nest) were observed in 1960 and 1965. Of the 4.5 eggs, 2.2 (50.2%) were hatched; and, in 1960, only 1.5 (32.9%) young left the nest (Table XVII). Adequate data concerning fledging times were not available in 1965 due to lack of access to the nesting colony under observation.

Of 48 nests observed in 1965, none was used more than three times; and, in several cases, nests were built but never utilized. The average number of times that a nest or nesting site was used during the breeding season was 1.54 times. Whether or not the nests were re-used by the same breeding pair was not known. Most of the nests were utilized either once or twice during the breeding season (Table XX).

TABLE XIX

INCUBATION AND NESTLING PERIODS FOR HOUSE SPARROWS
ACCORDING TO NOTES BY ABLES IN 1960

Areas	Incubation Period: 1st Egg to Hatching		Incubation Period: Clutch Completion to Hatching		Nestling Period: Hatching to Nest-Leaving		Total Days From 1st Egg Until Nest-Leaving	
	Nests (No.)	Av. No. Days	Nests (No.)	Av. No. Days	Nests (No.)	Av. No. Days	Nests (No.)	Av. No. Days
South Swine Barn and Dairy Barn	22	14.4	30	9.4	20	13.9*	13	29.4*
Range (days)		13-18		8-13		12-18		28-32

*The actual time was probably slightly greater than that shown since some nestlings left the nests earlier than normal due to disturbance by the investigator.

TABLE XX

FREQUENCY OF NEST UTILIZATION
AT MURRAY HALL IN 1965

Times Used	0	1	2	3	4
Number Nests	4	21	16	7	0

In 1965, house sparrows in the Murray Hall colony began laying the second week in April; and nests were in use until the middle of August. The greatest number of active nests occurred in April, May, and June. A sharp decline in the number of active nests began the first week of July and continued until the end of the breeding season. In August, only one active nest was found. By August 29, 1965, the breeding colony had been abandoned. A frequency distribution of active nests is shown in Table XXI.

TABLE XXI

ACTIVE NESTS IN THE MURRAY HALL COLONY DURING THE
1965 BREEDING SEASON

Active Nests	4/10	4/17	5/8	6/10	6/23	7/8	7/28	8/13	8/29
Nests with eggs or young	12	26	19	20	16	9	7	1	0
No. eggs present	27	78	30	28	35	10	7	0	0
No. young present	--	--	37	33	11	16	7	3	0

Communal Tree Roosts

Small communal roosts existed in protected situations during the entire winter. When nesting began in early spring, these winter roosts

were gradually abandoned. Nesting birds commonly roosted in or near their nests.

With the appearance of leaves in spring, communal roosts were formed in deciduous trees. The earliest roost of this type was found April 18, 1965. The numbers of birds using the roosts increased as more young sparrows left the nests. As nesting activity decreased, more adult birds were observed in the roosts. The largest roost studied contained about a thousand birds. Summers-Smith (1963), however, gives examples of roosts in Egypt containing as many as 100,000 house sparrows.

During summer and fall communal tree roosts were located throughout the city with no two in close proximity. Such roosts consisted of a single tree or a group of trees. Roosts were found in maple, oak, elm, sycamore, and cottonwood trees. Major factors seemed to be the density of the foliage and the height of the trees rather than the species. Trees at least twenty feet tall with dense foliage were preferred. Sparrows were seldom found roosting lower than ten feet above the ground. Tree roosts were often shared with other species of birds, particularly starlings.

Counts were made during September and October at four large roosts on the west side of Stillwater. The numbers and direction of flight of the roosting birds are summarized in Table XXII. Since these roosts, which were located in residential districts, all received their populations from the direction of the study area, it seems likely that many of these birds had been feeding on the agronomy farms. The locations of the roosts as well as the principal directions from which birds arrived are shown in Figure 2. Sparrows from all four roosts probably

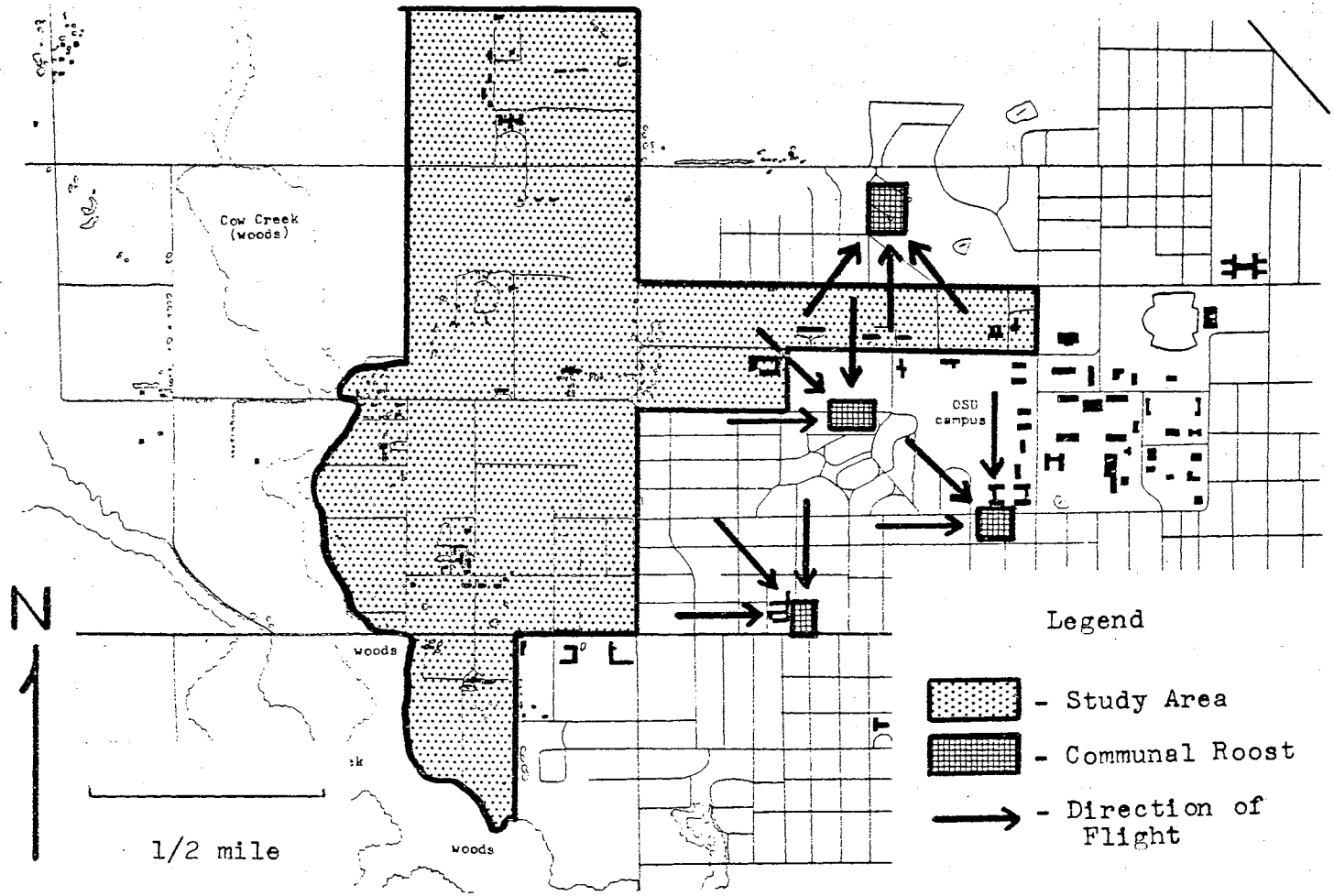

Figure 2. Directions of Arrival at Four Communal Roosts in the Fall of 1965

fed in the grain fields on the west side of the town during the summer and fall. Birds collared in field areas were observed at two of these four roosts.

TABLE XXII

DIRECTIONS OF FLIGHT FOR HOUSE SPARROWS ARRIVING AT SPECIFIC ROOSTS

Roosts	No. Birds Counted	Percent of Birds Arriving From:							
		W	NW	N	S	SE	SW	NE	E
Admiral Road	973	12%	73%	11%	*	*	3%	*	*
University Avenue	736	31%	27%	39%	*	*	*	2%	*
Kings Highway	668	55%	35%	6%	*	*	*	*	3%
Veterans's Village	357	3%	*	2%	59%	17%	11%	4%	4%

*Less than 1% of total birds

Close to the roosts there was often a congregating site. In the case of the Veteran's Village roost, this consisted of a clump of bushes located about 50 yards from the roosting trees. The sparrows arrived at this site initially and moved to the main roosting trees after 30 to 60 minutes. Cramp, Parrinder, and Richards (1957) also found that house sparrows (in London) often gather in trees before flying to roosts. Because of the communal singing that took place, these gathering places were called "chapels."

Frequent observations from June to December, 1965 were made of the roost located at Veteran's Village. This roost consisted of three large cottonwood trees. Sparrows arriving in the area in the evening did not fly directly to the roosting trees, but first congregated on certain

telephone wires and later flew down into bushes where communal singing took place. They collected on the telephone wires in early evening while it was still light, and the presence and color of the collars were easily detected. Birds marked at the Beef Barn were most frequently noticed; but those marked at Veterinary Medicine, the North Swine Barn, and the North Bottomland Plots were also observed using this roost. This was to be expected, since these farm areas were commonly frequented by Beef Barn birds. In addition, birds marked at Graham's Farm, the Dairy Barn and the South Swine Barn were seen in the Veteran's Village area but were not observed actually using the roost (Figure 3).

Sparrows began arriving at the roosts or "pre-roosting" congregation sites 1 to 1 3/4 hours before sunset, and all were in the roosts by 15 to 30 minutes before sunset. Some 10 to 15 minutes after the first birds arrived communal singing began which lasted until well after sunset. When the sky was overcast, the birds began arriving at the roost 15 to 30 minutes earlier than usual.

Sparrows began chirping half an hour before sunrise; and they left the roost some 30 minutes later. Under overcast conditions departure was delayed for nearly an hour, and the time spent singing in the roost was doubled.

Only one summer communal roost outside of town was discovered during the study period. A large roost, active during the fall of 1965, was found on J. C. Rogers' farm two miles northeast of town. This roost contained approximately 500 birds. This was the only example of town birds forming a communal summer roost in field areas observed during this study.

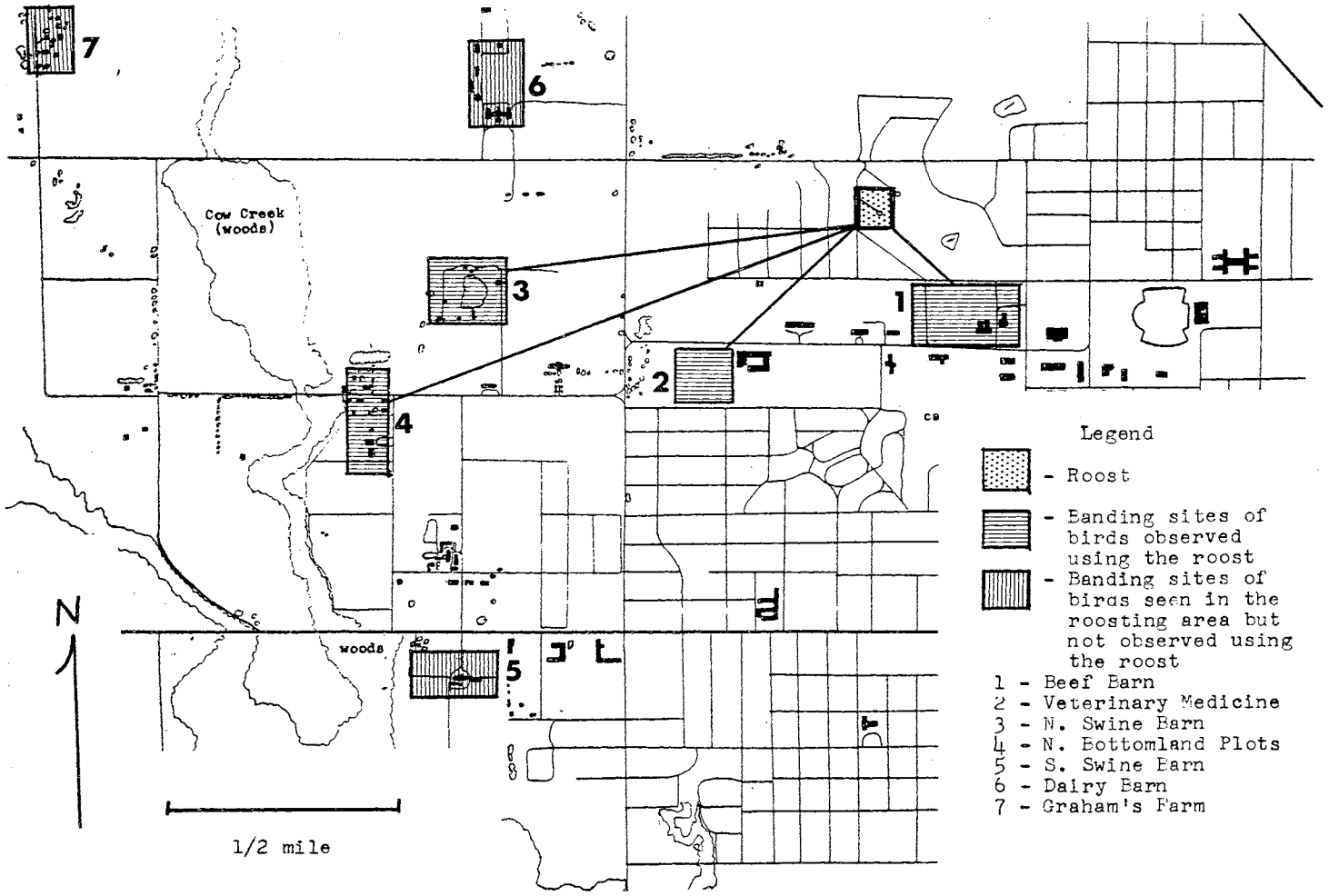

Figure 3. Banding Sites of Collared Birds Using the Veteran's Village Roost in 1965

If not vacated earlier, communal tree roosts were abandoned in late fall as the leaves were lost. The birds moved from the summer roosts to more numerous, smaller, and more sheltered roosts for the winter.

The process by which the Veteran's Village roosts was abandoned began with the partial loss of leaves by one of the cottonwood trees. By November 13, 1965, the northeast cottonwood tree had lost about half of its leaves; and the remaining half had turned yellow. At this date, the sparrows were still using this tree as a roost; but the numbers were declining. By November 14, most of the birds were roosting in the northwest cottonwood which still had most of its leaves; and these leaves were still green. By November 20, the northeast tree had few remaining leaves and had been completely abandoned by roosting sparrows. The northwest tree still retained most of its leaves which had turned yellow. The southwest tree had now lost about half of its leaves and had been abandoned by roosting sparrows. The number of roosting birds using the entire roost had decreased considerably from the peak population size. By November 22, the whole roost appeared to be breaking up. A few birds arrived and flew to the northwest cottonwood, but no singing was heard. By November 30, the roost had been abandoned. The northeast and southwest trees were bare, and the northwest tree had lost more than half of its leaves.

Feeding and Roosting Flight Routes

Feeding areas towards the edge of town were often employed as "staging" areas. The term "staging area" refers to a site where birds

congregated prior to a general movement to another location. These combination "feeding-staging" areas provided suitable cover in the form of trees or bushes as well as a readily available food supply.

During every month, from early May until late October, observations of flocks of house sparrows leaving for the fields from a feeding-staging area (Veterinary Medicine) were recorded. The outgoing birds commonly departed in small flocks of 2-25 individuals, whereas flocks returning from the fields were often larger. In the late afternoon, flocks containing more than 100 birds were frequently observed returning to town.

Specific flight-lines were generally followed by the outgoing and incoming birds. Routes to distant grain fields were more indirect in the early stages of development, becoming increasingly direct with continued use. For example, routes during June and July from Veterinary Medicine to the Bottomland Plots included stops at the Sheep Barn and the North Swine Barn. Later in the year none of these intermediate stops were made. Schmidt (1954) also found that house sparrows leave roosting sites and fly by regular routes to feeding areas in fields.

In early May, flocks of 200 to 500 immature sparrows were observed feeding in the pastures and cut hayfields close to town. Birds also began feeding in the fields of standing and harvested wheat in the small grains area in June. Only a few adult males were observed in these flocks. Routes from these feeding sites toward staging and roosting areas are shown in Figure 4. These routes were in daily use during May, June, and July in 1965. During late spring and early summer, flocks of house sparrows were seldom seen feeding in fields more than half a mile from town. Minor routes of some length to two different feeding sites

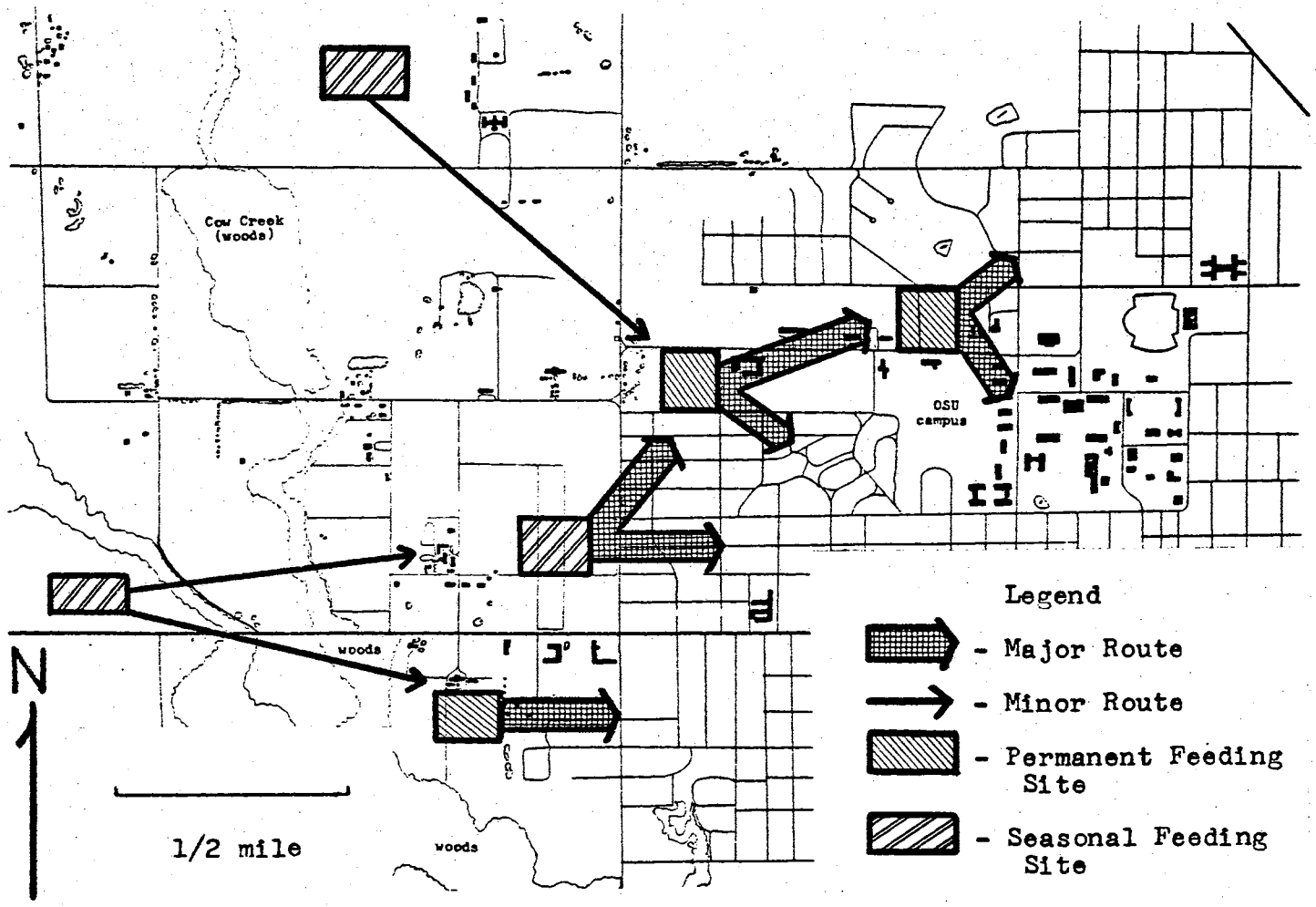

Figure 4. Routes From (and to) Feeding Areas in Early Summer in 1965

are also illustrated (Figure 4). Traffic along all routes continued throughout the day with birds moving both to and from town.

An example of long feeding flights by adults was first noted on June 10, 1965. The birds were flying more than a half mile from the Small Grains buildings and the South Swine Barn to a recently cut alfalfa field west of Stillwater creek. Some 50 birds, the majority of which were adults, were engaged in catching insects. House sparrows making long flights seemed to fly higher than usual. Enroute these birds maintained an altitude of about 100 feet, passing over tall cottonwood trees along the creeks. They arrived and departed singly or in pairs. Two distinct "minor" routes from this field are shown in Figure 4.

During July, another long feeding route was regularly used. A flock of some 500 sparrows was found feeding in a cut alfalfa field and adjoining hayfield west of the Dairy Barn. This was a mixed flock of immature and adult birds. The young birds remained at the feeding site during the day while adults, carrying insects, were observed making frequent trips back towards the Veterinary Medicine area. Of 300 individuals observed on July 4, 1965, seven were marked birds from the Beef Barn and Veterinary Medicine areas. This "minor" flight route is shown in Figure 4.

In late July, grain sorghum began to ripen in the Bottomland Plots, and extended flight-lines developed. Birds which had been flying from the Veterinary Medicine area to the North Swine Barn to feed now moved on west to the North Bottomland Plots. During late summer and fall the principal feeding area for field flocks were the North Bottomland sorghum plots. Counts of house sparrow flocks numbering up to 2,000 individuals were made on this area during August, September, and October in

1964 and 1965. Two principal routes were in daily use during these three months. One route was nearly direct from the North Bottomland Plots to (and from) the Veterinary Medicine area which served as a staging area for these birds. When returning to their roosting sites in late afternoon and evening, the birds moved farther east toward the Beef Barn and into the residential districts of town. The second route led from the Bottomland Plots to the South Swine Barn and from there into town. Stops were often made at the Small Grains buildings; and the South Swine Barn was occasionally bypassed by flocks using this route (Figure 5).

In addition to routes used by large numbers of sparrows, several flight routes used by smaller flocks were observed. A flock of house sparrows containing three birds marked with orange collars was reported arriving from the west and landing on a house at 105 North Main Street. This occurred at 5:00 p.m. (1 3/4 hours before sunset) on September 9, 1965. Orange collars were used on birds captured at the Bottomland Plots. On two occasions a flock of some 75 birds, flying at a high altitude in this same direction, had been previously observed by the investigator. If the birds flew directly from the Bottomland Plots to Main Street, this was a flight of more than three miles. Due to the time of day, it would be considered a roosting flight. The general direction of this flight is shown as a "minor route" in Figure 4. Cramp, Parrinder, and Richards (1957) noted that in London no sparrows were seen flying more than 1.4 miles to a roost. However, Summers-Smith (1963) stated that in Egypt birds were drawn to a large summer roost from as far as 4 miles.

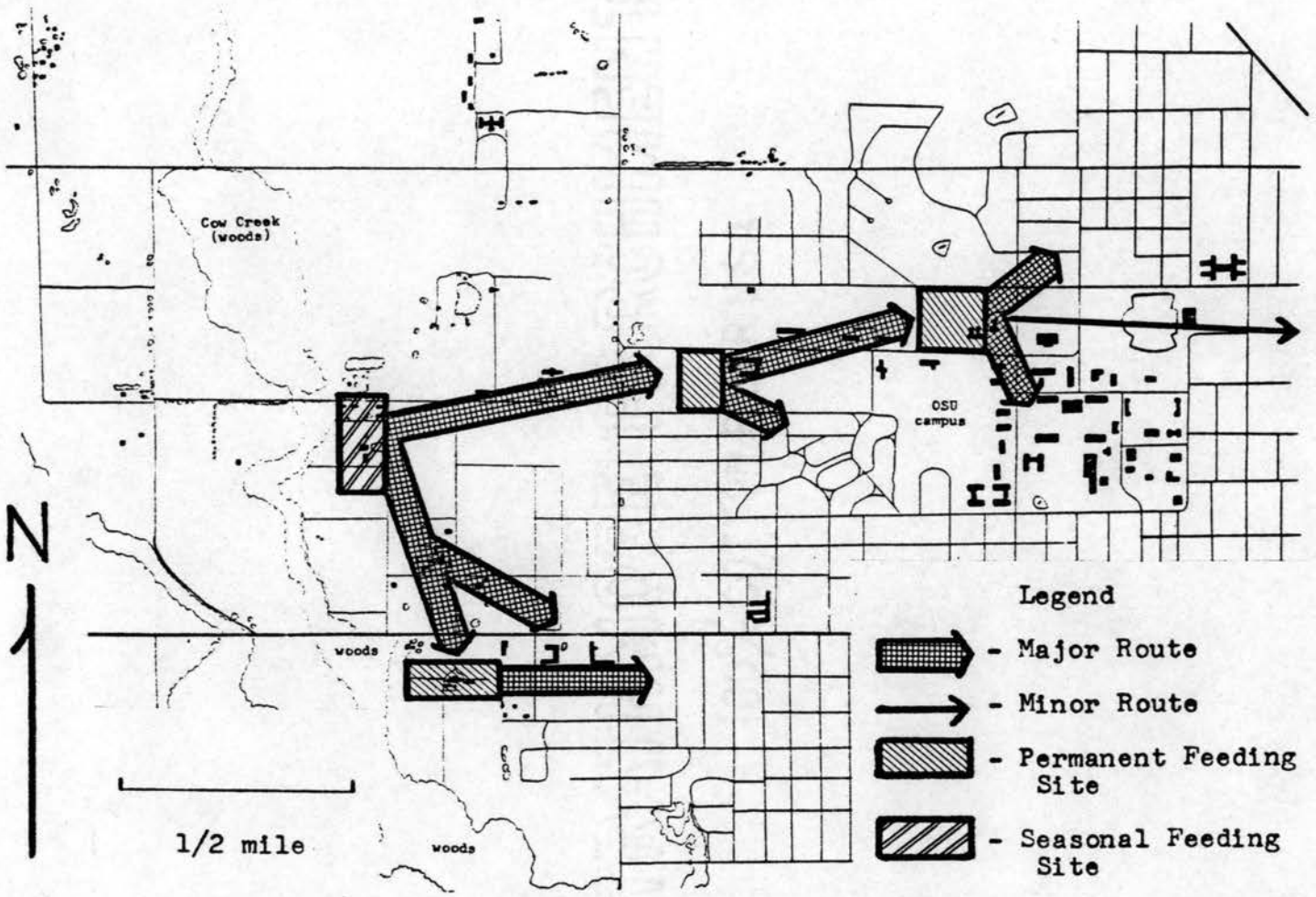

Figure 5. Routes From (and to) Feeding Areas in Late Summer and Fall in 1965

A route which was employed in the fall and winter of 1964-65 is shown in Figure 6. During this time a small winter roost of about 150 birds was present at Graham's Farm. A number of sparrows were moving between Graham's Farm and the South Swine Barn, a distance of about 3 1/2 miles. However, bird movements along this entire route were not traced. Flocks and individuals were observed flying due south from Graham's farm, and birds marked at Graham's Farm (light green ties) were seen at the Flesner Farm about a mile to the southwest. House sparrows commonly followed routes offering cover, and it is likely that the proposed route was utilized. From the Flesner Farm to the Entomology Laboratory, where more marked birds were observed, sparrows were observed flying the entire distance non-stop (about 1/2 miles). Flights between the Entomology Laboratory and the South Swine Barn were also observed. Marked individuals were seen at several points along this route. Birds marked at Graham's Farm (light green ties) were also sighted at farms to the north and west (Focht Farm - 2 1/2 miles west of town, Fowler Farm - 3 miles northwest, Stewart Farm - 2 miles northwest, and on the Weather Farm 4 1/2 miles west of town). In addition, individuals from the South Swine Barn (blue collars) were sighted on Graham's Farm and on two farms northwest of Graham's Farm (Fowler's Farm - 3 miles to the northwest, and Friedeman's Farm - 2 1/2 miles northwest). Apparently, therefore, this flight route extended at times farther northwest than Graham's Farm. Birds using this extended route during fall and winter of 1964-65 were probably feeding in a large unharvested grain sorghum field on the Swart Farm (3 1/2 miles northwest of Stillwater and 1/2 mile west of Fowler's Farm).

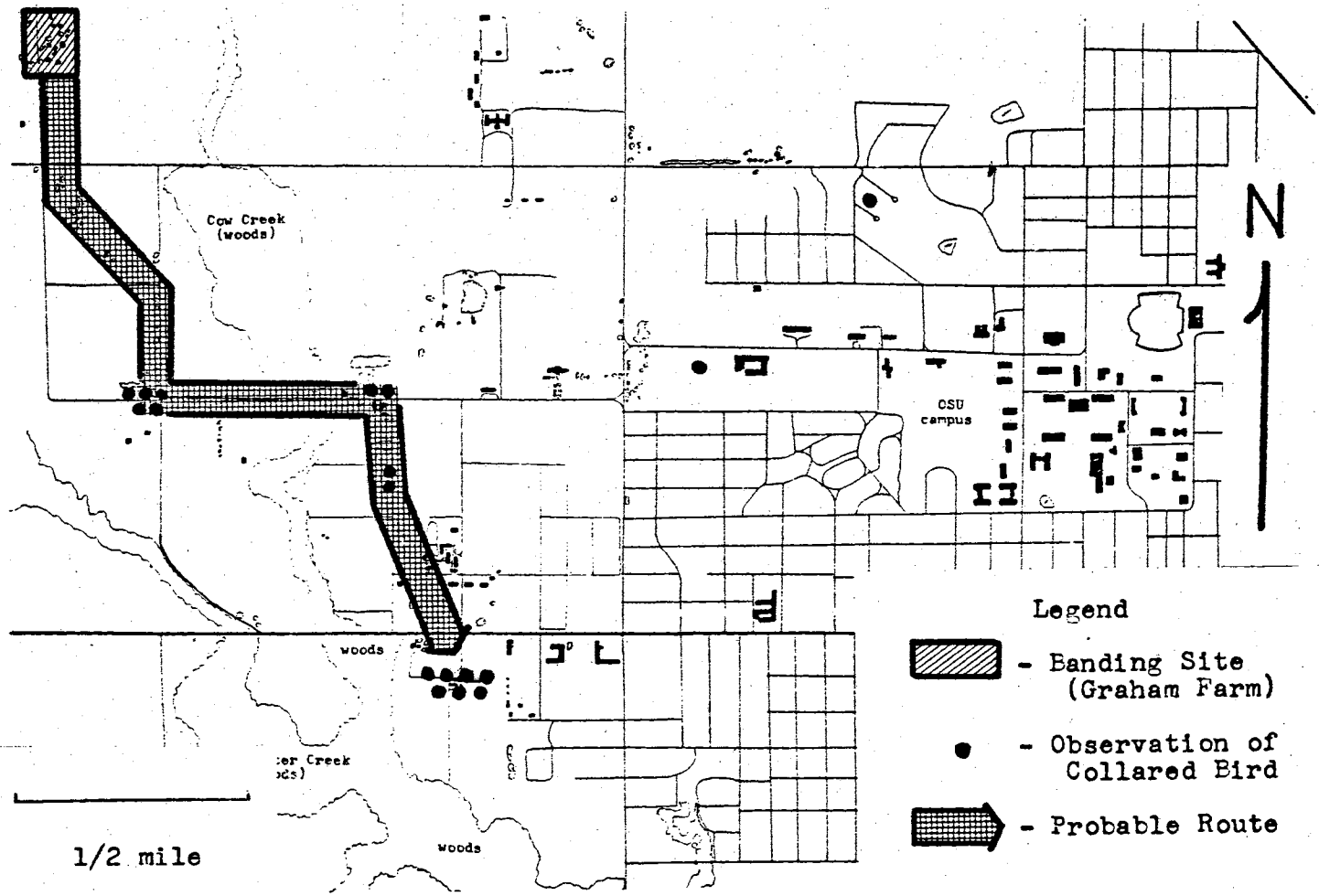

Figure 6. Probable Flight Route Between the Graham Farm and the South Swine Barn

House sparrows feeding in the fields commonly returned to town to roost. Roosting flights were often more direct and involved larger flocks than the flights to the grain fields. However, the same flight-lines were generally utilized. Flocks of birds began leaving the fields about two hours before sunset; and all the birds were gone by 1 1/2 hours before sunset.

Instead of going directly to a roost, the returning birds often congregated in feeding-staging areas. In many cases, additional feeding was done here before they retired to their roosts. For example, sparrows returning from the Bottomland Plots often stopped on the west side of the Beef Barn area 1 1/2 to 2 hours before sunset. As they fed, they moved eastward until they reached the shrubbery on the east edge of this area. Here communal singing took place before the birds finally left for their roosts. Cramp, Parrinder, and Richards (1957) also found that house sparrows often gather in trees near their feeding places before flying to roost.

In 1965, the field flocks broke up in late October. No large field flocks were seen after October 21. This agrees with Preiser (1957) who also found that field flocks disappeared towards the end of October.

Foraging Ranges and Emigrations

According to band recoveries (721) and sightings of collared birds (1,310), the distribution of house sparrows marked on the study area was determined (Figure 7). At least 95% of the recoveries and sightings of birds banded on the study area occurred within an area 2.6 square miles or 1,664 acres in size. Birds banded at the Veterinary Medicine Building (1), North Swine Barn (2), Bottomland Plots (3), Small Grains (4),

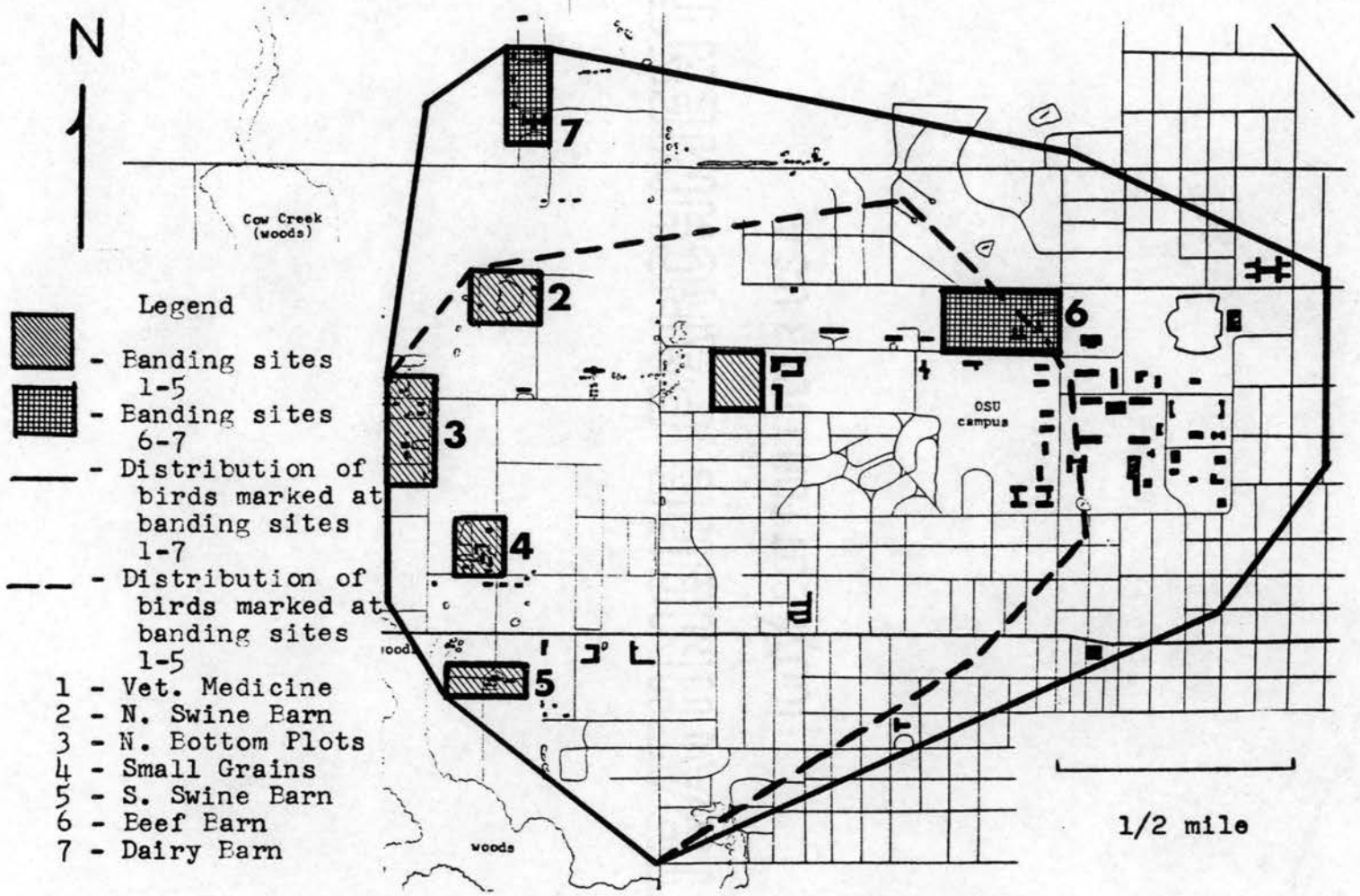

Figure 7. Annual Foraging Ranges of Birds Banded in the Study Area

and South Swine Barn (5) all used the same general foraging range which included 1.4 square miles or 915 acres. The inclusion of the ranges of birds banded at the Beef Barn (6) and Dairy Barn (7) added an additional 1.2 square miles or 768 acres.

The size of the foraging range of sparrows marked at the Beef Barn showed considerable seasonal variation (Figure 8). The smallest range was observed during the early part of the breeding season in spring. As young birds left their nesting sites and moved towards the fields in late spring and summer, the foraging range was expanded. In late summer and fall sparrows were feeding in grain sorghum plots on the west side of the study area which extended their range more than a half mile. Well over 90% of the observations made during each season occurred within the areas outlined in Figure 8. The entire foraging area used by birds banded at the Beef Barn was 1.9 square miles or 1,216 acres.

The seasonal movements of house sparrows marked at the Beef Barn are shown in Table XXIII. Of a total of 563 collar sightings, 18.3% were outside a one-mile radius, and 0.5% were outside a two-miles radius of the banding site. The three birds reported at distances greater than two miles were immature birds observed in the late summer and fall.

In winter and early spring very few house sparrows were observed at distances greater than one mile from their respective banding sites. In late spring, summer, and fall the general movement was west to the grain fields; whereas the primary movement in winter and early spring was south towards the residential district where birds were commonly fed during cold weather (Table XXIV).

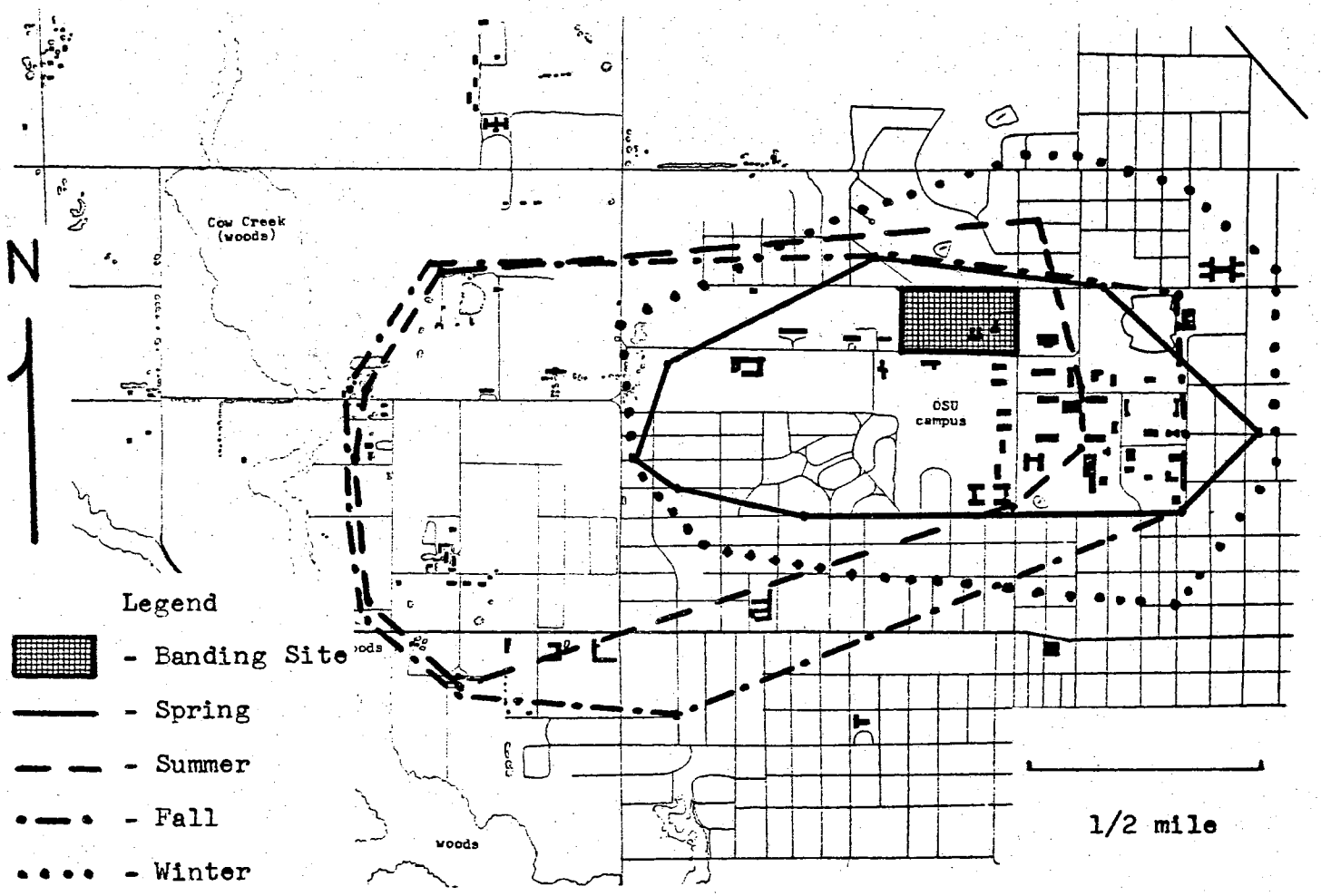

Figure 8. Seasonal Foraging Ranges of Birds Banded at the Beef Barn

TABLE XXIII

DISTANCES AND DIRECTIONS OF SEASONAL MOVEMENTS OF BIRDS
MARKED AT THE BEEF BARN IN 1964 AND IN 1965

Season	(Total Birds) Sample Size	Distances Traveled From Banding Site					
		Over 1 Mile			Over 2 Miles		
		No.	%	Principal Direction	No.	%	Principal Direction
Spring	94	11	11.7	S	0	0.0	--------
Summer	137	53	38.7	W	1	0.7	E
Fall	143	31	21.7	W	2	1.4	N, SE
Winter	189	8	4.2	S	0	0.0	--------
Total	563	103	18.3		3	0.5	

TABLE XXIV

MOVEMENTS OF BIRDS BANDED IN DIFFERENT LOCALITIES

Banding Areas	Number of Collar Sightings and Band Recoveries	Distance From Banding Sites					
		Over 1 Mile		Over 2 Miles		Over 5 Miles	
		No.	%	No.	%	No.	%
Edge of Town	1,552	188	12.1	7	0.5	1	0.06
Field Areas	424	90	21.2	13	3.1	1	0.23
Isolated Farm	55	23	41.8	4	7.3	0	0.00

Seasons when flocks of town birds moved into the fields are shown by the percentages of birds observed more than one mile from their banding sites (Table XXIV). Sparrows seldom traveled more than two miles during feeding flights. This agrees with Gersdorf (1955), Speyer (1956), Summers-Smith (1956), and Preiser (1957), who found that field flocks moved a maximum of two to three kilometers from town.

Sparrows were trapped and banded at feeding areas on the edge of town, in grain fields 3/4 of a mile west of town, and at an isolated farm some 1 1/2 miles northwest of Stillwater. Seemingly, the farther from town the sparrows were banded, the farther from their banding site they were subsequently recovered or observed (Table XXV). This suggests that these birds were moving periodically to and from town. Individuals marked on the edge of town were occasionally observed on farms from one to four miles west of Stillwater. A field of grain sorghum some 3 1/2 miles northwest of town received considerable use by house sparrows, and several of these birds had been marked at feeding areas on the edge of town. These data show that long-range flights of town birds to distant farms and grain fields did occur. These conclusions were consistent with those of Beer (1961), Przygodda (1954), Summers-Smith (1956), and Fallet (1958a).

The rate of emigration of house sparrows from the banding localities was derived from the total band recoveries and observations of collared birds acquired during the study period. Of 721 recoveries of banded birds, 89.5% were recovered within a one-mile radius of their respective banding sites, and a two-mile radius included 99.4% of the band recoveries. Only one bird was recovered at a distance greater than 5 miles (Table XXV). The data from observations of collared

TABLE XXV

MOVEMENTS OF BANDED BIRDS ACCORDING TO RECOVERIES AND OBSERVATIONS DURING 1964 AND 1965

Method	Sample Size	Distance From Banding Sites							
		Less Than 1 Mile		Less Than 2 Miles		Less Than 5 Miles		Over 5 Miles	Over 20 Miles
		No.	%	No.	%	No.	%	No.	No.
Band Recoveries	721	645	89.5	717	99.4	720	99.87	1	1
Collar Sightings	1,310	1,085	82.8	1,290	98.5	1,309	99.93	1	0
Total	2,031	1,730	85.2	2,007	98.8	2,029	99.9	2	1
Band Recoveries by Public Only	41	35	78.0	3	92.7	1	97.6	1	1

sparrows showed similar results. Of 1,310 observations, 82.8% were within a one-mile radius, and 98.5% were within a two-mile radius of the banding sites. Only one bird was observed at a distance greater than 5 miles (Table XXV). Combining collar sightings and band recoveries resulted in 85.2% being found within a 1 mile radius and 98.8% within 2 miles. Only two (0.1%) of the total sparrows which were either sighted or recovered were found more than 5 miles from their banding sites. Since many recoveries were obtained by trapping and by control programs on the study area, and since many of the collared birds were sighted by the investigator in this same area, banded sparrows on or near the study area were much more likely to be recovered or observed than those some distance away. A more realistic sample may have been obtained by using only the recoveries reported by the public. Of the 41 banded birds thus recovered, 78% were found within one mile, 92.7% within two miles, and 97.6% within 5 miles (Table XXV). Banding studies by Rademacher (1951) and Preiser (1957) in Germany, and by Summers-Smith (1963) in Britain showed a similar range of movements by house sparrows.

The greatest distance that a banded bird traveled during the study period was 68 miles. This immature male had been trapped on June 18, 1965 at Veterinary Medicine and marked with a yellow neck-tie. It was shot in Renfrow, Oklahoma, on October 29, 1965. Another sparrow with an orange neck band (trapped at the North Bottom Plot) was sighted on the Jess Russel farm 5 miles west and 4 1/2 miles north of Stillwater, a distance of approximately 7 miles. Both birds had traveled northwest.

From former banding operations at Oklahoma State University, only one house sparrow had been reported farther than two miles from its

banding site. This bird, banded on June 6, 1961, and recovered 25 miles east of Tulsa, Oklahoma, on February 10, 1962 (90 miles from Stillwater), had been dyed red and marked with a red neck band. Preiser (1957) remarked that long-distance returns (for house sparrows) were very rare. Two of his recovered sparrows, however, traveled 545 and 450 kilometers respectively toward the southwest.

CHAPTER V

DISCUSSION

Trapping, Banding, and Marking

The principal purposes of this investigation, which were to study the distribution and movements of house sparrows, could best be accomplished by banding and marking a considerable number of birds. Several devices were used for trapping; and, by October 29, 1965 when banding operations were discontinued, 4,805 house sparrows had been banded and released.

Reactions of house sparrows to the different types of traps were of considerable interest. The double-funnel type traps produced very few captures after the young birds became older and more experienced. Adults were rarely taken by this method. In fact, adults were observed to enter the first funnel, feed on the bait grain, and leave through the entrance funnel. However, no bird was observed to escape after having entered the second funnel of the trap. The fact that sparrows were difficult to retrap in funnel traps and that funnel traps were not effective after September, indicates that sparrows became trap-shy quickly. The ability of these birds to avoid capture was also noted to a lesser extent in relation to the crow trap. Possibly the use of decoys made this trap more effective than funnel traps in the fall. Catches were made with the crow trap until the last of October. No birds were ever observed to escape through the entrance slots of this

trap. There is a possibility that these traps became less effective due to an increased amount of available food in late fall. However, the same traps were also ineffective in winter when food was scarce.

Mist nets were productive in catching sparrows during the winter and early spring when the other techniques were ineffective. Sparrows apparently never learned to avoid these nets. The sparrow-use of a netting site would decrease after a time, but the nets could then be moved to other sites.

Some birds were banded in their nests prior to fledging. A large scale banding of nestlings would be interesting in that their dispersal from nesting areas could be demonstrated. However, it was felt that placing collars on nestlings would cause undue mortality, and they were banded only. Unless improved marking techniques are developed or unless a tremendous number of nestlings are banded, such a project might still be unprofitable.

A high percentage (15%) of the banded birds were recovered. The fact that about half (51.2%) of the recoveries were made within two weeks of the original banding date indicates that trap-avoidance was very quickly learned, and/or that the birds left the banding area soon after being banded. Most of the newly banded birds were young immatures. Nichols (1934b) stated that house sparrows are very trap-shy, and also that young birds soon left his trapping area.

Although over half of the birds were recovered in the two weeks following banding, an average of 44.2 days was required to recover a bird. This is further evidence of trap-shyness in house sparrows.

The "trap-habit," which is prevalent in some other species of small passerine birds, seems to be an unusual occurrence with the house

sparrow. Frequent repeats by individual sparrows were uncommon. Only one bird repeated as many as five times. Birds recovered two or more times made up only 13.5% of the total recoveries. Preiser (1957) found that only 9.1% of his recoveries were retaken more than once.

Evidences of trap avoidance by house sparrows have been derived from several different sources: 1) observations of responses to types of traps, 2) time required for recovery, and 3) the number of times recovered. Evidence from these sources indicated that even immature birds quickly learned to avoid most types of traps; and, with increasing age, house sparrows became very difficult to catch. These findings are in accord with the general adaptability of this bird which seems superior to that of many native species. The ability of the house sparrow to adapt to new situations and to compete with native species is comparable in many ways with that of the Norway rat and the starling.

Additional mortality due to the use of collars was possible to estimate since only half of the banded individuals had been collared. Evidence of stress caused by collars was observed in the behavior of newly-marked birds, but the rate of mortality could only be determined from recovery data. Several types of collars were used, and each affected the mortality rate to a different extent. A high percentage (17.4%) of birds marked with thin neck bands were recovered; and nearly 50% (48.3%) of these were collared, which suggests that little differential mortality occurred with this type of collar. The use of semi-corrugated neck bands and ties resulted in the highest mortality. As a whole, 44.3% of the recovered birds were collared and 55.7% were uncollared. Accordingly, an uncollared bird was 1.25 times more likely to be recovered than a collared bird. There was, however, a greater

difference in the mortality than this figure indicates since more collared than uncollared birds were recovered during the first two weeks after banding.

The presence of collars also affected the average time from the original banding until the first recovery. Collared birds were recovered for the first time in an average of 31.6 days, while the average time for uncollared birds was 49.9 days. Seemingly, collared birds were more easily recovered and/or differential mortality occurred.

The best data concerning the rate of mortality caused by collars was collected by means of control programs. Before being poisoned the birds were presumably all in good condition, and collared and uncollared birds were equally susceptable to this method of recovery. Of the 162 banded birds recovered during control programs, 38.3% were collared and 61.7% were banded but uncollared. A differential mortality rate had occurred in which 1.6 times more collared than uncollared (banded) birds had died. This figure was used in estimating the total numbers of birds using the study area.

Compositions and Sizes of Populations

Positive sex identification of live birds in juvenal plumage was not possible. Several external plumage characteristics were used for sexing, but only about 90% accuracy was attained. The sexing technique, which was tested during the present study, should be further refined and subjected to repeated tests for accuracy. Sex ratios of house sparrow populations were determined in the fall and winter when all the birds were in adult plumage. Of 1,260 individuals observed during this time, 51.4% were males and 48.6% were females (a ratio of 1.06:1).

Mansfeld (1950), Piechocki (1954), Löhrl and Böhringer (1957), and Pfeifer and Keil (1962) agreed that slightly more males than females were present in house sparrow populations. Boesenberg (1958) found that 1.5 times more males than females were fledged. Nichols (1934a) found that 55% of nearly 8,000 birds observed in winter and early spring in New York were males, and 52% of all birds banded were males.

Aging house sparrows was difficult in many instances. Until the annual molt was completed, the adult birds could be distinguished by feather wear. After molting was completed, however, aging birds by plumage differences was impossible. With dead birds the stage of ossification of the cranium was an accurate aging method until November or December (Nero, 1951). After that time, no differentiation of age groups was possible. By observing the proportion of adult males in populations and calculating the probable number of females (48.6%), the proportions of immature birds in these populations for May through August, 1965 were determined. The highest percentage of immatures (73.1%) was present in June, 1965. Of 20,600 individuals observed during this period, 33.8% were adult and 66.2% were immature. Summers-Smith (1959) found that the largest percentage of immatures in a suburban district (61.5%) were present in September. In November and December, Löhrl and Böhringer (1957) recorded a ratio of 32.8% adults to 67.2% immatures.

Regular censuses served as an index to the daily numbers of birds in each division of the study area during each month. There was a steady increase in the population size from May to October and a decrease from October to May. During the four months in 1965 when the largest house sparrow populations were present, 4.64% of the birds had

collars. The percentage of banded birds that would be present if differential mortality due to collars had not taken place (14.84%) was calculated. Using these data, an estimate of 20,475 house sparrows using the study area in 1965 was obtained. Using other methods, Griffin (1960) reported a population estimate of 25,583 house sparrows for the same area in 1959.

This seems to be a large number to be feeding in 661 acres (about 30 birds per acre). However, the highest daily count for this area (taken on August 28, 1964) was 5,670 sparrows. It must be remembered that the counts pertained only to the number of birds actually present at a given time of day. House sparrows were constantly moving to and from the study area, and the area was not necessarily visited by the same birds each day. Therefore, an estimate which is four times greater than the largest daily count may not be too large. If unchecked by control measures, the numbers of house sparrows would have been even larger.

Reproductive Biology

House sparrows began mating late in January and February, 1965. Initial nest-building activities began late in February and March, with the first eggs being laid early in April. Instances of winter nesting have been reported (Cottam, 1929; Nice, 1931; Weaver, 1943; Snow, 1955). This, however, seems to be an unusual occurrence and was not observed.

The last eggs were found in late July. Active nests with eggs or young were observed in April, May, June, and July (one in August). In the Tulsa area, Nice (1931), noted that the first eggs were laid on April 10, and the latest broods of small young were found on August 21, 1930. This coincides closely with the findings of the present

investigation. However, Weaver (1943) found that the nesting season in New York lasted from early April to early September, with the first eggs being laid the first week of April and the last eggs in late August. Seemingly, the nesting season in New York lasts approximately a month longer than in Oklahoma.

Clutch sizes varied from two to seven eggs with an average of 4.5. Clutches of four or five eggs were most frequent. Weaver (1942) found an average of 4.7 eggs per clutch in New York. Summers-Smith (1963), on the other hand, found the average clutch size in England to be 4.1 eggs. Boesenberg (1958) in Germany recorded an average of 4.0 eggs per clutch.

A hatching success of 50.2% and a breeding success of 32.9% was determined, which was considerably lower than that reported by other investigators. Summers-Smith (1963) found a hatching success of 71% and a breeding success of 50% in England. Weaver (1942) reported 70.5% breeding success in New York. Boesenberg (1958) recorded 52% breeding success in house sparrows in Germany.

A period of 28-32 days (average - 29.4 days) was required from the laying of the first egg until fledging. This included 13-18 days (average - 14.4 days) from the laying of first egg until hatching. Weaver (1943) reported that in New York, an average of 15 days was required from the laying of the first egg until hatching.

The young remained in the nest for another 12-18 days (average - 13.9 days). Disturbance by the investigator occasionally caused the young birds to leave the nest prematurely. This fact suggests that the nestling period estimate (13.9 days) was probably too short. The mean

nestling period according to Summers-Smith (1963) was 14.4 days with variations from 11 to 19 days.

Adults were observed feeding the young after they had left the nest. Summers-Smith (1963) and Burrage (1964) agreed that this additional feeding period lasts at least a week after nest-leaving. Weaver (1942) stated that adults feed the young for two weeks or more after fledging.

It seems unlikely that more than three broods could be produced annually by a breeding pair. Few active nests were found before the middle of April or after the last of June which indicates that the vast majority of the breeding birds utilized only about 2 1/2 months for nesting. Therefore, it would seem that few birds produced more than two broods per year. Birds found nesting in July and August may have begun nesting late in the season or were renesting after destruction of the initial nests. Further research is needed to establish the number of clutches produced annually in this part of Oklahoma. Weaver (1943) and Burrage (1964) stated that a maximum of two broods per season were raised by one pair of sparrows. On the other hand, Kalmbach (1940) and Summers-Smith (1963) found that three and occasionally four clutches per year were not uncommon. Boesenberg (1958) stated that usually three and sometimes five broods were produced yearly. In England, an average of 2.1 clutches per year were produced (Summers-Smith, 1963).

No nesting site was used more than three times (average - 1.54 times). Whether the nests were re-used by the same breeding pair was not determined. Weaver (1943) reported that in New York as many as four clutches per nest site (average - 1.68) were produced.

No indication was found in the literature of female house sparrows successfully nesting during the same breeding season in which they were hatched. Few young birds were observed before May, and the likelihood of these birds nesting before the end of July seems highly improbable.

With 2.1 clutches per year (a maximum estimate for birds in the study areas) and an average of 1.5 young per clutch leaving the nest, 3.15 young per breeding pair would be produced each year. Thus the numbers of individuals would be increased from the two original breeding birds to 5.15 (2 + 3.15) if no mortality took place. Annual mortality of 61% (3.15/5.15) would then result in homeostasis for the population.

If the adult mortality rate in Oklahoma corresponds with the 42% adult mortality rate in England (Summers-Smith, 1956), which is the only available estimate of adult mortality in house sparrows, the annual juvenal mortality rate can be calculated if a stable population is assumed. Of a breeding pair, in this case, only an average of 1.16 birds would survive until the following year. In order to replace this loss, 27% of the 3.15 young (.84 ÷ 3.15) must survive. Therefore, an annual juvenal mortality of about 73% could be sustained, and the population would still remain stable.

Distribution and Movements

Due to a tendency of sparrows to form nesting, feeding, and roosting aggregations in specific areas at certain times of the year, the seasonal distribution of house sparrow populations in the Stillwater vicinity varied considerably.

By February, nesting colonies were being formed in ivy on the sides of buildings, under the eaves of sheds, and in trees. Most nesting activity took place in the residential districts of Stillwater; and the lowest populations in the study area (mainly a feeding area for sparrows) occurred in February, March, and April. By May, fledglings were being produced, and populations on the study area began to increase.

The production of young birds and the availability of small grain crops on the study area resulted in large numbers of sparrows visiting the study area from June through October. During these months, flocks containing as many as 2,000 individuals were observed in the fields. Field flocks began to break up in October, and the birds remained in town until the following June.

Roosting aggregations were observed during every month of the year. When leaves in spring formed adequate cover, large communal tree roosts were formed which often were used continuously until the leaves were lost in the fall. No roosts were observed in close proximity to one another, which may have limited overcrowding in sparrow populations. No species of tree appeared to be favored as a roosting site. However, these communal roosts were in large trees (over 20 feet in height) with dense foliage. Few sparrows were observed roosting in the same field areas where they fed during the day. Roosts were usually located well within the residential districts. However, in Europe, roosts were commonly formed in field areas (Summers-Smith, 1963).

Flocks left the roosts half an hour before sunrise, and began arriving in the fields soon afterwards. Flock movements to and from the fields continued until late afternoon, when large flocks began to move back to town. By 1 1/2 hours before sunset, no house sparrows remained

in the fields. After leaving the fields, many birds moved to feeding areas within the city and continued to feed. Sparrows began arriving at the roosts about 1 1/2 hours before sunset and continued to arrive until about 1/2 hour before sunset. In the morning, roosts were vacated by sunrise on clear days; but, under overcast conditions, sparrows remained in the roost as much as an hour longer.

House sparrows did not fly directly from their roosts to the fields, but congregated at intermediate staging areas along established flight routes. The routes were generally shorter in spring and early summer, and were extended in late summer to reach outlying sorghum fields. Individuals and small flocks were observed moving back and forth along these routes during most of the day until retiring from the fields in late afternoon. The final flocks leaving the fields for the day were considerably larger than outgoing flocks and often numbered more than 100 birds.

A general movement of young birds towards the edges of town and into the fields occurred. This was verified by counts showing that 92.5% of the individuals in field flocks were immature birds; whereas, in the center of town, only 51.2% of the birds were immature. This movement was probably a type of population dispersal, and may have tended to limit the amount of inbreeding. While Southern (1945) stated "that there can be any great movement of sparrows from urban parts of towns seems unlikely," Przygodda (1954) and Fallet (1958a) found that large numbers of young birds migrated from the city in late summer and returned in late fall.

Immature birds do not necessarily return to their original home range but become dispersed over a large area. The tendency of immature

birds to scatter into new flock areas when the field flocks break up was demonstrated by the build-up of collared birds at the South Swine Barn in the fall of 1965. No birds were marked at the South Swine Barn in 1965, and only 1.0% of the birds observed there in September, 1965 were collared. The percentage of collared birds in this area increased to 3.1% in October and to 5.2% in November. The increase in the numbers of collared birds can be explained by the disintegration of field flocks in late October, and subsequent recruitment by the South Swine Barn populations. The ingress of birds into town areas as the field flocks broke up in the fall was demonstrated by increases in numbers of birds and simultaneous decreases in the proportions of collared birds at the Beef Barn in 1965. Studies by Summers-Smith (1963) and Preiser (1957) have shown that, while adult house sparrows usually return to their flock area, juvenals have little attachment to their place of birth and tend to become more widely distributed.

Maximum distances from which field flocks were recruited is not known. Seemingly, few birds traveled daily more than 2 miles from their roosts to feed. However, in one case, an apparent flight of 3 miles from the feeding area to the roost was observed. It is not unlikely that some of the immature birds in the fields were hatched near the center of town (3 or more miles from the field areas). However, no definite conclusions could be drawn. A large-scale marking project of birds in the center of cities might produce interesting results.

The foraging range of house sparrows on the study area varied considerably according to the time of year. This was demonstrated by the summer and fall expansion and subsequent contraction of the foraging range of birds banded at the Beef Barn. The expansion of the foraging

range in summer and fall was a consequence of the formation of field flocks. The flocks moved farther and farther from town in search of fresh grain fields. Since field flocks were made up primarily of immature birds, and since most of the birds were banded and recovered as immatures, estimates of foraging range sizes in summer and fall were actually those for immature sparrows. The foraging ranges for adults may well have been smaller. In winter and spring, when the birds tended to congregate near nesting areas located mainly in the residential districts of Stillwater, the foraging range was most restricted. However, these birds were mainly adults and may have had smaller foraging ranges during all seasons of the year.

Birds marked at the Beef Barn commonly utilized an area approximately 1.9 square miles in size. Sightings of marked birds outside this normal foraging range were uncommon. Records of birds sighted several miles from their banding sites were probably due to emigrations of young birds. Weaver (1939) found that house sparrows feeding at the Beef Barn on the Cornell University campus were drawn from an area three or four miles in diameter.

During the late fall, birds from town made regular flights to a farm about 1 1/2 miles northwest of town. This route may have been extended several additional miles in some instances since marked birds were observed up to 4 miles from the study area in this same general direction, and the two birds recovered more than 5 miles from Stillwater had traveled in this same northwest direction. Preiser (1957) found that a directional movement occurred with house sparrows in Germany.

The two birds which were reported at distances greater than 5 miles were banded as immatures and recovered or sighted in late October and

November which suggests that long-distance movements occurred primarily with immature birds in the fall. Gersdorf (1955), Summers-Smith (1956), Preiser (1957), and Fallet (1958a) agreed that most emigration occurred with immature or first-year house sparrows. Preiser (1957) found that population expansion took place mainly from August to November. However, Rademacher (1951) and Gersdorf (1955) determined the primary time of emigration to be in late winter and early spring.

House sparrows banded in the study area seemed remarkably sedentary. Only 14.8% of the birds were reported more than one mile from their banding sites, 1.2% were found at distances of two miles or more, and only 0.1% had traveled more than five miles. However, since many of the observations and recoveries were made by the investigator on or near the study area, more long-distance movement probably occurred than was indicated by the above figures. It is certain that some immature birds leave their original home range and emigrate to distant areas, but the actual proportions of these emigrants is unknown. If such emigrations did not occur regularly, the house sparrow would not have spread throughout North America so rapidly.

CHAPTER VI

SUMMARY

1. In order to determine the distribution, movements, composition, and sizes of house sparrow populations using a 661 acre study area, a banding and marking program was initiated. From June 2, 1964 until October 28, 1965, 4,805 sparrows were banded. Approximately half of the banded birds were marked with colored plastic collars.

2. New sexing and marking techniques were developed and tested. The technique used in sexing birds prior to the post-juvenal molt was about 90% accurate. Recovery data indicated that the mortality rate for collared birds was 1.6 times that for uncollared ones.

3. Fifteen percent of the banded birds were recovered. The average recovery time was 44.2 days. House sparrows soon became trap-shy, and few birds developed a trap-habit.

4. Observations of 1,260 sparrows during fall and winter showed 51.4% males and 48.6% females or a sex ratio of 1.06:1. A total of 20,600 observations, made from May 10 to August 31, 1965, showed 33.8% adults and 66.2% immatures in the populations.

5. During both 1964 and 1965, population trends derived from census data showed that the numbers of house sparrows in the study area reached a peak in September and were lowest in April. The method employed in calculating the numbers of sparrows using the study area in

1965 resulted in an estimate of 20,475 birds or approximately 30 sparrows per acre.

6. A considerable variation in the proportions of immature birds was observed according to the locations of the populations. In the center of town 51.3% were immature, on the edge of town 72.1% were immature, and in the fields 92.8% were immature. This indicated that a general movement of young birds away from the center of town took place.

7. The nesting season in 1965 extended from early April until the middle of August. Breeding activity declined during July, and few breeding pairs were nesting in August. An average of 14.4 days was required from the laying of the first egg until hatching. Most nestlings were fledged 14 to 15 days after hatching. An average of 29.4 days was required from the time the first egg was laid until the young were fledged. Clutch sizes averaged 4.5 eggs of which 2.2 eggs hatched and 1.5 young were fledged. This was a hatching success of 50.2% and a breeding success of 32.9%.

8. Considering the average number of fledglings per clutch, the time required to fledge the young, and the length of the breeding season, it seemed that few breeding pairs could produce more than two broods or average more than four fledged young annually.

9. Communal roosts in trees were established during late spring, summer, and early fall. Times of arrival and departure varied according to day length. Most roosts were located in town, and field flocks returned daily to these roosts by regular flight routes.

10. With the ripening of grain crops in the summer and fall, flight routes between town and the fields were established. The routes were

often more than a mile long. Intermediate staging areas along these routes were frequently utilized.

11. The habit of feeding in the fields and roosting in town resulted in relatively large foraging ranges in summer and fall. These ranges were much smaller in winter and spring. Birds banded at the Beef Barn had an annual foraging range of 1.9 square miles. A range of 2.6 square miles was determined for birds banded on the entire study area.

12. Of 721 band recoveries and 1,310 sightings of collared birds, 85.2% were reported within 1 mile, 98.8% within 2 miles, and 99.9% within a radius of 5 miles from their respective banding sites. Only two birds were reported farther than 5 miles from the study area. One had traveled 7 miles and one 68 miles.

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