MOBILITY PATTERNS, HABITAT RELATIONSHIPS AND REPRODUCTIVE SUCCESS OF GREATER PRAIRIE CHICKENS (*TYMPANUCHUS CUPIDO PINNATUS*) IN NORTHEASTERN KANSAS

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TABLE OF CONTENTS

INTRODUCTION

Sound ecological knowledge of any wild animal species is requisite to its effective management. To obtain such knowledge for the greater prairie chicken (*Tympanuchus cupido pinnatus*), a 6-year study of the ecology of this bird was initiated in 1963 in the north-central portion of the Flint Hills region in northeastern Kansas.

The objectives of the overall study were to determine: 1) seasonal and daily movement patterns, 2) behavioral patterns, and 3) habitat preferences of the greater prairie chicken. This thesis includes findings of the 1967-1968 phase conducted by the author, as well as a discussion of and conclusions drawn from the findings accumulated thus far in the 6-year study (Cebula, 1966; Viers, 1967; Silvy, 1968; Briggs, 1968).

The primary objectives of the current phase of the study were to supplement data obtained by the foregoing workers regarding monthly and seasonal movement patterns, and habitat preferences; to determine the effects of nesting date, site location, disturbance, and controlled burning on nesting success; and to gather additional information on brood movements, brood survival, and brood dispersal.

Radio-telemetry techniques were used throughout this study to gather much previously inaccessible data concerning the aspects of the ecology of the greater prairie chicken indicated by the objectives listed above.

REVIEW OF LITERATURE

Home Range and Movements

The origin of the concept of home range is generally attributed to Seton (1909:26), who stated that "No wild animal roams at random over the country; each has a home region, even if it has not an actual home". Home range was defined by Burt (1940:25) as: "that area about its established home which is traversed by the animal in its normal activities of food gathering, mating and caring for young". Blair (1953:5) gave a simpler and more inclusive definition of home range as: "the area over which an individual travels in its normal daily activities".

Sanderson (1966:219) stated that the size and shape of an animal's home range have little or no significance of themselves, and that investigators should concentrate on ecological studies and place less emphasis on movements and points of observation. Sanderson further pointed out that if all the requirements of a species could be provided in a small area, its home range would be smaller than the average reported for the species.

Silvy (1968:6) noted that before the advent of workable radio-telemetry techniques, studies of home range and movements were limited to direct observation of marked birds and analysis of band returns. A considerable amount of information concerning movements of greater prairie chickens and closely related species has been obtained by direct observations.

Early observations of greater prairie chickens include reports of extensive migratory movements, particularly in the northern portions of their range. Migrations of large flocks of greater prairie chickens from Minnesota and northern Iowa into southern Iowa and northern Missouri were reported by Cook (1888:105). This early report was perhaps substantiated by Bennitt and

Nagel (1937:47) who noted an influx of greater prairie chickens into northern Missouri from southern Iowa during the fall months. Mohler (1952:13) presented circumstantial evidence of a flock which he believed was migrating and had stopped in Nebraska to feed and rest. Schwartz (1945:84) stated that older residents of southern Missouri maintained that local birds formerly migrated into Oklahoma and Arkansas.

Schwartz believed that early migrations may have been related to food requirements. Leopold (1931:174) noted a reduction in the tendency to migrate as early as 1888, which he attributed to the widespread introduction of corn. When corn became a common crop in Iowa about 1880, prairie chickens wintered in areas from which there had previously been marked winter emigration.

Reports of migration included statements that only females migrated, or that most of the birds that migrated were females (Cook, 1888:105; Schmidt, 1936:197; Hamerstrom, 1941:100). Schmidt attributed the difference to requirements of the sexes for food and cover.

Hamerstrom and Hamerstrom (1949:329) reported there was almost no migration in Wisconsin, though some still occurred in the "Lake States" at the time of their study. Schwartz (1945:84) believed large numbers of birds seen during the winter in northern Missouri were simply large aggregations of local birds, and that prairie chickens in Missouri probably spent their entire lives within relatively small areas which provided adequate year-round habitat. Ammann (1957:77) reported that there was little evidence of long migrations or emigrations of prairie chickens during recent years.

The consensus of prairie chicken investigators has been that summer is the season of least extensive movements. Schwartz (1945:83) believed solitary males and females probably stayed within areas of 0.5 square mile or less in Missouri. Hamerstrom and Hamerstrom (1949:315) suspected summer was the time of least movement of male greater prairie chickens in Wisconsin, and estimated the daily cruising radius to be less than 1.0 mile. Baker (1953:17) reported similar findings in Kansas, and noted that females not successful in bringing off broods exhibited the same general movement patterns as males. Similarly, Lehmann (1941:23) and Copelin (1963:43) found summer movements of Attwater's prairie chickens (Tympanuchus cupido attwaterii) in the coastal prairies of Texas, and lesser prairie chickens (Tympanuchus pallidicinctus) in Oklahoma were less extensive than during other seasons.

Yeatter (1943:386) noted that in southeastern Illinois, certain groups of males tended to stay together in the vicinity of booming grounds after termination of the spring booming season. Schwartz (1945:83) and Hamerstrom and Hamerstrom (1949:315) reported males became more solitary and showed reduced flocking tendencies as the booming season drew to a close. Schwartz (1945:83) found groups of males used common feeding areas in early morning and late evening, but disbanded during the day. Baker (1953:38) noted that adult males began to molt after the cessation of breeding activity, and at that time they became secretive and reluctant to fly.

Increased movement and flocking activity in autumn was noted by Hamerstrom and Hamerstrom (1949:315), who found that small flocks and individuals gathered to form large packs. Schwartz (1945:83) reported small unisexual flocks formed during the fall months in Missouri. Autumn packs were found to remain within definite ranges by Hamerstrom and Hamerstrom (1949:318). Schwartz (1945:83) observed flocks ranged over areas of different sizes, depending upon the proximity of booming grounds to feeding, roosting, and loafing areas. Hamerstrom (1941:20) found fall packs of greater prairie chickens formed as close to the breeding grounds as food supply permitted.

Hamerstrom and Hamerstrom (1949:30) observed daily cruising radii of fall packs were from 1 to 1.5 miles, and Baker (1953:21) reported that one flock observed during fall had a range of approximately 1 square mile. Mohler (1952:19) observed no movement greater than 0.75 mile from take-off point by fall flocks. Schwartz (1945:83) observed that ranges of fall flocks varied from 0.25 square mile to more than 1 square mile, and believed that ranges were determined by the proximity of different types of required habitat. Hamerstrom (1941:27) stated that hunting pressure apparently did not drive autumn packs from their established fall ranges.

Schwartz (1945:83) and Ammann (1957:77) reported fall flocks of greater prairie chickens were of separate sexes, and contained both adults and young of the year. Lehmann (1941:21) reported similar findings for Attwater's prairie chickens in Texas. Baker (1953:23) noted that observations of winter flocks revealed that they were comprised predominantly of males, and concluded that the daily routine of females probably involved fewer conspicuous movements by flight than that of males. Schwartz (1945:59) and Baker (1953:20) reported daily visits to the booming grounds by males in early morning and evening during the fall months. Copelin (1963:27) stated that fall courtship ground displays of lesser prairie chickens were nearly as common as spring activities, though not all display grounds had bird activity during the fall.

Schwartz (1945:83) found the area traversed in a day by a large pack during winter was often less than 1 square mile, though over longer periods of time, it might cover the entire area formerly covered by its smaller component flocks (approximately 5 square miles or more).

Baker (1953:22) observed that different flocks shared the same feeding area during winter, but acted as distinct units at other times. He estimated the winter cruising radius of flocks and individuals at approximately 0.5 mile.

Mohler (1952:22) reported an approximate winter range of 3 square miles for winter flocks in Nebraska. Ammann (1957:76) noted population shifts were most likely to take place during late fall and winter; and that birds were much more mobile during that period.

Schwartz (1945:83) found that during periods of severe winter weather, unisexual fall flocks combined to form large bisexual packs. Baker (1953:17) noted that winter packs functioned as units in their daily movements, and that some were comprised of all one sex and others contained both sexes. Lehmann (1941:21) noted late fall and winter flocks of Attwater's prairie chickens were always of one sex. Hamerstrom (1941:100) observed some shifting of individuals from flock to flock while large winter packs were together. Hamerstrom and Hamerstrom (1949:321) found that winter packs were aggregations of varying degrees of tightness, and that they became tighter and less mobile as winter progressed, except during periods of mild weather, when they tended to disperse into component flocks which fed in different places. Such moves were interpreted as either simple extensions of daily cruising radii in response to milder weather, or as movements of small flocks oriented back toward their breeding places.

Schmidt (1936:197) stated that male prairie chickens wintered within a few miles of their booming grounds, and sought whatever grain was available. Schwartz (1945:84) noted similarities between winter and fall activities, except that visits to booming grounds were omitted from the daily routine in winter. Hamerstrom and Hamerstrom (1949:324) observed that males frequently displayed on winter feeding areas and booming grounds long before the main booming season had begun. Baker (1953:22) reported observations of prairie chickens on booming grounds during his winter visits.

Spring movements were characterized by the return of males to booming grounds (Hamerstrom and Hamerstrom, 1949:326; Yeatter, 1943:384; and Baker, 1953:17), with regular morning and less regular evening periods of displaying.

Hamerstrom and Hamerstrom (1949:328) found the spring range of males was near, or part of their winter range. They also observed a strong tendency for the birds to remain within a rather small area during spring, staying within 1 mile or less of booming grounds during the spring (Hamerstrom and Hamerstrom, 1949:327). It was observed that males tended to stay together during the time they were away from the booming ground, and that they often roosted on the booming ground and fed close by, sometimes within a few hundred yards.

Hamerstrom and Hamerstrom (1949:327) observed hens coming to booming grounds from points 0.3 to 0.5 miles away and further.

Movements of males from one booming ground to another during the same season were recorded by Schwartz (1945:41), Hamerstrom and Hamerstrom (1949:328) and Robel (1967:112). Hamerstrom and Hamerstrom (1949:327) also reported use of different booming grounds by certain males in different years. Robel (1967:112) reported use of different booming grounds by males during the same morning.

Robel (1964:709) found that two different flocks of males used the same booming ground during one spring season; one flock during the regular season, and the other after the regular season had ceased.

Habitat Preference

Jones (1963:757) pointed out that until information on habitat requirements becomes available, effective management of any species will be hampered. He noted that it is not enough to recognize the fact that prairie chickens need grasslands. Since stands of grass vary in character, those stands useful and attractive to prairie chickens must be identified, and the reasons for their usefulness and attractiveness must be ascertained.

Schwartz (1945:53) and Baker (1953:16) stated that 30 and 60 percent of the land in Kansas and Missouri, respectively, must be in permanent grassland in order to support stable populations of greater prairie chickens. Hamerstrom et al. (1957:20) showed that prairie chickens in Wisconsin were best adapted to regions where the land was at least 30 percent grassland, and that birds were abundant only in areas having more than 35 percent in permanent grassland.

Prairie chickens are dependent not only upon the quantity, but also the quality of grassland available. Hamerstrom and Hamerstrom (1960:289) stated that: "Prairie chicken management is primarily range management". Jones (1963:758) presented a detailed analysis of greater and lesser prairie chicken habitat in Oklahoma, based on 'use' of habitat components by birds. He stated that there must be elements within the habitat to meet the birds' needs for food, shelter, and reproduction. Each segment of the habitat could be classified according to 'time' of use, as night-roosting and day-resting; or according to 'type' of use such as courtship, nesting, or brood-rearing areas. Briggs (1968), working on the same study area as the author, analyzed radio-telemetry location data in terms of three dominant range sites of the area. He presented species composition and vegetation density data for each range site, as well as the seasonal and daily occurrence of birds of all sex and age classes in the selected sites.

Much has been written about the reduction of the original range of prairie chickens (Bennitt and Nagel, 1937:48; Schwartz, 1945:90; Mohler, 1952:9; and Christisen, 1967:182). Leopold (1931:188) observed that prairie chickens, like quail, had been the victims of clean farming in the prairie regions of the north-central states. He proposed preferential taxes and incentive programs for landowners to ensure practices favorable to prairie chickens.

Some workers have indicated that the widespread introduction of agriculture was not entirely harmful to prairie chickens in all portions of their range. Stemple and Rodgers (1961) stated that when row crops were introduced into Iowa, prairie chickens utilized them and even increased in numbers until nesting habitat was replaced by crops. Mohler (1963:738) stated that small cornfields located near extensive grasslands provided good winter habitat for prairie chickens in Nebraska. Farm crops were more important in the diet of prairie chickens in Missouri than were native plants (Korschgen, 1963:316). He pointed out that such preference may have been due simply to availability.

Baker (1953:63) believed that prairie chickens benefit from moderate grazing. Activities of cattle cause the formation of paths through the vegetation, allowing brood movements, and making it possible for birds to sun after a rain or during other periods when vegetation is wet. Ammann (1957:54) concurred in the belief that breaks in continuous cover were beneficial to greater prairie chickens, and stated that grazing by livestock and wildlife produced such openings where they did not already exist. Lehmann (1941:56) stated that moderate grazing encouraged favorable food and cover conditions for Attwater's prairie chickens in Texas, and Copelin (1963:51) similarly reported moderate grazing was vital to high quality habitat of lesser prairie chickens in Oklahoma.

Schwartz (1945:91) believed that promiscuous burning of grasslands as commonly practiced in Missouri was detrimental to the soil, vegetation, and wildlife. Burning in the Bluestem Hills area of Kansas has long been a common practice, especially on leased land, and large continuous areas were burned (Baker, 1953:15). Baker believed that spring burning, along with poor interspersion of food and cover, were primary limiting factors for the greater prairie chicken in that area. Lehmann (1941:38) observed that unregulated fire restricted good nesting cover for Attwater's prairie chickens, and that concentration of both nests and predators in the same small areas resulted in high levels of nest predation. Fire accentuated the results of drought, and was one of the most important factors that limited prairie chicken numbers in pastures (Lehmann, 1941:38).

Burning in the Kansas Flint Hills is as old as the grasslands they support (Anderson, et al., 1968). Natural fires, caused chiefly by lightning, were always an important ecological factor of the prairie (Komarek, 1966:122). The advent of primitive man probably changed grassland fires little except to increase their frequency. Fires were intermittent and occurred at nearly any time of year, but were most frequent in dry periods. Fire and grazing by then-abundant wild herbivores periodically removed dead vegetation that otherwise would have accumulated to substantial depths. "It is indeed unlikely that prairies could exist as such without repeated removal of tops." (Anderson, et al., 1968).

Flint Hill settlers discovered that steers selected forage from burned range and gained more rapidly on burned than on unburned range. With fencing confining animals to limited areas, reduced herbage yield from frequent burning led to heavy grazing, which caused changes of botanical composition, or reduction in range condition as it is now known (Anderson, et al., 1968).

Baker (1953:63) noted that the usual practice in the Flint Hills was (as it still is) to begin grazing on approximately the first of May. This is especially true of rangeland leased for the grazing of cattle from the southwest, in which case the desire of cattlemen is to attain the most rapid and early gain possible. Cattle may be taken from the pastures as early as July first, and the growth of grass thereafter is not only wasted, but it interferes with the efficient utilization of forage the next spring. The usual method of removing such unwanted growth is by burning.

Management recommendations concerning controlled burning of grassland in order to damage prairie chicken habitat as little as possible have been made by several investigators. Schwartz (1945:91) recommended that burning be conducted: 1) on a day or night when vegetation and ground were moist and a slight wind was blowing, 2) before the end of March in order to precede the season of new plant growth--as well as the nesting season of the birds. Lehmann (1941:53) found that in areas in which cover was scarce because of general burning, conditions for Attwater's prairie chickens were improved by leaving 40 percent or more of the grassy cover unburned each year. He stated that unburned cover should be well distributed over the pasture, the greater part being on the highest, most well-drained ground, in patches of 5 to 40 acres. Lehmann concurred with Schwartz (1945) concerning optimal moisture and wind conditions for burning.

Baker (1953:15) stated that:

> "So long as absentee ownership and the leasing of rangeland are prevalent, there seems to be no cure for the harm done to upland game by burning, except through a program of education and a system of refuges. Ranchers who insist on burning should be encouraged to do so only when the ground moisture is plentiful and after a rain. Under such conditions some cover is left."

Anderson, et al. (1968) found that early spring burning (20 March) of grazed bluestem range in the Flint Hills of Kansas resulted in reduced forage production, depletion of range condition (retrogression), and loss of soil moisture.

Mid-spring burning (10 April) resulted in intermediate forage yields and no retrogression of range condition. Weight gains of steers were greater than on unburned control areas.

Late spring burning (1 May) resulted in improved range condition (percent of original or climax species composition), greater weight gains of livestock, and no reduction in forage production. Therefore, Anderson, et al. (1968) recommended late spring as the most desirable time for burning.

Reproductive Studies

Schwartz (1945:48) believed each booming ground had a "sphere of influence" within its portion of the range, and the limits of influence were determined by the distance and direction from which booming was audible.

The principle purpose of the booming ground was believed by Schwartz (1945:51), Baker (1953:17) and Hamerstrom and Hamerstrom (1955:464) to be that of courtship and mating, though they shared the opinion that such activities functioned only indirectly in mating, and that its direct purpose appeared to be the attraction and concentration of females.

Hamerstrom (1941:42), Hamerstrom and Hamerstrom (1955:464) and Main (1937:40) believed that most mating activity occurred away from the main booming grounds. In contrast, Schwartz (1945:53) and Robel (1967:112) observed numerous successful matings on booming grounds.

Hamerstrom (1941:24), Schwartz (1945:43) and Robel (1967:111) found that the number of males occupying a booming ground during the breeding season fluctuated from time to time. Hamerstrom (1941:24) and Robel (1967:111) observed that the greatest numbers of males on booming grounds were present early in the booming season. Schwartz (1945:53) observed the largest numbers of males appeared later, during the "height of the season". Copelin

(1963:26) noted that only a few of the traditional gobbling grounds of lesser prairie chickens were occupied by large numbers of males, and that as the season continued birds began to use additional grounds and large concentrations dwindled. Hamerstrom (1941:25) believed some males left the booming grounds on their own accord, possibly to set up "nesting territories". Hamerstrom (1939:108 and 1941:22) and Yeatter (1943:285) reported the number of males on booming grounds gradually diminished as the spring season progressed.

Schwartz (1945:43) noted attendance during the morning booming period was more regular than during the evening period, except during the height of the season, and that attendance was less regular early and late in the season.

Schwartz (1945:51) stated that no females were seen on booming grounds in Missouri until late March, when an occasional hen visited the booming ground for a short time. "Such infrequent visits lasted for a week or more, then suddenly the number of hens visiting booming grounds increased to a rather constant maximum, marking for several days or a week the height of the season." The observations of Baker (1953:23) were in agreement with Schwartz, i. e., the peak of mating was during the second week in April on his study area in Kansas. Schwartz (1945:43) found that before and after the peak of the booming season, females were present only occasionally, and then only for short periods and in small numbers. Hamerstrom (1941:26), Hamerstrom and Hamerstrom (1955:463) and Robel (1967:111) observed that the number of females visiting a booming ground on a given morning, and the number of visits by females to a booming ground on a given morning were greatest early in the season.

Schwartz (1945:53) stated that matings were not restricted to the height of the season, and that males attempted to mate whenever a female appeared receptive. Hamerstrom (1941:36) found that females were more likely to be receptive as the season progressed, but that unreceptive females appeared at any time. Hamerstrom (1941:37) stated that he had not recognized the lessening of readiness with the onset of broodiness, but that the less receptive behavior of females seen toward the end of the season reflected this condition.

Yeatter (1943:413) noted evidence of a time differential in the development of the sexual cycle among both male and female prairie chickens. Hamerstrom and Hamerstrom (1955:464) reported individual females came to a booming ground over a period of several days before they were receptive to males, and that copulation marked the end of their visits, at least for some time. Schwartz (1945:22) stated that females were most receptive during the height of the season, and that at other times they wandered at random over the booming ground. During the height of the season, females remained in a loose flock near the center of the booming ground for most of the morning.

Schwartz (1945:54) and Hamerstrom (1939:112) thought it probable that almost the entire oopulation of females was mated during the height of the season. Robel (1967:112) observed that matings on booming grounds occurred primarily during two oeriods, one at the height of the season, and another approximately a month later. Baker (1953:24) observed matings over at least a 6-week period, and stated that both sexes seemed to become physiologically incapable of breeding shortly after the first of June.

Schwartz (1945:83) found that during a year of high populations, individual flocks of 30 to 50 males combined into groups of 100 or more on a single booming ground during the fall. Numbers of males in excess of 100 on individual fall booming grounds were reported by Baker (1953:22) and Horak (1967:14) in Kansas. Horak (1967:14) noted that three booming grounds adjacent to one which had a maximum of 123 birds during the fall booming season were vacant, and hypothesized that birds from these three grounds and their young all came to the same ground.

Copelin (1963:26) reported that fall courtship ground displays of lesser prairie chickens in Oklahoma were almost as common as spring activities, though birds appeared on fewer grounds. Hamerstrom (1939:109) reported that in Wisconsin, a few males were seen on booming grounds in September, and that densultory booming was heard on three mornings in mid-October. Schwartz (1945:61) noted that while males were engrossed in fall booming ground activities, smaller flocks of females either visited the booming grounds, or remained in the vicinity. The largest group of females observed on a fall booming ground contained 22 birds.

Schwartz (1945:61) stated that females on fall booming grounds were not receptive, and that there were neither matings nor attempted matings. Anderson (1965:8) and Silvy (1968:25) found that males responded sexually to female decoys mounted in a receptive position during the fall season. Copelin (1963:27) noted the appearance of hens on fall gobbling grounds of lesser prairie chickens, and that males courted hens, even to the extent of nuptial bowino, but that no copulations were observed. Schwartz (1945:61) believed that males were incapable of breeding during the fall season.

Marshall (1961:310) recognized three internally regulated phases of the annual sexual cycle of birds. These included a "regeneration" phase, immediately following reproduction, during which the neuroendocrine apparatus does not respond to photostimulation; an "acceleration" ohase, which automatically follows the regeneration phase and during which the neuroendocrine apparatus is susceptible to external stimuli; and a final "culmination" phase which follows the acceleration phase and includes the period of insemination and ovulation.

Nesting

Baker (1953:64) believed the reproductive success of prairie chickens is low because the reproductive season is short, and because adverse weather conditions may be detrimental to both eggs and young. He concluded that: "The reproductive season seems to be the most critical period of the year for the species". Yeatter (1943:401) pointed out that the welfare of greater prairie chickens in Illinois was dependent chiefly on suitable environment during the nesting period, and when the birds were very young.

The production of an annual crop of young is the most important factor affecting grouse abundance. Because grouse are short-lived, one season with a high percentage of nesting failures could result in a marked drop in numbers, and two successive years of poor success could be disastrous. Fortunately, complete failures probably never occur over a large area, and two or more extremely poor nesting seasons in succession are rare (Ammann, 1957:87).

Hamerstrom (1941:52) reported that, as with most gallinaceous birds, many prairie chicken nests were unsuccessful. Ammann (1957:99) found by combining his own data with previous reports from the literature, 52 percent of 165 observed nests of greater and Attwater's prairie chickens were unsuccessful. Horak (1967:6) reported that 60 percent of 10 nests observed during one season were unsuccessful.

Lehmann (1941:15), in discussing nesting success of Attwater's prairie chickens, stated: "A successful season depends largely on the fate of the early nests, so that a primary objective should be to safeguard these attempts". Baker (1953:28) concluded that early clutches were larger, more successful, and produced most of the young. He observed that 68 of 79 chicks produced were from the earliest 8 of 16 nests studied. Conversely, Yeatter (1943:392) reported that clutches laid early in the season suffered high losses from predators (35 percent), while those begun later in the nesting season had fewer losses. He believed that this was due to better vegetative cover later in the season.

Hamerstrom (1939:113) listed known causes of nest failures of prairie chickens as skunks, unidentified canids, man, minks, unidentified mammals, crows, great horned owls, heat of sun, and desertion, while snakes were the most important nest predators encountered in a study of three grouse species in Wisconsin (Grange, 1948:115). Skunks ranked second, and abandonment, crows, dogs, great horned owls, cattle and badgers accounted for the balance. Yeatter (1943:414) stated that the chief causes of nesting losses of greater prairie chickens in Illinois were 1) predators (crows, skunks, opossums, minks, racoons, and snakes), 2) desertion by females, 3) farming operations, and 4) failure of eggs to hatch. Lehmann (1941:37) reported that skunks and opossums were responsible for the destruction of more nests of Attwater's prairie chickens than any other predator. Other causes of nesting losses included predation by red wolves, domestic dogs, and feral house cats, as well as desertion caused by man and flooding. Lehmann (1941:38) pointed out that increased predation resulted from concentration of nests and predators in small unburned portions of burned pastures. Schwartz (1945:66) reported cases in which horses and cattle stepped on nests and crushed eggs, but believed that such losses were of minor importance.

Yeatter (1943:399) reported that no killing or injury of a female on the nest by a predator was evident in 39 nests under observation. He believed that the reduced emission of scent during the incubation which "occurs in the prairie chicken and certain other gallinaceous birds" was in part responsible for the relative safety of the nesting female. Stoddart (1932:189) reported that of 65 bobwhite quail (Colinus virginianus) nests destroyed by skunks, 52 were destroyed before incubation started. Lehmann (1941:38) presented evidence indicating that a red wolf killed one female Attwater's prairie chicken and destroyed her nest. Gross (1930) reported that four nesting hens were killed while on their nests, two by coyotes, and the other two by a great horned owl and mink, respectively.

Baker (1953:25) noted that the value of studying nests was sometimes questioned because of the effects of disturbance caused by the study. He stated that other than the nests which were destroyed by his efforts to find them, his study had little effect on the success of nests. He approached nests only in a vehicle, theorizing that this practice minimized the possibility of predators following human trails. Yeatter (1943:393) stated that nest desertions in Illinois occurred more frequently during the early part of the nesting season, usually when only a small number of eggs had been laid. He believed that females were more wary at the beginning of their nesting efforts, and that they deserted as the result of even slight disturbances. Later, when the incubation period was well underway, hens did not desert their nests readily when disturbed. Lehmann (1941:38) observed three cases of abandonment of nests by female Attwater's prairie chickens, all of which were attributed to repeated visits by man. He stated that nesting prairie chickens seemed to be especially sensitive to interference, and that repeated visits should be avoided.

Yeatter (1943:401) pointed out that the welfare of greater prairie chickens in Illinois was dependent chiefly on suitable environment during the nesting period and when the birds were very young. Schwartz (1945:67) stated that heavy rains were known to destroy many nests, though some advantageously placed have withstood torrential downpours. He believed the most serious effect of rain was when it occurred at the time of, or shortly after hatching. Lehmann (1941:32) reported that in coastal Texas, where percolation and drainage were slow in heavy prairie soils, the amount, rather than the severity, of rainfall during the nesting and brooding season appeared to be the most important hazard to reproductive success.

Gross (Bent, 1932:248) found that eggs of captive greater prairie chickens and those in one nest of a wild bird were laid at the rate of one egg every other day but not necessarily on alternate days. Baker (1953:45) and Silvy (1968:60) presented evidence that eggs were laid one per day until the clutch was completed. Schwartz (1945:66) stated that the time required to complete a clutch probably depended on such factors as weather, the health of the bird, and the availability of food. Lehmann (1941:15) reported that Attwater's prairie chickens in Texas normally laid one egg per day until the clutch was complete, but that sometimes there were intervals of one to three days between the times of egg-laying.

Clutch sizes reported for greater prairie chickens ranged from 5 to 26 eggs, and averaged between 11 and 13 (Hamerstrom, 1941:50 and Ammann, 1957:97). The largest clutches were believed by Gross (Bent, 1932:248) to have been laid by two or more females. The largest clutch of a single female was reported by Hamerstrom (1941:52) to contain 17 eggs. Yeatter (1943:391) reported one complete clutch of 16 eggs. Hamerstrom (1939:113) and Baker (1953:28) believed that the largest single clutches were begun during the height of the booming season, and became progressively smaller as the season advanced. Baker observed a negative correlation (r = -0.702) between the date of laying of the first egg and ultimate clutch size of 13 nests.

✓Schwartz (1945:67) and Gross (Bent, 1932:249) observed that during incubation, female greater prairie chickens left the nest to feed during both the early morning and late evening, walking several yards from their nests before flying to feeding areas. Gross (Bent, 1932:249) observed that females were absent from nests for period of approximately 50 minutes. Lehmann, working with Attwater's prairie chickens, noted that two feeding periods occurred each day, extending from about 7 to 8 a.m. and from about 5:30 to 6:30 p.m. When incubation was advanced, morning feeding was frequently dispensed with.

Hamerstrom (1941:53) and Schwartz (1945:67) noted that females did not cover their nests when they were away feeding during the incubation period. Gross (Bent, 1932:248) reported similar findings, but that one female was observed to cover her rather exposed nest with nesting material before departing the nest during the laying period.

Gross (Bent, 1932:66) found evidence that incubation was started before all eggs were laid. Lehmann (1941:15) reported initiation of incubation by female Attwater's prairie chickens varied from 1 day before until 4 days after the last egg of the clutch was laid.

An incubation period of 23 days for one greater prairie chicken nest was reported by Gross (Bent, 1932:247). Schwartz (1945:66) reported incubation periods of 23 and 24 days for two nests, and Baker (1953:26) found that one successful nest hatched after 22 or 23 days of incubation. Lehmann (1941:15) noted that two clutches of Attwater's chickens pipped approximately 23 and 24 days after incubation was begun, in each instance requiring about 48 hours more for the chicks to emerge. Schwartz (1945:67) found the time required for chicks to emerge from the eggs after pipping started was from 0.5 to 24 hours, and that 8 to 24 hours elapsed before all chicks had emerged and were ready to leave the nest. Gross (Bent, 1932:252) reported that the first eggs were pipped at about 22 days after the beginning of incubation, and that the time required for all chicks to emerge was sometimes less than 1 hour.

Gross (Bent, 1932:252) observed that in cases when incubation started before the last one or two eggs were laid, one or two eggs failed to hatch before the female left the nest. Conversely, Schwartz (1945:68) observed no nests from which the female departed before all eggs had hatched.

Gross (Bent, 1932:252) and Yeatter (1943:396) reported that broods left the nests a few hours after hatching, unless hatching occurred in late afternoon, in which case the females brooded the chicks overnight on the nest and left the next morning as soon as weather and temperature conditions were suitable for the chicks to move.

Schwartz (1945:66) reported that fertility of greater prairie chicken eggs appeared to be high; 100 percent of 60 eggs in five nests under observation hatched successfully. Hamerstrom (1941:52), Yeatter (1943:392) and Ammann (1957:97) also found fertility of greater prairie chicken eggs to very high.

Yeatter (1943:391) found that nests of greater prairie chickens in Illinois tended to be grouped close to booming grounds. Most nests were within a radius of 0.25 mile from the nearest booming ground, and a number of nests were from 150 to 330 yards from a booming ground. Hamerstrom (1939:115) reported that 9 of 23 nests were located within 0.5 mile of a booming ground and 10 were between 0.5 mile and 1.25 miles from booming grounds. Hamerstrom stated that such grouping of nests was not by chance, and believed that females tended to nest near the booming ground on which they were mated. Jones (1963:772), working in Oklahoma found that nests were within 0.5 mile of the nearest booming ground, or at most, a mile from the nearest booming ground. Horak (1967:7) reported that 10 nests in Kansas were an average of 0.78 mile from the nearest booming ground, and that the distance ranged from 0.61 to 1.13 miles. All nests of Attwater's prairie chickens observed by Lehmann (1941:14) were within a radius of 0.5 mile from occupied booming grounds.

Yeatter (1943:389) stated that the distance of nesting cover from booming grounds apparently influenced the choice of nest site. Schwartz (1945:63) reported that in Missouri, 56 percent of 57 nests were found in ungrazed meadows, 21 percent were in lightly grazed pastures, and 22 percent were in sweet clover, fencerows, sumacs, old fields, or barnyard grass. The cover immediately around the nest was variable, but a preference was shown for grassy sites. Hamerstrom (1941:54) found that most nests in Wisconsin were in mixed stands of open herbaceous cover. Yeatter (1943:391) noted areas near field margins, hedges, small trees and streams were often used for nesting in Illinois. Jones (1963:772), reported that nests of greater prairie chickens were very close either to cultivated pastures or old fields that were characterized by short vegetation and large percentages of forbs. Schwartz (1945:63) found that most nests were located on slopes, with no apparent selection of any direction of slope. Horak (1967:7) reported that most nests were found on north and west-facing slopes of less than 20°. No nest was more than 0.5 mile from open water, or more than 20 yards from the nearest "edge". Edge was defined as any notable change in habitat, such as trails, fencerows, creeks or marked vegetation change. Jones (1963:772) reported that all nests observed were within 0.25 mile of open water. Yeatter (1943:392) and Schwartz (1945:64) reported that concentrations of nests were observed in small areas of favorable nesting cover. Schwartz attributed concentration of nests to burning in one instance. Similar concentration of nests due to burning was reported by Lehmann (1941:15).

Schwartz (1945:64) found that nests of greater prairie chickens were rather flimsily built, and were lined with dead grass found at the nest site.

Nests were located in natural hollows of the ground or in slight excavations made by the females. Vegetation around the nest was usually quite thick, and provided concealment by arching high over the nest. Similar descriptions were presented by Gross (Bent, 1932:246), and Hamerstrom (1939:117; 1941:53).

Hamerstrom (1941:56) and Schwartz (1945:54) suspected renesting of greater prairie chickens, but could provide no direct evidence.

Baker (1953:28) noted that the dates on which first eggs were laid occurred in three groups, and that the mean intervals between groups were 16 and 17 days. He believed that such grouping indicated that renesting occurred after failure of first nests. Yeatter (1943:385) and Robel (1967:112) also believed that late nests were the products of renesting. Hamerstrom (1939:115) believed that greater prairie chickens renested, but to a lesser extent than quail, Hungarian partridges, or pheasants. Lehmann (1941:15) found that some Attwater's prairie chickens renested as many as two times after failures, for a total of three nesting efforts. Yeatter (1943:392) believed that a comparatively high percentage of female greater prairie chickens finally brought off broods successfully because of renesting. Lehmann (1941:37) also believed that nest losses to predators were somewhat compensated by renesting of Attwater's prairie chickens, though he also noted that in most cases, destructive agents had even greater opportunities to destroy renestings. Ammann (1957:101) stated that it seemed unlikely that females could renest if their first clutches were destroyed late in the incubation period. Zwickel and Lance (1965:403) presented evidence that blue grouse (Dendrapagus obscurus fulginosus) were capable of successful renesting even when a first clutch was destroyed in late stages of incubation, or possibly even shortly after hatching. They further believed that yearling hens were less capable of renesting than adults.

Broods

Schwartz (1945:68) found that female prairie chickens with broods stayed in the immediate vicinity of the nest for the first few days after hatching, and gradually moved to nearby swales if they were available. After about two weeks, the hen and chicks began to range farther from the nest toward higher areas and fields of small grain, often visiting dusting spots in grain fields, cattle trails, paths, and other spots of bare ground. Broods continued to use grain fields until late June or July. Baker (1953:71) stated that females that were successful in bringing off broods remained with their young all summer, frequenting both permanent grasslands and croplands.

Lehmann (1941:21) found broods of Attwater's prairie chickens spent their first several weeks of life in close proximity to the places where they were hatched. He believed that the daily cruising radius of a brood was small, probably less than 300 yards in the case of birds under 4 weeks old in a favorable environment. Movement of young and adult Attwater's chickens was to the vicinity of surface water, though abundant shade as well as water was available in each case, and may have been the requirement sought. Copelin (1963:37) found that broods of lesser prairie chickens in Oklahoma seemed to be more mobile in dry years when cover was sparse. One brood during a drought year had a range of 256 acres in July and August, and the greatest distance between points of observation was 1.43 miles. In a wet year, the observed range of three marked broods of lesser prairie chickens was approximately 160 acres.

Investigators utilizing radio-telemetry techniques during preceding phases of this study found brood movements to be more extensive than reported above. Cebula (1966:32) reported that two hens with broods left their nests on the day of hatching, and traveled between 1.5 and 2.0 miles in two weeks. Viers

(1967:33) found that one hen and her brood departed the nest and moved nearly 2 miles overland in 7 days. Movements of broods in late summer were not extensive, and were confined to grassy ravines. Silvy (1968:92) reported that a radio-tagged hen and brood moved 2 miles from the nest site in 6 days.

Schwartz (1945:69) stated that greater prairie chicken chicks between 8 and 10 weeks old were seldom found with the hen, and that family groups gradually dispersed after chicks reached that age. Lehmann (1941:19) found that many young Attwater's prairie chickens left family groups at 6-8 weeks of age to take up life on their own, but that all young did not leave the hen at the same time. He found that some young remained with hens well into the fall. He believed that young prairie chickens at the age of 6 weeks were as capable of foraging and resisting adverse weather as were adults.

Copelin (1963:46) observed that some, and perhaps most, young lesser prairie chickens used display grounds during the first fall after they were hatched. Some occupied grounds within 0.25 or 0.5 mile of their brood range, while others moved more than 2 miles. He believed that additional movement and mixing of the population occurred in spring as juveniles moved from feeding grounds to display grounds and from one display area to another. Young females moved further than males, and birds of the same brood sometimes gathered on the same display ground, whereas other broods sometimes split up, going to separate display grounds.

Jackson (1967:35) reported that band returns from prairie grouse banded as juveniles (predominantly sharptails) revealed average distances from banding sites of 4.35 miles for 62 females, and 1.89 miles for 61 males. Sixty-five and 85 percent of the band returns for juvenile males and females, respectively, were from within three miles of the banding sites.

Baker (1953:17) observed that, by the first of September, young prairie chickens in Kansas were indistinquishable from adults, and at that time they began to assemble in flocks.

Yeatter (1943:414) found an average loss of approximately 46 percent of young prairie chickens during the first 5 weeks after hatching. Lehmann (1941:20) believed that the actual survival of young prairie chickens was probably always well below the potential yield, even when favorable weather conditions obtained during the critical period of the breeding season. He found that the juvenile mortality of Attwater's prairie chickens was heaviest during the first 4 weeks of life and comparatively light thereafter.

Jones (1963:772) found that brood ranges generally had greater percentages of forbs than areas used for other activities. The cultivated pasture association was most frequently selected by hens with broods. He found that cover was dominated by low weeds and annual lespedeza, with pockets of taller weeds which provided resting cover for small chicks. Insects were the principal foods of greater prairie chicken broods, comprising 97 percent of identified foods. Vegetation of feeding sites were closely correlated with food requirements, with greater insect availability in areas with greater percentages of forbs. Lehmann (1941:30) found that broods were found in light to medium cover, while Briggs (1968:49) reported that moderate to heavy cover was perhaps required in the Flint Hills region of Kansas.

Radio Telemetry

Cebula (1966), Viers (1967) and Silvy (1968) presented extensive reviews of the literature on radio-telemetry, including history, development, systems, techniques, accuracy, and lists of species studied by use of radio-telemetry. Since it appears that equipment and techniques have become established, accepted, and to some degree, standardized, the reviews of the foregoing workers will not be repeated herein. However, as noted by Silvy (1968), the following general references to radio-telemetry techniques have gradually become available.

Slater (1963) presented the reports of contributing authors of Bio-Telemetry concerning many aspects of radio-telemetry. Pienkowski (1965) gave formulae for prediction of range and life of transmitters, and Ko (1965) reported on progress and problems involved in radio-tracking studies. Adams (1965) evaluated radio-telemetry as a technique in ecological research. Siniff and Tester (1965) and Tester and Siniff (1965) described the use of digital computers to process and accumulate vast amounts of data obtained by automatic radio-tracking equipment. An automatic tracking system and digital computer were used by Heezen and Tester (1967) to evaluate the accuracy of radio-tracking by triangulation.

MATERIALS AND METHODS

Study Area

The study area was located in north-central Geary County, approximately 9 miles east-southeast of Junction City, Kansas. All or part of sections 3-5, 8-11, 14-16, 21-24, and 25-27 each inclusive, of T12S, R7E, Geary County, Kansas were included in the study area. Most of the area was within the borders of the 6,000-acre Simpson Ranch.

The topography of the study area (Fig. 1) was dominated by a high, slightly rounded, branched ridge 0.9 to 3.9 miles wide which was fringed with limestone rock outcrops and intersected with small drainages of intermittent streams. This ridge, one of a series of similar ridges in the general area, was oriented in a northwest-southeast direction with secondary ridges and drainages of intermittent streams generally oriented southwesterly toward Humboldt creek, and northeasterly toward McDowell creek. The low, flat floodplains of McDowell and Humboldt creeks provided natural boundaries along either side of the area.

The elevation of the area varied from an average of about 1400 feet along the highest portions of the major ridge, to slightly greater than 1100 feet in the bottom of the creek drainages.[1/]

Vegetation of the area was characteristic of the Flint Hills region in northeastern Kansas (Herbel and Anderson, 1959) except that some ridge tops were cultivated in the late 1920's and have an abundant growth of annuals. Vegetation on the upland portions of the area consisted of tall, mid and short grasses, with dominants being little bluestem (*Andropogon scoparius*),[2/] big bluestem (*Andropogon gerardi*), tall dropseed (*Sporbolus asper*), western wheatgrass (*Agropyron smithii*), sideoats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*), and buffalo grass (*Buchloe dactyloides*). Other grasses and forbs occurring in the area were slimflower scurfpea (*Psoralea tenuiflora*), prairie three-awn (*Aristida* spp.), Japanese brome (*Bromus japonicus*), downy brome (*Bromus tectorum*), western ragweed (*Ambrosia psilostachya*), western yarrow (*Achillea millefolium*), green milkweed (*Asclepias viridiflora*), broomweed (*Guiterrezia dracunculoides*), purple prairie clover (*Petalostemum purpureum*), and Louisiana sagewort (*Artemesia ludoviciana*). Briggs (1968) presented results of detailed vegetation analysis of three major range sites on the study area; the claypan site, the shallow site, and the limestone breaks site.

[1/] U.S. Department of Interior Geological Survey Contour Map, 1955

[2/] Common and scientific names follow Anderson (1961)

Trees and shrubs found in the uplands, especially in overgrazed areas, around field borders, along limestone breaks and intermittent streams included: coralberry or buckbrush (Symphoricarpos orbiculatus), smooth sumac (Rhus glabra), aromatic sumac (Rhus aromatica), dogwood (Cornus drummondii), New Jersey tea (Ceanothus ovata), wild plum (Prunus americana), American elm (Ulmus americana), cottonwood (Populus spp.), willows (Salix spp.) and false indigo (Amorpha fruticosa). The latter three species were restricted to wetter, lowland sites.

The stream valleys along either side of the study area were heavily wooded, with such representative species as burr oak (Quercus macrocaroa), chinquapin oak (Quercus muhlenbergii), black walnut (Juglans niger), ash (Fraxinus spp.), box elder (Acer negundo), hackberry (Celtis occidentalis), and other deciduous trees and shrubs. Eastern redcedar (Juniperus virginiana) was dominant along the steep east-facing slopes of the Humboldt creek valley, perhaps as a result of continued heavy grazing of wetter sites.

Cultivated crops grown on the study area included winter wheat (Triticum aestivum), grain sorghum (Sorghum vulgare), oats (Avena sativa), and alfalfa (Medicago sativa), and were limited to 97 acres adjacent to the northwest corner of the Simpson Ranch.

Two cultivated fields on the Simpson Ranch which previous to 1966 produced winter wheat (75 acres) and grain sorghum (65 acres) were reseeded to native grasses during the summer and fall of 1966. A considerable growth of volunteer grain sorghum was present in the 65-acre field during the fall and winter of 1967-1968, though dominants on the old field areas were tall annual forbs with a few annual grasses. Superficial examination of the areas during the summer of 1968 revealed that annual grasses were dominant, and that a few native perennial grasses were beginning to appear. Additional small old fields occurred within the area, and were in varying late stages of grassland succession.

From the time of initiation of the study in 1963, grazing practices included moderate year-round grazing of cow-calf units, with a limited amount of season-long grazing by steers and rotation of pasture use. A marked change occurred in the spring of 1968, when breeding of registered stock was discontinued by the owners and the ranch was leased for season-long grazing by steers brought in from the southwestern United States.

On 18 April 1968, the entire northern portion of the ranch was intentionally burned. Additional grassland acreage adjoining the ranch on the north was also burned at that time through cooperation of adjacent landowners.

The area had not been burned previously during the course of the study, but an accidental fire burned most of the northern portion of the Simpson Ranch in the fall of 1963. Native prairie hay was baled and removed from some slopes during the period 1964-1966.

Three traditional booming grounds, designated "north", "central", and "south" (Fig. 1), were utilized by displaying males during each season from 1964 through 1967. An additional "territorial" booming ground (Hamerstrom and Hamerstrom, 1949:327) was observed by Silvy (1968:23) during the spring of 1967. Only two of the three traditional grounds were utilized during the spring booming season of 1968.

Live-trapping and Banding

Prairie chickens were live-trapped during the study in order to attach leg bands, patagial markers, and miniature radio transmitters. Most live-trapping was accomplished on established booming grounds during the spring and fall booming seasons.

Japanese mist nets, rigged in the manner described by Silvy and Robel (1968) were the most extensively used method for display ground trapping (Plate I, Fig. 1). Nets[1/] were 2-ply, 4-inch mesh black or sand-colored nylon with three shelf-strings and measured 7 x 60 feet. Nets were inclined at ground level with the distal edge to the booming ground elevated about 30 inches above the ground. Steel rods were used to anchor the ends of each net. Mist nets were erected on the booming grounds before dawn each morning, and were constantly tended during each trapping period from a blind erected on the edge of the booming ground. As many as three nets were used at a time, but most often two were used arranged in a "V" pattern with the open end facing toward the expected direction of approach by the birds.

Bow nets (Plate I, Fig. 2) constructed after the design of Anderson and Hamerstrom (1967:829) were used during the spring booming season of 1968. Modifications of the original design included the substitution of 8-foot lengths of 3/8-inch aluminum alloy rod for 7-foot lengths of 3/8-inch iron rod in constructing bow frames, and the use of a sensitive trigger (Plate I, Fig. 2) rather than a simple pull-stake type trigger.

Bow nets were placed on level ground within the territories of males to be trapped. Hen decoys mounted in the receptive position were placed within the crescent of the cocked trap and served to attract males into position where they could be trapped by tripping the trigger device with a long nylon cord leading to the blind. Bow nets were set with the open end of the set

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[1/] Obtained from Bleitz Wildlife Foundation, Hollywood, California. A special permit from the U. S. Fish and Wildlife Service is required for use of mist nets to capture migratory birds in the United States.

trap facing the blind, as recommended by Anderson and Hamerstrom, so that the struggles of a bird in attempting to escape the trapper were directed into that portion of the trap which was firmly stapled to the ground.

No attemot was made to camouflage bow nets by dyeing or painting, but litter from the booming ground was used to cover the cocked trap, providing effective concealment.

A 14 x 60-foot drop net was constructed by splicing two 7 x 60-foot Japanese mist nets along their long edges. Peripheral edges of the joined nets were bound with dark-colored parachute shroud line to provide strength and additional weight, and aluminum rings were attached at three equidistant locations on each of the 14-foot sides to engage trigger pins. The net was supported by three 6-foot lengths of 3/4-inch electrical conduit along each of the 14-foot edges of the net. These support poles were set into the ground about three feet and inclined at angles of about 30^{0} away from the center of the net. One-quarter-inch holes drilled through the support poles at an angle of 60^{0} permitted insertion of trigger pins which engaged rings attached to the net. The trigger mechanism used for this net was similar to that illustrated by Jacobs (1958) and was operated by a long nylon pull cord extending from the trap into a blind located on the edge of the booming ground. The trap was constructed so that it could be used in the same manner as the Japanese mist nets oreviously described. Either the proximal or distal edge could be placed against the ground, and the remainder of the net could be dropped by tripping the trigger from the blind.

A 40 x 60-foot woven nylon net of 2-inch square mesh, projected by three "composite" cannons (Smith, 1962:3) was used during the last week of active booming of the 1968 spring season in attempt to capture females for nesting studies. Earlier use of the cannon net was avoided because of possible behavioral disturbance (Silvy, 1968:70).

A portable electric fence was constructed around the booming grounds during trapping operations to prevent interference by cattle. Tape recorded vocalizations (Silvy and Robel, 1967; Silvy, 1968:25) of displaying male prairie chickens were used daily during the display seasons to expedite trapping by all methods. Recordings were placed on Scotch III plastic magnetic tape at a speed of 7.5 ips and were broadcast by a Wollensak 1700 tape recorder powered by a 12-volt storage battery. An Olson TA-146 endless tape device was used during the spring of 1968, which freed the observer from constant watching of tape reels, and allowed uninterrupted concentration on trapping activities.

Broadcasts were made from blinds at the edge of booming grounds with either the internal speaker of the recorder or a Lafayette SK-128, 8-inch biaxial speaker. The speaker was oriented upward, usually located in the center of the booming ground, and concealed with vegetation.

Female decoys mounted in the receptive position (Anderson and Hamerstrom, 1967; Silvy, 1968:26) were used in conjunction with all display ground trapping methods to attract males to areas on the booming grounds where traps were placed.

A dip-net, 5 feet in diameter and covered with a shallow bag of 2-inch square mesh knotted nylon netting, with a handle fashioned from a 10-foot length of 1-inch aluminum tubing, was used for night recaptures of radio-tagged birds and to capture incubating females on nests. During night re-captures, the bird was first located by use of a portable receiver and hand-held antenna, blinded with a 7-cell flashlight, and then netted by the investigator or an assistant who approached the bird from the same direction.

Funnel-type walk-in traps of two types were used on feeding areas during late fall, winter, early spring, and mid-to late summer. Two large (6 x 10 x 4-foot) rectangular traps were constructed of 2 x 4-inch welded wire mesh, turned inward at one end to provide a funnel entrance approximately 4 inches wide at the narrowest point. These traps were covered on top with 2-inch mesh cotton fish netting to prevent injury to birds attempting to escape. Mature heads and grain of grain sorghum were used for bait during the entire period. Walk-in traps used in wheat and oats stubble fields during mid-to late summer were smaller and lower (4 x 4 x 2 feet) with single funnels constructed of 1-inch mesh chicken wire, with the outer opening approximately 12 inches in diameter, the inner opening 6 inches in diameter, and 18 to 20 inches in depth. A 1:1:1 mixture of grain sorghum, oats, and wheat was used during summer trapping.

Other equipment used included: 1) black cotton stockings which were placed over the heads of captured birds to calm them, 2) numbered aluminum butt-end leg bands, 3) colored plastic bands (Hamerstrom and Mattson, 1964) and 4) patagial tags (Anderson, 1963). All captured prairie chickens were released immediately at the capture site after banding, marking and attachment of transmitters.

Radio-telemetry

Radio-tracking materials and techniques used in this study were developed by Marshall (1960), described by Cebula (1966), Viers (1967) and modified by Silvy (1968). Transmitters and receivers were constructed by Sidney L. Markusen of Esko, Minnesota. The transmitters measured 0.5 x 1.25 inches, weighed 6 to 7 grams and were encased in nylon tape coated with epoxy (Plate II, Fig. 1). Transmitters were of the continuous-broadcast type and operated at discrete frequencies between 150.815 and 151.085 Mc/S with a power output of 0.01 watt. A crystal oscillator circuit transistor and an 11-inch soring steel wire antenna comprised each transmitter. Transmitters were powered by either one or two mercury batteries, each weighing 12 grams (Mallory RM401).

Harnesses fashioned from 0.1-inch diameter plastic tubing were used to attach transmitters to prairie chickens in the manner described by Silvy (1968:29). Two 10-inch lengths of the plastic tubing containing wire leads were installed by the manufacturer on the front of each transmitter. A loop large enough to fit around the neck of a prairie chicken was formed from the two 10-inch lengths of tubing (Plate II, Fig. 1). A slit was made in the tubing approximately 4 inches from the point where tubing and leads were attached to the transmitter body. Wire leads were then extracted through the slits, and clipped at a point about 0.5 inch from the openings in the tubing. The end of each lead wire was then stripped back about 0.1 inch and inserted through the center of a plastic "snap cap" and soldered to a 0.25-inch square piece of thin sheet brass. The snap caps were then fitted over both ends of a olastic vial consisting of the too 0.5-inch of two 5 cubic-centimeter artificial inseminating vials cemented together, producing a vial with snap caps at both ends. The snap caps supplied enough oressure to make a strong connection between the brass contacts and the battery. The battery package was then taped with plastic electrical tape to seal out moisture. Two such battery packs were connected in parallel (Silvy, 1968:29) and attached to most transmitters intended for use on adult male prairie chickens during this phase of the study.

Attachment of transmitters to prairie chickens was accomplished by placing the loop between the transmitter and battery pack over the head of the bird so that the battery was suspended over the bird's crop. The plastic tubing extending beyond the battery pack was passed under each wing and both ends threaded through a tape and epoxy loop at the rear of the transmitter and tied with a square knot. Excess tubing was clipped about 1.25 inches from the knot and the protruding ends were taped securely to the transmitter body with plastic electrical tape.

Receiving equipment consisted of three portable receivers specifically designed for radio-tracking. Receivers were 12-channel, transistorized, crystal controlled, double conversion superheterodyne mechanisms. The two receivers on hand during this phase of the study were powered by 10 size "C" flashlight batteries. Receiver components were contained in an aluminum case 6 x 7 x 12 inches. Total receiver weight was 4.5 pounds. Padded canvas carrying bags with neckstraps were constructed for each receiver for protection and ease of handling (Plate II, Fig. 2). Receivers were equipped with earphones for audible detection of transmitter signals. Controls included an on-off switch and volume control, channel selector, battery test button, circuit switch, sensitivity control, beat frequency oscillator (BFO) switch and control, meter grain and vernier tuner. Directional antennas were connected by means of coaxial fittings.

Receivers were operated by turning the set on and selecting the desired channel for receiving a particular transmitter. The vernier tuner was slowly adjusted back and forth, while the antenna was rotated until a tone was audibly detected. Vernier tuning was continued to obtain maximum volume of the signal. Finer tuning was obtained by adjusting the BFO and sensitivity controls. The antenna was then swung in an arc to determine the null points on either side of the maximum signal reception. The azimuth of the signal was calculated by bisecting the arc between the null points. This procedure was repeated at one or two other locations in order to locate the transmitter by triangulation.

Three types of directional antennas were available for use in combination with portable receivers. Eight permanent receiving stations were located in a grid-like pattern along the ridge tops in the central portion of the study area, and were spaced approximately 0.5 mile apart. Details of construction, location, accuracy and use of the permanent antennas were given by Slade, et al. (1965), Cebula (1966:11), Viers (1967:14) and Silvy (1968:32).

Two mobile receiving stations were constructed by mounting directional yagi antennas in "stake pockets" at the corners of the beds of two pickup trucks as shown in Plate III, Fig. 1. Compass cards were secured to the bed of the truck and a pointer was inserted through a hole in the mast. A lead-in cable extended from the yagi to the bed of the truck where the receiver was located. Azimuths were recorded as degrees deviation from imaginary base lines connecting the mobile stations with visible landmarks.

Hand-held directional antennas (Plate III, Fig. 2) were the most frequently employed type during this phase of the study. Each hand-held antenna consisted of a tubular conduit handle supporting two 30-inch heavy wire elements at right angles to the handle. A lead-in cable about 2 feet long connected the antennas to portable receivers. Radio-tagged prairie chickens were located by circling the position of the bird and obtaining several bearings from different locations. Locations of radio-tagged birds were noted in relation to visible landmarks and plotted on maps derived from aerial photographs of the area. Hand-held antennas were also used to flush radio-tagged birds to ascertain their physical condition, to locate nesting females, and to check the accuracy of the equipment.

Attempts were made to locate each radio-tagged prairie chicken once or twice each day at different hours to determine daily and seasonal movements. All radio-determined locations were plotted on base maps of the areas to provide histories of all birds tracked.

Monthly ranges in acres were calculated for each individual prairie chicken for which 15 or more locations were made during a particular month. Ranges were determined by joining outermost points of location (Mohr, 1947) and measuring the map area within the joined points with a compensating polar planimeter.

Distance in yards between each successive daily location was determined by measurement from a base map. Ranges and distance of movement for each individual prairie chicken were placed in month-classes. A table of random numbers was used to select the location to represent a particular day if two or more locations were made during that day. Movements from the last day of a month to the first day of the succeeding month were included in the values for the former month.

Means, variances, standard deviations and standard errors were calculated for monthly ranges and movements using methods described by Snedecor (1956).

Reproductive Studies

Observations were made on both the central and north booming grounds during the spring booming season of 1967-1968. With the exception of a few small unburned areas, the entire area presumed to comprise the "sphere of influence" (Schwartz, 1945:48) of the north booming ground was intentionally burned on 18 April 1968. Attendance records, particularly of the visits and numbers of females on the two grounds, were compared in order to ascertain the effects of burning on nesting success.

Three methods were used to locate nests of female prairie chickens: 1) flushing radio-tagged birds when nesting was suspected, 2) direct observation of females making flights from nests to feeding areas, and 3) searching areas of suspected nest habitat with the aid of a dog.

Thermistor probes placed in prairie chicken nests and attached to a Rurtrak model 133 dual channel recorder were used for recording laying periods and nest attentiveness of female prairie chickens. Electronic equipment was used by Baldwin and Kendeigh (1927) for measuring nesting activities of the house wren (Troglodytes aedon) and Kessler (1960) to measure egg temperatures of the ring-necked pheasant (Phasianus colchicus).

The recorder was powered by a 12-volt storage battery, and was capable of recording temperatures between 20^{o} and 120^{o}F. Two model 1333 banjo-type probes equipped with 60 or 110-foot lead cables were used to monitor temperatures in the nest and in a "dummy" nest site located near the nest. The sensor end of the probe was placed in the center of the natural nest at a height of approximately 1.25 inches, and was held in place by a small wire loop attached to a short wooden peg imbedded in the ground flush with the bottom of the nest (Plate IV, Fig. 1). Ambient air temperature was measured in the same manner in an artificial nest located within 5 yards of, and constructed to resemble, the natural nest. Leads of both probes were camouflaged along their entire length by covering them with natural vegetation and litter. An 8 x 13 x 20-inch plastic container was used to house the recorder and its power source, and was located in tall vegetation as far from the nest as the leads would allow. The plastic container was surrounded by rocks and the open front covered with transparent polyethylene film to protect the instruments (Plate IV, Fig. 2).

In order to estimate the extent of nesting losses, two sets of ten dummy nests of ten uncleaned domestic pullet eggs each were constructed in sites similar to those in which natural nests had been found. Nest sites were stratified according to the three major range sites on the area, and were randomly located within site. Nests were left in place for two weeks (13-27 June, and 14 July to 2 August) during the summer of 1967. Hair catchers, constructed from number 12 wire which was flattened at one end and slit at intervals along the top to provide burred edges (Hartesvelt, 1951), were placed around each dummy nest to aid in identification of predators responsible for destruction. Nests were checked each day, and any missing or destroyed eggs were replaced. Nests were checked on foot or from a vehicle without alighting, with each nest being checked the same way each time.

During the summer of 1968, 64 dummy nests were set out on the study area during each of three 21-day periods beginning 2 May, 3 June, and 7 July. Sixteen nests of each set were placed in each of four different sites; claypan range site, shallow range site, limestone breaks range site and a burned site. Nests in the burned site were placed in small areas of grass left unburned by the controlled burn on 18 April 1968. The method (treatment) by which each nest was checked was randomly assigned. Of the 16 nests in each site, 4 were checked by approaching on foot, designated "walk"; 4 from a vehicle without alighting, designated "drive"; and 4 marked with red surveyor's flags and checked by driving to within 25 yards and making the final approach on foot. The marked group were designated by the term "flag". The fourth treatment consisted of four "control" nests which were not checked during the 21-day period. Hair catchers were not used in conjunction with dummy nests during the 1968 period, though standard references were used to identify predators responsible for destruction (Rearden, 1951; Einarsen, 1956).

Brood searches were conducted during early morning hours between the dates of 29 June and 17 August 1967, and 28 June and 15 August 1968. Approximately 50 hours were spent in the field with one dog and one or two observers during the 1967 period, and about 40 hours with one observer and two dogs during 1968. Search periods lasted from 2 to 3 hours, depending on temperature and humidity conditions for optimum dog work. Areas searched included wheat and oats fields (mature plants and stubble), one alfalfa field, old field areas, and field borders.

Habitat Preference

Vegetation Density

During the 1967-1968 phase of the study, vegetation density was sampled at each of 20 transects established on the study area by Briggs (1968). Sampling was accomplished during the summer (10 July through 30 August), fall (6-11 November), winter (10-20 March) and spring (25-27 May). Nine transects were located on the limestone breaks range site and five transects each were located on the shallow and claypan sites. One transect was placed on an unseeded portion of an old field. Twelve transects in addition to those of Briggs (1968:15) were located in the northern portion of the ranch which was intentionally burned on 18 April, and were sampled during the spring period of 1968. Four of the twelve transects established on the burned area were placed in each of the three major range sites.

Vegetation density along each of the transects was measured by the method described by Briggs (1968:17). A round stake, 3 x 150 cm. was painted brown and white in alternating decimeters (Fig. 2). The midpoint of each decimeter was marked with a narrow black stripe, making it possible for an observer to distinguish half-decimeters on the pole.

At the zero-meter plot of each transect, the pole was placed vertically in the vegetation 10 cm. to the west of the tape. The observer, positioned exactly 4 meters due south of the pole, viewed the density pole from heights of 0.5, 0.8, and 1 meter. The lowest half-decimeter visible on the pole was recorded for each of the three respective heights of observation. The observer then moved to a distance of 3 meters from the pole and repeated the three height observations. This was done again at a distance of 2 meters south of the pole. The density pole was then moved to each subsequent alternate meter mark along the 20-meter tape and the series of observations repeated for a total of 90 density readings per transect. These 90 readings were averaged and then used as the density index for the transect.

In order to test the assumption that Briggs' method provided an accurate estimate of vegetation density, seventeen 20-meter transects were selected which presented visibly different densities that were evenly distributed along a scale from the lowest to the highest density on the area, and which contained different proportions of plants of several life forms. Each transect was first sampled by the method of Briggs, and then ten 0.10 square-meter plots located at alternate meters along each transect were clipped to 0.5 decimeter above ground level, collected and oven dried at 60°C for 48 hours before weighing.

Habitat Relationships

Radio-telemetry locations of prairie chickens were analyzed in terms of site, season, and time of day. Site classifications included the three major range sites; claypan, limestone breaks, and shallow, as well as two general types of cropland; wheat and oats combined, and grain sorghum.

The day was divided into three portions to determine possible relationships between site preference and time of day: 1) a morning period, between midnight and the first 20 percent of the sunrise-to-sunset period, 2) a mid-day period, between 20 and 80 percent of the sunrise-to-sunset period, and 3) an evening period, including the last 20 percent of sunlight and all locations made before midnight.

RESULTS

Trapping and Banding

A total of 176 greater prairie chickens was trapped during the entire study, with 45 of these being trapped during the 1967-1968 phase (Table 1). Of 112 birds banded during the period 1964 through 1968, 29 were banded during the 1967-1968 phase. Sixty-four birds were recaptured during the entire study, with 16 taken during the 1967-1968 phase. Forty-seven radio-tagged birds were recaptured during the entire study, and nine such recaptures were accomplished during the current phase. Trapping operations killed seven prairie chickens during the entire study, five of which were killed during 1967-1968. Of the five killed during the 1967-1968 phase, two died in mist nets which were left unattended on a booming ground overnight, one was killed by a red-tailed hawk while in a walk-in trap, one was killed by a coyote while in a walk-in trap, and one died of suffocation while being handled.

Female decoys posed in a receptive position aided directly in the capture of three male prairie chickens, and probably contributed to the capture of most other males. Recorded vocalizations of displaying male prairie chickens aided in luring birds of both sexes into areas where traps were located.

Table 1. Summary of prairie chickens trapped by all methods for the entire study and for the 1967-1968 phase of the study.

	Trapping Method					
	Mist Net	Cannon Net	Walk-in	Hand Dip-net	Bow Net	Totals
1967-1968						
Males	7	1	3	5*	2	18
Females	5	0	4	3	0	12
Juveniles	6	0	4	4*	1	15
Totals:	18	1	11	12	3	45
Entire study						
Males	17	50	5	18*	2	92
Females	12	14	5	21	0	52
Juveniles	7	4	6	14*	1	32
Totals:	36	68	16	53	3	176

*Includes one bird caught by hand.

Radio Telemetry

All telemetry equipment performed satisfactorily during the 1967-1968 phase of the study. One hundred transmitters were placed on 70 different birds during the entire study. Of these, 49 were recovered and 43 were lost. Twenty-five transmitters were placed on 23 birds during the 1967-1968 phase, and ten were recovered and 13 lost.

Of the ten transmitters recovered during the 1967-1968 phase of the study, six were from birds known to have been killed by predators, two from birds recaptured when the phase was terminated, and one was from a bird found dead from unknown causes. Ten transmitters were lost for unknown reasons, one was known to have been lost by the bird which was carrying it, and inoperative transmitters were observed on two birds during routine field work.

During the entire study, four radios were known to have been lost from radio-tagged birds. Male AM86 was radio-tagged on 8 February 1968, and tracked until 13 April. When the bird was observed on the central booming ground on 13 April, it was noted that the harness had broken and the battery pack was dangling loose below his breast. Attempts were made to recapture the bird on 13, 14, and 15 April without success. On 17 April the bird was seen on the booming ground without the transmitter.

A total of 2,229 "bird-days" of location data was obtained during the entire study, 701 of which were collected during the 1967-1968 phase. An average of 32 days of location data per bird was obtained for the entire study, and 31 days per bird for the current segment. A total of 3,214 locations of 70 different radio-tagged prairie chickens were obtained during the study with an average of 46 locations per bird. During the 1967-1968 phase, 873 locations were made, with an average of 38 locations per bird.

Table 2 gives total and average number of bird days and locations for each sex and age class.

In only two instances were injuries to the radio-tagged birds noted. One case of abrasion under the wings was noted when bird AF83 was recaptured on the night of 11 July 1967 in order to accomplish a routine battery change as described earlier. The harness was readjusted, and when the bird was recaptured again on 30 August 1967, no evidence of injury was apparent. One 10-week old juvenile (JU112) was radio-tagged on the night of 12 August 1968. In order to fit a too-large harness, tubing was looped and taped to the transmitter body, causing it to ride in a nearly vertical position. When the bird was recaptured on 7 September 1968, it was unable to fly, and a large (1-inch diameter) open sore was noted on the bird's back. The transmitter was removed and the bird released near the capture site. The movements of JU112 had not differed from two other radio-tagged members of the same brood, and the hen and brood were together when the bird was recaptured on 7 September 1968.

Mobility Studies

Sufficient numbers of locations were obtained during the 1967-1968 phase of the study to estimate 28 individual monthly ranges for the 23 birds that were radio-tracked.

The mean monthly range (Table 3) of adult male prairie chickens was smallest in August (48±19 acres) and largest for the month of March (952±143 acres).

Table 2. Summary of radio-telemetry data obtained during the 1967-1968 phase and during the entire study.

Sex and age class	Bird-days of radio-tracking			Number of locations	
1967-1968	N	Total	Average	Total	Average
Adult Males	7	261	37	351	50
Adult Females	11	243	22	294	27
Juvenile Males	2	142	71	168	84
Unsexed Juveniles	3	55	18	60	20
Total:	23	701	31	873	38
Entire Study					
Adult Males	27	943	35	1,465	54
Adult Females	28	761	27	1,129	40
Juvenile Males	7	322	43	351	50
Juvenile Females	3	138	46	187	62
Unsexed Juveniles	5	65	18	82	16
Total:	70	2,229	32	3,214	46

Table 3. Mean monthly ranges of 23 prairie chickens, by sex and age class, for the 1967-1968 phase of the study. Numbers in brackets represent number of birds tracked during each month.

Month	Mean Number of Locations				Mean Area of Monthly Ranges*			
	Adult Male	Adult Female	Juvenile Male	Unsexed Juvenile	Adult Male	Adult Female	Juvenile Male	Unsexed Juvenile
January	- - -	- - -	50 {1}	- - -	- - -	- - -	440**	- - -
February	23 {1}	- - -	26 {1}	- - -	655**	- - -	208**	- - -
March	37 {2}	- - -	28 {1}	- - -	952±143	- - -	697**	- - -
April	20 {1}	- - -	- - -	- - -	370**	- - -	- - -	- - -
May	- - -	16 {1}	- - -	- - -	- - -	2590**	- - -	- - -
June	23 {2}	25 {3}	- - -	- - -	629±443	754±543	- - -	- - -
July	31 {1}	33 {2}	- - -	- - -	275**	457±134	- - -	- - -
August	23 {2}	32 {2}	- - -	17 {3}	48±19	441±383	- - -	163±3
September	- - -	18 {1}	- - -	- - -	- - -	158**	- - -	- - -
October	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
November	31 {1}	- - -	- - -	- - -	360**	- - -	- - -	- - -
December	30 {1}	- - -	28 {2}	- - -	701**	- - -	2171±132	- - -

* All ranges in acres; mean ± $S_{\bar{x}}$

**$S_{\bar{x}}$ not calculated

Sufficient data for adult females were obtained to calculate mean ranges for the months of May through September. Mean ranges varied in area from 158[1] acres in September to 2,590 acres in May.

Ranges for juvenile male prairie chickens were obtained for the December through March period only. The greatest mean range during this period was in December (2,171±132 acres), and the least average area was recorded for the month of February. January, February, and March averages were calculated from locations of only one bird during each month, and may not be representative of trends of monthly ranges.

Ranges for three unsexed juvenile prairie chickens, presumed to have been members of the same brood, were calculated for the month of August. During the period between the approximate ages of 10 and 12 weeks, the brood remained together and with the hen (though temporary departures were noted) and traversed an area of 163±3 acres.

A goodness-of-fit test (Ostle, 1963:38) for daily movement data collected between 16 June 1967 and 15 June 1968 indicated that the movements represented samples from an exponentially distributed population (was not significantly different at the $P<0.01$ level). Goodness-of-fit tests of hypotheses that movement data represented samples from normal or Poisson populations were rejected ($P<0.05$). For this reason, the standard errors of the means are given, but it should be noted that the variability they represented was not symmetrical about the means. Normality was assumed for the mean monthly ranges.

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[1] $S_{\bar{x}}$ not calculated

The mean daily movements of adult male prairie chickens tracked during the 1967-1968 phase of the study varied from a low of 228 (23)[1/] yards in August to a high of 857 (124) yards in March (Table 4). Movements increased in magnitude from August through March, and showed a general, though not consistent decrease from March through August. The greatest movements during the summer months were recorded in June, with a daily average of 460 (55) yards. Of the fall months, data were obtained only for November with a mean daily movement of 296 (43) yards. The longest movements of adult males in winter occurred in February with a mean of 764 (124) yards, and spring movements were more extensive than during any other season, with the longest movements occurring in March, with a mean of 857 (124) yards.

The shortest movements of adult females were recorded in July, with an average of 363 (41) yards, and the greatest movement was in May, with 916 (174) yards. No movement data were obtained for adult females during the fall or winter months.

Movement data for juvenile males were obtained for the months of November through March. The shortest movements during that period were in March, with an average of 364 (102) yards, and the longest movements were in December, with a mean of 865 (87) yards.

Three unsexed juvenile birds, presumed to have been members of the same brood, were tracked from the age of 10 weeks to nearly 14 weeks during August and September 1968. Daily movements of the hen and brood during August averaged 284 (26) yards.

1/ $s_{\bar{x}}$

Table 4. Mean daily movement, by month, for 23 prairie chickens radio-tracked during the 1967-1968 phase of the study. Numbers in brackets represent number of birds tracked during each month.

	Number of Movements				Mean Distance of Daily Movements			
Month	Adult Male	Adult Female	Juvenile Male	Unsexed Juvenile	Adult Male	Adult Female	Juvenile Male	Unsexed Juvenile
January	5 {1}	- - -	31 {1}	- - -	531(95)*	- - -	493(74)	- - -
February	22 {1}	- - -	25 {1}	- - -	764(124)	- - -	514(58)	- - -
March	51 {2}	17 {4}	24 {1}	- - -	857(124)	454(98)	580(77)	- - -
April	11 {1}	10 {2}	- - -	- - -	524**	680(159)	- - -	- - -
May	6 {1}	11 {1}	- - -	- - -	759(126)	916(174)	- - -	- - -
June	57 {3}	80 {5}	- - -	- - -	452(52)	588(84)	- - -	- - -
July	33 {2}	70 {3}	- - -	- - -	460(55)	363(41)	- - -	- - -
August	35 {2}	40 {2}	- - -	39 {3}	228(23)	595(55)	- - -	284(26)
September	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
October	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
November	25 {1}	- - -	9 {1}	- - -	296(43)	- - -	364(102)	- - -
December	25 {1}	- - -	46 {2}	- - -	532(104)	- - -	865(87)	- - -

* All distances in yards; mean ($S_{\bar{x}}$)

** $S_{\bar{x}}$ not calculated

Sufficient data were obtained to determine seasonal and daily movement patterns of several birds. Portions of the histories of selected individual birds are presented herein to exemplify movements and activities of particular interest.

Movements of birds of both sexes between booming grounds were observed during the 1967-1968 phase of the study. One male and one female marked with red plastic leg bands were observed on the north booming ground during the spring booming season of 1968. Neither bird could be specifically identified since band numbers could not be read, but red bands were placed only on birds trapped on the central booming ground. Two adult male birds were observed by radio-tracking to move from one booming ground to the near vicinity of another. Bird AM40 was trapped on the central booming ground on 18 May 1967, and on 20 June was located within 150 yards of the north booming ground. By that date, regular booming activity on the north ground had ceased. Bird AM87 was trapped on the central booming ground on 10 March 1968, and remained in its vicinity until 22 March when movement toward the north ground was detected. Locations of AM87 were made within 150 yards of the north booming ground on 25 and 26 March, and he remained in the area until 4 April, when the signal from his transmitter was lost.

During the entire study, only four radio-tagged prairie chickens were known to have left the study area by crossing McDowell or Humboldt creek drainages along the southwest and northeast edges. Of these, three such movements were observed during the 1967-1968 phase. The fourth case was a band return from a radio-tagged bird killed by a hunter. Three of the birds which left the study area were juvenile males (JM28, JM84, and JM82) and the fourth was an adult female. Movements from initial capture point for the three juvenile males were 6.7, 4.3 and 2.7 miles, respectively, before radio contact was lost. Losses of all three juveniles were due to the death of the birds, two by predation, and the third by hunting. The adult female (AF105) that crossed McDowell creek (at its upper, narrower, end) moved 4.8 miles before her transmitter signal was lost for unknown reasons. Another adult female (AF83) moved a distance of 3.5 miles along the long axis of the study area, but had not left the study area when her signal was lost. Movements of both females were during the spring nesting season, one after the known abandonment of her nest, and the other presumably after an unsuccessful nesting attempt.

Reproductive Studies

Annual spring censuses of the three booming grounds (Fig. 1) during the height of the booming season, revealed totals of 31 and 35 males during 1964 and 1965 respectively (Cebula, 1966:7), 35 males during the spring of 1966, and 30 in 1967. Twenty-two males were present on the two remaining booming grounds during the height of the season of 1968. Four or five additional birds were observed booming in a wheat field approximately one mile northwest of the north ground, and it is possible that the south ground may have been relocated outside the study area to the south, though this was not confirmed.

Fifty-nine mornings of observation and trapping were conducted on the central booming ground during the fall booming season of 1967. Observations were made from 25 September through 18 December. The greatest number of males observed on the booming ground was 21, with that number of birds present on 20 October and 5 November. No clearly evident peaks in fall booming activity were noted, and the number of birds present on a given day was not predictable.

Only one observation of a female prairie chicken on a fall booming ground was made during the entire study. On 20 October 1967, a female prairie chicken visited the central booming ground and remained there for about 15 minutes. None of the 18 males present showed any sexual attraction to the female.

During the spring season of 1967-1968, 83 observation-mornings were spent on the central booming ground from 26 January through 1 June. Active trapping attempts were made on 70 of these mornings. Fifty-one mornings of observations were conducted on the north booming ground by another investigator (Silvy, pers. comm.) from 24 March through 10 June 1968.

During the peak of the 1968 mating season (the first two weeks of April) an average of nine territorial males were present on the central booming ground, and seven territorial males were on the north ground. Though one male established on the north ground was believed to have been injured as the result of controlled burning on 18 April 1968, numbers of territorial males showed no long-term change after the burn, except for the establishment of one additional male, giving a total of eight.

Decline in attendance by males on the central booming ground as the season progressed is shown by Fig. 3. The largest numbers of males were present on the central booming ground during the first week of March, and corresponded with the largest numbers of birds observed during the fall booming season (21 males). By the end of May, visits by males to the central ground had ceased, and males could not be attracted to the ground even by the use of recorded vocalizations of displaying males.

The area presumed to comprise most, if not all, of the "sphere of influence" of the north booming ground was intentionally burned on 18 April 1968, with the exception of a few small patches. Attendance of females was compared on the two grounds to ascertain the effect of burning on renesting activity of females. It was assumed that the presence of receptive females on the booming ground late in the season was the result of previous unsuccessful nesting attempts.

Figure 4 shows that a peak of numbers of females visiting both booming grounds occurred during the first two weeks of April, and that a second, though lesser, peak occurred during the second and third weeks of May. This second peak in numbers and visits of females was much more obvious on the north booming ground, and began earlier and lasted longer than that on the central ground. Fifty-three visits by females were recorded on the north ground between 25 April and 30 May. Only four such visits occurred on the central ground during the same period, and all were between 14 and 20 May.

It was possible to attract females to the north ground after regular displaying activities of males had ceased, and one female (AF102) was trapped after having been so attracted on 21 June 1968.

During the entire study, more than 1,040 hours of egg-laying and nest attentiveness data were obtained for three renesting female prairie chickens using a Rustrak dual-channel thermistor recorder. Of these data, more than 302 hours were collected during the 1967-1968 phase of the study (Fig. 5). The 13-day oeriod monitored included the laying of the last of nine eggs in the third nest (second renest) of bird AF70, and approximately 12.5 days of incubation prior to destruction of the nest and death of the female by predation. Incubation was begun at the time of, or possibly before the last (ninth) egg was laid.

During the period between placement of thermistor probes in the nest and its destruction by a predator, absences of the female during late afternoon (1200-2400[1/] hours) averaged 55 minutes for 18 such absences. Absences from the nest during the late afternoon period ranged from 17 to 24 minutes in duration. Departures occurred between 1310 and 2215 hours, and returns from 1348 to 2215 hours. On 4 of 12 full days monitored, 2 absences were recorded during the afternoon-evening period.

Of 13 recorded morning absences (0000-1200 hours), the mean duration was 61 minutes, with a range of 23 to 153 minutes. Times of morning departure ranged from 0342 to 1125 hours, and returns from 0416 to 1212 hours. Eleven of 13 absences occurred between 0735 and 1212, and on 2 of 13 mornings, two absences were recorded. No increase or decrease in duration or frequency of absences was noted as the incubation period progressed.

Dummy Nest Studies

During the first two-week period, only 2 of 10, or 20 percent of the dummy nests were destroyed, and after replacement of eggs, these same nests were repeatedly destroyed for a total of 13 times. A similar percentage loss of dummy nests of the second set was noted with 30 percent destroyed. With replacement, these three nests were destroyed a total of 16 times. In three cases, the predator responsible for nest destruction was positively identified as the striped skunk (*Mephitis mephitis*), and an additional 11 instances were believed to have been the work of skunks. One dummy nest was destroyed by cattle, and insufficient evidence was available to determine the agency responsible for the remaining four losses. All dummy nests destroyed during the 1967 period were located in the shallow range site, though approximately equal numbers were placed in the limestone breaks site.

[1/]All times military, central daylight time

Table 5 gives results of the 1968 dummy nest studies. During the entire spring and summer period, 117 of 192 nests were destroyed. Of these, only 29 were destroyed during the May period, as compared to 45 during June and 49 during July.

For the three periods combined, dummy nests marked with red surveyor's flags sustained 40 losses, as compared with 29 of those checked from a vehicle (the "drive" category), 24 of those checked on foot (the "walk" category), and 24 of the control nests (not checked until the end of each 21-day period).

The nests located in burned sites sustained a total of 43 losses during all three experimental periods. Twenty-nine of the nests located in the claypan site were destroyed, as were 25 of those in the shallow site and 20 in the limestone breaks site.

Numbers of nests destroyed in each treatment category varied from period to period. During the May period, 11 of the 29 nests destroyed were marked with flags, 9 were controls, 6 were in the "drive" category, and 3 were in the "walk" category.

Of the 47 nests destroyed during June, 15 were marked with flags, 13 were in the "drive" category, and 9 each were in the "walk" and control categories.

During July, 14 of the 42 nests destroyed were marked with flags, 11 were in the "walk" category, 10 were in the "drive" group, and 7 were controls.

Site comparisons also varied during the three experimental periods. For the May period, 13 nests in burned sites were destroyed, 6 in the claypan site were destroyed, and 5 each in the limestone breaks and shallow sites were destroyed.

Table 5. Summary of losses of artificial nests, by site and treatment, spring and summer, 1968.

Treatment		Numbers of Nests Destroyed				
		Claypan Site	Shallow Site	Limestone Breaks Site	Burned Sites	Totals
	May	0*	1	0	2	3
Walk	June	4	3	0	4	11
	July	3	3	1	4	11
Totals:		7	7	1	10	25
	May	1	1	0	4	6
Drive	June	3	4	2	4	13
	July	1	2	4	3	10
Totals:		5	7	6	11	29
	May	2	1	4	4	11
Flag	June	4	4	3	4	15
	July	4	4	2	4	14
Totals:		10	9	9	12	40**
	May	3	2	1	3	9
Control	June	2	1	2	3	8
	July	2	0	1	4	7
Totals:		7	3	4	10	24
Grand Totals:		29	26	20	43**	118

* Number of nests in each cell = 4

**Significantly (P>0.05) greater than other totals in the respective row or column.

During the June period, 15 of the nests destroyed were located in the limestone breaks site. Twelve were in claypan site and 11 were in shallow site. Seven of the nests in the limestone breaks site were destroyed.

During the July period, 15 nests in the burned sites, 10 in the claypan site, 9 in the shallow site, and 8 in the limestone breaks site were destroyed.

Of 117 dummy nests destroyed during the three periods, cattle were responsible for 75, striped skunks 14, undetermined agencies 9, coyotes 9, crows 7, badgers 2, and one was accidentally destroyed by the research vehicle.

Natural Nests

Of 21 nests located during the period 1964-1968, 11 were nests of radio-tagged females, five were discovered by accident, two were found by observing females returning from feeding areas, two were brought to the attention of investigators by ranch personnel and other persons, and one was found as a result of searching burned areas after controlled burning. Fragments of eggs from one additional nest were also discovered while searching the burned area, but the original nest site could not be determined. This nest was not included in the total, since the site or number of eggs was not determined.

The average distance from the nearest booming ground for all nests discovered during the entire study was 1163±106 yards. Sixteen of 21 nests were located on shallow range sites, and the remaining four were on limestone breaks sites. Thirteen nests were located on north-facing slopes, three on south-facing slopes, three on ridge tops, and one was found on an island formed by an intermittent stream. Two nests were located within 8.5 feet of each other.

Only four of 20 nests observed during the entire study hatched successfully. Eleven were destroyed by predators, two were deserted, one was destroyed by cattle, one was destroyed by intentional burning, and one was destroyed by an undetermined agency. One additional nest was not found again after being reported to investigators by other persons. Of the four nests that hatched successfully, three were located in the limestone breaks range site, and the others were in shallow sites. Two of the successful nests were on south and southeast-facing slopes, and the other two were on north-facing slopes.

The nest found on the burned area was the only one found during the 1967-1968 phase of the study. It was located 450 yards from the north booming ground, and contained six eggs when found on 30 April 1968. It was presumed that the last egg was laid on 17 or 18 April, and assuming one egg per day, the clutch must have been begun on 11 or 12 April. The nest was located in the shallow range site on a slight north-facing slope.

Estimated dates of laying of the first egg for all 21 nests observed ranged from 11 April to 7 June. Seven clutches were begun between 11 Aoril and 27 April, nine between 4 and 26 May, and one on 7 June. Three female prairie chickens were known to have renested during the study. First renests (second attemots) were begun between 20 and 28 May, and one second renesting was begun on 7 June. All of the four successful nests were begun between 18 and 26 May of 1965 and 1966.

The average full clutch observed during the entire study contained 12 eggs. Complete clutch sizes of six nests of which the first egg was estimated to have been laid before 1 May contained an average of 13.8 eggs, and eight begun after 1 May contained an average of 10.3 eggs. The numbers of eggs comprising complete clutches of renesting females became smaller with each succeeding attempt.

Nest searches with a dog during the nesting season of 1967 were not successful, nor were observations of feeding areas in attempt to follow nesting females back to their nests. Nest searches with a dog were not conducted in 1968, and attempts to locate nests were limited to observation of feeding areas and radio-tracking females during the nesting season. Seven adult females were captured and radio-tagged during the breeding season of 1968, but in no case could radio contact be maintained until nesting was begun.

Three radio-tagged female prairie chickens were observed to have renested during the entire study. On 12 May 1966, the first nest of female AF41 was found containing nine eggs. This first attempt was destroyed on 13 May 1966 by an unidentified mammalian predator. Female AF41 was observed to visit the central booming ground twice after 19 May, and apparently was mated. On 4 June her second nest was found 1276 yards from the first nest. The second clutch contained seven eggs and was destroyed by a mammalian predator on 25 June, and the radio signal of AF41 was not relocated after that date.

The first nest of bird AF71 contained a full clutch of 13 eggs, which were destroyed by a mammalian predator during the second day of incubation, on 13 May 1967. On 23 May, following two visits to the north booming ground, AF71 was located on her second nest containing two eggs, 528 yards from the first nest. The complete clutch of the second nest contained 11 eggs, which were destroyed on 9 June by a mammalian predator. Female AF71 was not observed to visit a booming ground after destruction of the second nest. She was radio-tracked continuously from the beginning of the 1967-1968 phase of the study until 11 July, when her transmitter was found. Tape around the transmitter and battery pack bore a number of small holes, and death was presumed to have been caused by an avian predator, possibly a great horned owl (Bubo virginianus).

Female prairie chicken AF70 renested twice during the 1967 season. Her first nest was found on 6 May, and contained a full clutch of 14 eggs. This first nest was destroyed on 12 May, also by a mammalian predator. Female AF70 was known to have visited the south booming ground prior to the discovery of her second nest on 27 May 1967. The second nest was located 2486 yards from the first. The complete clutch of 11 eggs was destroyed on 1 June by a mammalian predator. Female AF70 was observed to visit two booming grounds, the south ground and another ground 1.9 miles south of the south ground, before beginning her third clutch of the season, which was discovered on 13 June. The third clutch contained 9 eggs when laying was completed on 14 June. On 28 June, the third nest was destroyed, and a 12-inch length of intestine with cecae was found 15 yards from the nest in a large pile of feathers. It was assumed that her death was due to predation, probably by a large mammal such as a coyote (Canis latrans), and that the nest was destroyed by the same predator.

Broods

Brood searches were conducted during early morning hours between 29 June and 17 August 1967, and between 28 June and 15 August 1968. Approximately 50 hours were spent in the field with one dog and two observers during the 1967 period, with search periods lasting from 2 to 3 hours, depending on temperature and humidity conditions necessary for optimal dog work. Areas searched included wheat and oats fields and surrounding grassland, annually mowed bluestem, stubble fields, an alfalfa field, several old fields, and field borders. Areas searched intensively were selected because of obviously high insect availability, prior observations of broods, and information from the literature indicating that such areas were utilized by hens with broods (Jones, 1963:772; Horak, 1967:10).

During the 1967 period, 10 brood observations were recorded, ages were estimated for each brood, and an approximate range of hatching dates estimated (Table 6). No attempt was made to estimate to nearest week the age of broods believed to be more than 10 weeks of age. One brood was aged to the nearest half-week by primary feather replacement (Baker, 1953:37) since one chick was captured and examined in hand. It is possible that more than one observation was made of the same brood.

Numbers of young per brood observed during 1967 ranged from 2 to 12, averaging 4.2 young for all ten broods observed. The average size of seven broods believed to be more than 10 weeks of age was 3.6 young, and three broods estimated to be less than 10 weeks of age averaged 4.3 young. The average proximity of broods to the nearest "edge" when observed was 64 yards. Four broods were observed in field border vegetation when located by the dog.

An approximately equal amount of time was spent in searching for broods during the summer of 1968. Two dogs were used regularly, with either one or two observers. The same areas were covered as during the summer of 1967.

Only one brood was found as a result of searches conducted during 1968. On 17 July, a hen and her brood of eight young, which were estimated to be from 6 to 8 weeks old, were flushed from a shallow site 143 yards from the edge of a wheat field at the northwest corner of the study area. Another brood was observed on 14 June 1968 while carrying out routine radio-tracking operations. Three chicks estimated to be less than 2 weeks of age and a hen were seen in an old planting of post oaks within 30 yards of a small reseeded area.

Table 6. Summary of brood observations during summers of 1967 and 1968.[1/]

Date	No. of young	Estimated age (wks.)	Range site or crop	Distance to nearest "edge" (yds.)	Vegetation of edge
July			1967		
10	2	10+	Claypan	70	Alfalfa
11	12	6½	Claypan	90	Oats (mature)
14	4	10+	Limestone break	130	Wheat (mature)
19	5	8	Limestone break	290	Wheat (mature)
24	4	4	Alfalfa	0	Alfalfa/big bluestem
31	4	10+	Oats (mature)	0	Oats/lightly grazed claypan site
31	4	10+	Wheat (stubble)	0	Wheat stubble/ungrazed claypan site
August					
7	4	10+	Wheat (stubble)	20	" "
10	4	10+	Wheat (stubble)	20	" "
17	3	10+	Old field	0	Dogwood/old field
June			1968		
14*	3	1-2	Claypan/post-oak planting	30	Reseeded old field/ claypan site
July					
17	8	6-8	Shallow/annually mowed bluestem	140	Wheat stubble

[1/] All broods found with aid of one or two dogs, except as marked by asterisk (*)

Few data on the dispersal of broods were obtained during the 1967-1968 phase of the study, partly as a result of difficulty encountered in tracking female prairie chickens during the nesting season.

However, on 12 August 1968, three juvenile greater prairie chickens (JU108, JU112 and JU113) were captured in a walk-in trap located in an oats-stubble field near the northwest corner of the Simpson Ranch. Primary feather replacement (Baker, 1953:37) indicated that the three birds were all approximately 10 weeks old. All were radio-tagged, banded, and released near the trap-site.

The three radio-tagged young remained together and were joined by a radio-tagged adult female (AF102) on 15 August. AF102 remained with the brood until 19 August, when she departed and was not subsequently located with the brood. Bird AF102 had been radio-tagged and tracked since 21 June 1968, and it was known that she had not nested successfully during the 1968 nesting season.

The radio-tagged young were flushed on 23 August to determine the number in the brood. Eight young accompanied by an adult female (not AF102) were counted. From 12 through 25 August, the hen and brood remained in or near wheat and oats stubble fields and old fields, feeding, dusting, and resting in the shade of tall forbs and shrubs in and near field borders. After 25 August, when the brood had reached approximately 12 weeks of age, movements were further into unbroken grassland, and returns to the stubble or field borders were not noted.

A short-circuit in the case of the radio-receiver resulted in extremely limited range of reception between 25 August and 7 September. For this reason, distances between members of the brood were not obtained each day, and only general dispersal data were collected.

The earliest departure of one of the radio-tagged young (JU108) from the family group was on 27 August, and one other juvenile bird had departed by the night of 29 August. All three radio-tagged young roosted together with four other birds (presumably the hen and three young) on 7 September. At that time, bird JU112 was recaptured and its transmitter removed.

Bird JU108 roosted with five other birds on the night of 9 September 1968, but roosted alone on 14 September. Bird JU113 roosted alone about 30 yards from the rest of the brood on 9 September, and its signal was not received following that date, although attempts were made to locate it until 15 September.

Mortality

A total of 34 deaths of prairie chickens was recorded during the entire study, 18 of which were attributed to predators. Field evidence indicated that nine birds were killed by coyotes, four by hawks, four by great horned owls, and one by a skunk. Five birds died from unknown causes, five were killed in traps, four were killed by hunters, one was killed when it flew into a power line, and one was killed by a bird dog used for brood searches.

Of the total of 34 observed fatalities, 13 occurred during the 1967-1968 phase of the study.

Habitat Preference

Vegetation Density

Seasonal, site, and year differences in vegetation density were apparent (Fig. 6). During the period from summer, 1966 through spring, 1967, the limestone breaks range sites exhibited the highest density indices, followed by the shallow and claypan sites. With the exception of winter 1967-1968, the shallow range sites had the highest density indices during each season from summer, 1967 through summer, 1968, followed by the limestone breaks and claypan sites. At the end of the winter of 1967-1968, the limestone breaks site indices were greater than the shallow sites, which in turn were greater than those for the claypan sites.

The highest index values, when averaged over all three sites, were obtained at the end of the summer months of each year. Index values for the summers of 1966 through 1968 were 1.37, 2.13, and 1.26, respectively. Fall indices were 0.95 and 1.24 for 1966 and 1967, respectively. Winter indices were lowest, with a value of 0.74 obtained in 1966, and 0.87 in 1967. The index for the spring of 1967 was 0.96 with a similar value of 0.98 obtained in 1968.

During the spring of 1968, unburned sites exhibited higher densities than burned sites in each case (sampled 39 days after burning). The highest average index value for the burned area was obtained for the claypan sites (0.76), followed by the shallow (0.65) and limestone breaks (0.65) sites. In the unburned area, the shallow sites had the highest average density (1.06), followed by the limestone breaks (1.02) and claypan (0.82) sites.

Average density indices were also lower for each of the burned sites at the end of the summer of 1968. The highest indices obtained in both burned and unburned sites were the shallow sites (1.29 and 1.39), followed by the limestone breaks (1.15 and 1.31) and claypan (1.15 and 1.24) sites.

<u>Habitat Relationships</u>

A total of 2,019 radio-telemetry locations of 49 prairie chickens, obtained during the period 16 June 1966 through 30 August 1968, were analyzed in terms of the three major range sites and two crop types on the study area. Proportions of bird locations on each site and crop type are shown in Fig. 7, and preference indices (obtained by dividing percentage of bird locations by percentage of the study area) are given in Table 7. Habitat preference index values of 1.0 and larger indicate that use by prairie chickens was proportional or more than proportional to the availibility of a particular site. Values of less than 1.0 indicate that use was less than proportional to availability.

The shallow range site provided consistently higher preference indices than the claypan or limestone breaks sites. The average preference index for the entire period was 2.3, and seasonal values ranged from 1.5 to 2.9 for the entire period. Index values of 2.3 or greater were obtained for each season except the winter of 1967-1968 and the spring and summer of 1968.

Preference indices for the claypan site averaged 0.7 for the entire period, and ranged from 1.6 to 0.3 for all seasons. Increases in oreference for the clayoan site occurred during the summers of 1967 and 1968, during which index values were 1.6 and 1.9, respectively. However, the claypan preference index for the summer of 1966 was only 0.3, much lower than those for the two succeeding summers.

The limestone breaks site ranked third in preference as reflected by the indices, though values were more consistent from season to season than those for the claypan site. The average preference index for limestone breaks was 0.4 for the entire period, and values ranged from 0.2 to 0.5 for all seasons. No clear trends in preference of limestone breaks were apparent.

Habitat preference indices for the booming grounds showed that these small areas accounted for high proportions of bird locations, particularly during the spring months. The average index value for booming grounds was 11.1 for the entire period, with the highest values of 26.9 and 47.4 occurring during the spring of 1967 and 1968, respectively. Comparison of

Table 7. Seasonal habitat preference indices* calculated from 2,019 locations of 49 greater prairie chickens between 16 June 1966 and 30 August 1968.

			Range Sites					
			Limestone Breaks	Shallow	Claypan	Booming Grounds	Wheat & Oats	Grain Sorghum
	Percent of study area		(53)	(21)	(19)	(1)	(2.4)	(3.6)
		(n)						
1966	Summer	332	0.5	2.5	0.3	0.0	6.0	0.2
1966	Fall	317	0.5	2.4	0.1	0.9	5.3	1.4
1966	Winter	134	0.2	2.5	0.3	7.4	0.6	7.0
1966	Spring	398	0.3	2.3	0.3	26.9	0.0	1.6
1967	Percent of study area		(67)	(16)	(14)	(0.5)	(1)	(0.5)
1967	Summer	216	0.4	2.9	1.6	12.6	0.9	0.0
1967	Fall	61	0.5	2.8	0.5	9.6	0.0	16.1
1967	Winter	197	0.5	1.5	0.5	1.0	0.0	70.0
1968	Spring	188	0.3	1.8	1.1	47.4	0.0	23.6
1968	Summer	176	0.3	2.1	1.9	3.2	17.0	0.0
Total (N):		2,019						
Weighted Means:			0.4	2.3	0.7	11.1	3.2	7.1

$$\text{*Habitat preference index} = \frac{\text{percent of bird locations}}{\text{percent of study area}}$$

index values for the other seasons for the two-year period revealed no consistent seasonal pattern.

High preference index values for grain sorghum fields likewise were indicative of heavy use of small areas. Table 7 shows that when the proportion of grain sorghum in the area became smaller after the spring of 1967, the index values became larger, indicating its attractiveness to greater prairie chickens. The average preference index for the entire period was 7.1, and seasonal trends in use were apparent. Winter preference indices for grain sorghum were largest, followed by spring and fall during both years. Summer utilization was lowest, with no use recorded in 1967 or 1968, and an index value of only 0.2 for the summer of 1966. Utilization of grain sorghum, as shown by preference indices, reflects the availability of ripe grain, both before and after harvest.

Wheat and oats fields provided preference indices of 0.9 and 17.0 in the summers of 1967 and 1968, and were known to have been visited by prairie chickens only in summer during these two years. In 1966, a preference index of 6.0 was calculated for the summer months, and use continued through the fall and into winter, with index values of 5.3 and 0.6 obtained for the latter two seasons. Use of wheat and oats fields was related to availability of waste grain after harvesting, and the duration of use was regulated by the period between harvesting of grain and plowing.

The time-wise distribution, by site, of 2,019 prairie chicken locations made between 16 June 1966 and 30 August 1968 is shown in Fig. 8. Habitat preference indices for the same time and site categories are given in Table 8.

Weighted mean preference indices for the three daily time periods showed no apparent time-of-day preference for any of the three major range sites. Values for the shallow site ranged from 2.3 to 2.7 for the three time periods,

Table 8. Morning, mid-day, and evening[1/] habitat preference indices,[2/] by season, derived from 2,019 locations of 49 greater prairie chickens made between 16 June 1966 and 30 August 1968.

	Percent of Study Area	(n)			Limestone Breaks (53)			Shallow (21)			Claypan (19)			Booming Grounds (1)			Wheat and Oats (2.4)			Grain Sorghum (3.6)		
		M	MD	E	M	MD	E	M	MD	E	M	MD	E	M	MO	E	M	MO	E	M	MO	E
	Summer	38	165	129	0.3	0.6	0.3	3.6	2.5	2.4	0.3	0.3	0.2	0.0	0.0	0.0	0.0	3.8	11.3	1.5	0.3	0.0
1966	Fall	37	64	216	0.5	0.5	0.6	2.5	2.8	2.2	0.3	0.1	0.1	8.1	0.0	0.0	3.4	5.2	5.8	0.8	0.4	1.8
	Winter	51	28	55	0.0	0.3	0.2	2.3	3.2	2.3	0.2	0.0	0.4	19.6	11.0	0.0	0.8	0.0	0.8	6.5	5.0	8.6
	Spring	196	100	102	0.1	0.3	0.4	1.9	2.9	2.3	0.3	0.1	0.4	41.3	6.3	12.8	0.0	0.0	0.0	1.3	2.5	2.5
1967	Percent of Study Area					(67)			(16)			(14)			(0.5)			(1)			(0.5)	
	Summer	50	126	40	0.4	0.4	0.3	2.5	3.1	2.7	1.6	1.5	2.1	16.0	0.0	5.0	0.0	0.8	2.5	0.0	0.0	0.0
	Fall	27	27	7	0.4	0.7	0.2	2.8	2.5	4.5	0.5	0.5	1.0	14.8	0.0	0.0	0.0	0.0	0.0	22.2	14.8	0.0
	Winter	71	56	70	0.5	0.4	0.5	1.4	2.2	1.3	0.3	0.4	0.7	2.8	0.0	0.0	0.0	0.0	0.0	76.0	60.7	74.3
1968	Spring	123	51	14	0.3	0.4	0.3	1.6	1.8	3.1	0.9	1.8	1.0	70.0	0.0	14.3	0.0	0.0	0.0	16.3	43.1	14.3
	Summer	33	70	73	0.2	0.4	0.3	1.9	2.6	1.7	2.6	1.5	1.8	18.2	0.0	0.0	9.1	10.0	28.8	0.0	0.0	0.0
		626	687	706																		
	Weighted Mean Indices:				0.3	0.4	0.4	2.3	2.7	2.5	0.7	0.6	0.8	20.0	2.2	3.5	1.3	2.2	5.1	5.5	5.2	5.4

[1/]Morning (M) = midnight to first 20 percent of sunrise-to-sunset period. Mid-day (MD) = 20 through 79 percent of the sunrise to sunset period. Evening (E) = last 20 percent of sunrise-to-sunset period, including all locations made before midnight.

[2/]Habitat preference index = $\frac{\text{percent of bird locations}}{\text{percent of study area}}$

claypan site values from 0.6 to 0.8, and limestone breaks from 0.3 to 0.4.

The preference index for booming grounds, when averaged over all seasons, showed that morning use was greatest with a weighted mean preference index of 20.0, followed by the evening period with a mean index of 3.5. Mid-day preference for booming grounds was lowest, providing an average index value of 2.2.

The use of wheat and oats fields was greatest in the evening, as reflected by a mean preference index of 5.1. Morning was the time of least use by prairie chickens with a mean index of 1.3, and the mean for the mid-day period was slightly higher (2.2).

Average preference indices for the three time periods showed that use of grain sorghum fields was approximately equal, with mean indices ranging from 5.2 to 5.5.

DISCUSSION

Materials and Methods

Advantages and disadvantages involved in the use of Japanese mist nets for capturing greater prairie chickens were discussed in detail by Silvy (1968:70) and Silvy and Robel (1968). In comparing mist nets to cannon nets, Silvy and Robel found that mist nets had the advantages of fewer unintentional and unnecessary recaptures, some selectivity for females, a lesser degree of disturbance of displaying males, and lower operation and acquisition costs.

Though the above advantages of using mist nets were noted during the current phase of the study, additional disadvantages were also noted. Males were easily captured early in the booming seasons while territories were being established, and most males subsequently avoided the mist nets erected between the territories. However, two of the seven males captured in mist nets during 1967-1968 were unintentional recaptures. On at least two occasions during the 1968 spring booming season, possible captures of females present on the booming ground were thwarted by the unintentional capture of males which became entangled in the nets. Mist nets were observed to select for females after territorial disputes of males had diminished in intensity; however, poor success in actually capturing females in mist nets was noted by this observer. Though females frequently walked under and into mist nets, they seldom became entangled in nets to the extent that they could not escape. In many instances, females attempted to get through mist nets at several points along their length, but never became entangled. This problem continued even when slack in the nets was increased, allowing more "bag" to entangle the birds. The problem in capturing females in mist nets was due to their slow, cautious approach, especially when they arrived on the booming ground alone. Greater success was observed when females approached in a group, as fighting and chasing among females increased the chance of entanglement in mist nets. Unreceptive females being chased by courting males were also more easily entangled in mist nets.

In attempt to alleviate the above problem in capturing females for mobility and reproduction studies, a drop net was constructed by splicing two 7 x 60-foot Japanese mist nets together, giving a net with total dimensions of 14 x 60 feet. The trap was designed so that it could be used in the same manner as described for mist nets, except that either the proximal or distal edge could be placed against the ground, and the remainder of the net could be dropped by manually tripping a trigger from a blind at the edge of the booming ground. No captures were accomplished with the drop net during the 1967-1968 period, but it was not used until near the end of the 1968 booming season. Such a drop net or a similar device might well increase success in trapping females.

Bow nets were first used early in the spring booming season of 1968. Eight-foot lengths of 3/8-inch aluminum alloy rod were substituted for the 7-foot lengths of iron rod used for bow-net frames by Anderson and Hamerstrom (1967:829), allowing larger overall trap area, and presumably a more rapid "throw" or closure of the trap with springs of equal strength. A sensitive trigger (Plate I, Fig. 2) was also substituted for the pull-stake type used by Anderson and Hamerstrom, again allowing more rapid activation of the traps.

One unintentional bow net capture occurred as a result of use of the sensitive trigger, but in no instance was a net triggered by birds crossing the pull cord extending to the blind. Only three prairie chickens, all males, were captured by use of bow nets during the 1967-1968 phase of the study. However, it is believed that little difficulty would have been experienced in capturing more males. Since females were being sought for reproductive studies, little trapping effort was expended to capture more males after sufficient numbers had been captured for mobility studies. Anderson and Hamerstrom (1967:832) stated that hens reacted aggressively toward stuffed hen decoys, and that they often placed themselves in position for potential trapping. No such reaction of female prairie chickens toward decoys was observed during this study.

The use of the cannon net trap to capture greater prairie chickens on booming grounds was discussed and evaluated by Viers (1967:31). He found that cannon netting was a reliable technique for trapping prairie chickens on booming grounds. However, in attemoting to capture female prairie chickens, Viers found it necessary to fire the cannon net over a dominant male several times during the course of the 1966 spring trapping period. Such repeated firings (three days in succession) resulted in a shifting of the territory of the dominant male, and finally caused him to assume a more subordinate role on the booming ground. Robel (1964 and 1967) found that moderate use of the cannon net resulted in no apparent changes in behavioral characteristics of participating birds. Silvy (1968:25) developed the Japanese mist-netting technique described above in order to avoid the disturbances caused by continuous use of the cannon net. Only one prairie chicken was captured by use of the cannon net during the 1967-1968 phase of the study, since it was used only during the last week of active booming during the 1968 spring season to capture females for reproductive studies.

High winds, frequently encountered on booming grounds during early morning trapping periods, hampered the effectiveness of mist nets, the drop net, and the cannon net, but had little effect on the bow nets since they were laid flat against the ground when set, and provided little wind resistance when triggered.

Tape recorded vocalizations of displaying male prairie chickens (Silvy and Robel, 1967:370 and Silvy, 1968:26) aided in the trapping of 75 prairie chickens during the entire study, and 23 for the 1967-1968 phase. Because of increased success in trapping with the use of recordings, they were used during each trapping period of the 1967-1968 phase. Thus, no comparisons can be made for trapping success with and without such broadcasts. Mist nets and bow nets usually captured only one bird at a time, but birds could usually be recalled to the ground by broadcasting recorded vocalizations after the bird was removed from the trap and the observer had returned to the blind.

Silvy and Robel (1967:371) and Silvy (1968:72) also reported that the effective trapping period during the spring booming season was extended when recorded vocalizations were broadcast from booming grounds. Regular visits of males to the central booming ground during the spring season of 1967-1968 ceased on 2 June, despite the use of recorded vocalizations on that date and the three days following. The use of recorded vocalizations on the north booming ground after visits of males had ended during the first week of June resulted in the appearance of females on several occasions, and on 21 June a female (AF102) was captured in a mist net and radio-tagged.

Silvy (1968:73) stated that prairie chickens visited fall booming grounds sporadically, and the use of recorded vocalizations could probably be used to increase the likelihood of luring birds to trapping areas during fall and winter. This hypothesis was borne out during the 1967-1968 phase of the study. Recorded vocalizations were broadcast from the central booming ground for the first time of the fall booming season of 1967 on 25 September, and four males responded on that date. Recordings were again broadcast on 29 September, and though no birds were observed on the booming ground proper, two flushed from heavy vegetation at its edge when the observer departed from the blind. Recorded vocalizations were broadcast at the central booming ground during 35 mornings between 30 September and 21 November. Birds appeared on the ground on 28 of the 35 mornings.

Broadcasts were continued on 9 mornings between 28 November through 7 December, and birds failed to appear on only one occasion. Broadcasts of vocalizations on two mornings (17 and 18 January) between 7 January and 26 January 1968 brought no response. From 26 January through 2 June 1968, birds appeared on 98 of 101 mornings that observations were made.

Silvy (1968:73) reported that birds could be lured into specific areas on the booming grounds by placement of the external speaker of the recorder, and by alternating its use with the internal speaker. Similar observations were made during the 1967-1968 phase of the study.

Mounted female decoys in receptive poses were used in conjunction with recorded vocalizations to capture male prairie chickens in all types of traps employed during the 1967-1968 phase of the study. Males attracted to booming grounds with recorded vocalizations were easily lured into trapping position when female decoys were placed in front of the cannon net, directly under inclined mist nets, or in the crescent formed by cocked bow nets.

Silvy (1968:76) reported that response of males to female decoys was greatest at times other than at the height of the booming season, and that males tended to ignore the decoys when live females were present on the booming ground. He found that males began to show interest in female decoys toward the end of the spring booming season, when live females came to the grounds only occasionally. Anderson (1965:8) found that males responded sexually to decoys during the fall booming season, but to a lesser degree than during the spring. The greatest response of males to female decoys during the 1967-1968 phase of the study was noted between 31 January and 8 February 1968, when two different males mounted decoys 28 times during a period of 4 days. Only one case of a male mounting a female decoy during the fall booming season was observed, that on 25 October 1967.

Two funnel-type walk-in traps were used in an old field near the south-east corner of the study area during the fall, winter, and spring of 1967-1968. The traps were 7 x 10 x 4 feet in size, and covered on top with 2-inch mesh cotton fish netting. Traps were baited with intact grain sorghum (milo) heads and loose grain. Twice-daily checking revealed no captures during the fall and winter, but six birds were taken between 10 March and 19 March 1968. The field in which the traps were located was planted to grain sorghum in the spring of 1966 but was not harvested due to drought. It was aerially reseeded to native grass in the fall of 1966. During the fall and winter of 1967-1968, volunteer grain sorghum was abundant in the field, providing a substantial amount of feed for prairie chickens which had been observed to use the field as a feeding area during each fall and winter throughout the study.

Early spring success of walk-in traps may have indicated that the period of food shortage occurred at that time, rather than during winter, as might have been supposed. Early spring was the period when native seeds and cultivated grains were least available, and growth of succulent green forbs, used extensively later in spring, had not yet begun. Silvy (1968:78) believed that the poor success of walk-in traps in the same field during the winter of 1966-1967 was the result of abundant food provided by unharvested grain sorghum, and perhaps in part due to his use of shelled and ear corn for bait rather than grain sorghum, to which the birds were more accustomed.

Walk-in traps caused an excessive amount of injury to captured birds during the spring of 1968. Trapped birds became frightened and flew into the wire sides and netting top at high speed as investigators approached the traps. Three of the six birds captured in walk-in traps during the spring of 1968 were injured, and did not fly when released.

A flock of 7 to 12 prairie chickens was observed daily using oats and wheat stubble fields near the northwest corner of the study area during July and August of 1968. Walk-in traps were constructed and placed along the edges of the stubble fields, where birds were most often seen, apparently dusting and feeding on waste grain. In attempt to eliminate injuries such as occurred earlier, traps used in the summer were 2 feet rather than 4 feet in height. This change also made the traps less conspicuous and prevented birds from injuring themselves in their attempts to escape. Traps were baited liberally with a 1:1:1 mixture of wheat, oats, and grain sorghum and checked twice daily from 20 July until 15 August, once in the early morning, and once after sunset.

A total of six birds were captured by summer stubble field trapping, including two adult males, one adult female, and three unsexed 10-week old juveniles. Of these, one adult male and one adult female died in the trap. The adult male was killed and eaten by a juvenile red-tailed hawk in the trap. On that particular day, the trap had not been checked in the morning. The female died while being handled, presumably as a result of suffocation. No other injuries to birds that could be attributed directly to the walk-in traps were observed, and the remaining four birds were all radio-tagged and successfully tracked for sufficient periods to assume that trapping had not seriously curtailed their movements or ability to avoid predators. The method of late-summer stubble field trapping showed promise for obtaining birds for late summer and fall mobility studies, as well as for obtaining juveniles for dispersal studies. The inclusion of low chicken-wire leads to funnel young birds into the traps might prove useful, since broods were observed to move along the stubble field borders in both 1967 and 1968.

Routine recaptures of radio-tagged birds in order to change batteries or to remove a transmitter if movement data were no longer desired were easily accomplished by use of a portable receiver, hand-held antenna, powerful flashlight, and 20-foot dip net (Silvy, 1968:26). Attempts were begun to recapture radio-tagged birds carrying single battery packs at 30 days after initial tagging or last recapture. Birds carrying transmitters with double-battery packages were not sought until 60 days had elapsed. Difficulties in recapturing birds for battery changes were encountered only when the planned recapture date coincided with a full moon, and were compounded if there was little or no wind. Dark, windy nights or rainy nights provided optimum conditions for recaptures. Birds were dizzied before being released at night to prevent them from flying since evidence indicated the hazard of predation was somewhat greater for birds flying at night.

Cebula (1966:33) and Viers (1967:31) exnerienced difficulty in traoping sufficient numbers of greater prairie chickens for year-round mobility studies. Viers noted that prairie chickens were easily trapped during the spring booming season by using the cannon net on booming grounds, but that fall visits to booming grounds were erratic and caused difficulty in trapping during that period. Baker (1953:21) and Horak and Peabody (1966:3) experienced similar difficulty in fall booming ground trapping. Silvy (1968:79) experienced little difficulty in fall trapping on booming grounds with the aid of recorded vocalizations, but noted difficulty in carrying radio-tagged birds successfully through the late fall and early winter period. He found that radio-tagged birds were wary and quite difficult to recapture at night, especially during the last week of December and the entire month of January. For this reason, the double battery pack was developed by Silvy (1968:29) to alleviate the need for frequent battery changes. Four male prairie chickens were equipped with transmitters with double batterv oacks during the 1967-1968 phase of the study. One of these birds (JM82) was successfully radio-tracked through the "critical oeriod" described by Silvy (1968:79), and provided the longest continuous movement record (119 bird days) of any bird tracked during the 1967-1968 phase of the study.

Some difficulty in trapping during the fall booming season of 1967 was experienced, though not because of failure of birds to appear on the booming ground. Poor trapping success during this period was attributed to several factors: 1) a large creep-type calf feeder was placed on the west edge of the central booming ground by Simpson Ranch personnel, 2) on many occasions cattle attracted by the feeder interfered with trapping activities, even after an electrified fence was installed around the booming ground, and 3) the arrival of ranch personnel to feed cattle often resulted in birds being flushed from the ground before trapping could be attempted.

Silvy (1968:79) pointed out difficulties in obtaining birds of each sex and age class for year-round mobility studies. Similar difficulties were experienced during the 1967-1968 phase of the study. Males could be taken on booming grounds during most of the year by use of recorded vocalizations, but females, both juveniles and adults, were much more difficult to obtain. Juvenile birds large enough to carry radio transmitters were non-existent during June and July. Silvy (1968:80) noted that during the 1966-1967 phase of the study, only juvenile males trapped on the fall booming grounds and juveniles captured with radio-tagged birds during the fall and winter were available. The technique of using walk-in traps baited with grain in stubble fields during late summer, first used during the summer of 1968, showed promise in obtaining juveniles of both sexes for mobility and dispersal studies.

The radio-telemetry equipment used during the current phase of the study was thoroughly described and discussed by Cebula (1966) and Slade, et al. (1965). Significant modifications developed by Silvy (1968:29) included snap-cap battery containers which provided for more rapid attachment of transmitters to birds and simplified the procedure of changing batteries of transmitters on radio-tagged birds. The double-battery packs, also developed by Silvy, eliminated the need for frequent recaptures for routine battery changes.

The eight permanent antennas erected on the study area and described in detail by Cebula (1966:11) were seldom used during the 1967-1968 phase of the study, since most of the movements of radio-tagged prairie chickens were outside the effective range of the receivers at antenna locations. Hand-held antennas were used almost exclusively during the 1967-1968 phase of this study.

The principal disadvantage of using the hand-held antennas was that considerable topographic deflection of radio signals was noted, especially when a radio-tagged bird was on either side of a long, deep, draw. In such cases, a line bisecting the signal arc nearly always followed the long axis of the draw, producing an error of as much as 5^0 from the true bearing, depending on the distance of the bird from the observer. This problem, once recognized, was easily remedied by taking three or more bearings from positions more or less perpendicular to the long axis of the draw. This problem was not observed by Slade, et al. (1965) who evaluated the accuracy of the permanent antennas early in the overall study. The lack of topographic interference with signal reception was presumably due to the greater height of the permanent towers (20 feet). Despite their height, many more of the permanent antennas would be necessary to effectively track prairie chickens in all portions of the study area that they were observed to traverse during the 1967-1968 phase. The cost in money and time for construction and maintenance of large numbers of permanent antennas would be great, and would certainly not offset the minor disadvantages of the hand-held antennas.

Since one of the major objectives of the 1967-1968 phase of the study was to gather information concerning nesting and broods, much effort was expended in trapping and radio-tagging female prairie chickens. An average of only 13 days of location data were obtained for eight females trapped and radio-tagged between 10 March and 21 June 1968. Of these eight, only one loss to a predator could be verified, and the remainder were lost for reasons that could not be determined. The following possible reasons for poor success in trapping females were considered: 1) trapping injuries or psychological effects of trapping may have resulted in high predation losses which were not detected due to destruction of transmitters by predators, 2) the weight or psychological effect of the radio transmitter may have resulted in high predation losses, 3) mortality of females may be greater during the spring, 4) extremely long movements by radio-tagged females may have occurred which were not detected by searching surrounding areas, or 5) losses may simply have been due to transmitter failure.

The last reason seems an unlikely cause for high losses, since male birds trapped and radio-tagged during the same period were successfully tracked for an average of 30 days each. The fourth reason also seems unlikely, since in each instance when a bird could not be located near its last known position, an extensive search was conducted, covering a considerable area in all directions, including areas outside the study area. However, searches outside the study area were usually limited to public roads, and birds with active transmitters could have been missed. No information was available which indicated that natural mortality of females was greater than that of males, though the possibility should be investigated further. The combined effects of trapping and handling were believed to have accounted for the poor success experienced. Three of the eight females were captured in large walk-in traps, and two were unable to fly when released. One of the three (AF94) was known to have been killed by a predator, and none were tracked for more than two days following their release. None of the three had moved more than 550 yards from the trap site when last located, and one had moved only 198 yards. In view of the above, it is almost certain that trapping injuries accounted directly or indirectly for the loss of the three females captured in walk-in traps. Smaller and lower traps were used thereafter, and fewer injuries were observed. The remaining five females captured during the 1968 nesting season were all trapped in mist nets on booming grounds, and were tracked for an average of 21 days. The five females had moved an average distance of 3,630 yards (2.06 miles) from their capture sites, and one (AF105) moved 4.75 miles from her capture point in 13 days, indicating that the radio did not hinder her movements. It appeared that the effects of trapping and handling were overcome by females at approximately the 10th day after capture, as the only female which was located after the 13th day continued to transmit for 69 days. An examination of the data of Silvy (1968) reveals a similar pattern for females captured and radio-tagged during the spring of 1967. Of eight females captured and radio-tagged between 23 March and 6 June, five were tracked for less than eight days and averaged four days. Two losses were known to be due to transmitter failure. The remaining three were still transmitting at the time of initiation of the 1967-1968 phase of the study on 16 June, and were tracked for an average of 96 bird-days. The data of Viers (1967) revealed that difficulty in tracking female prairie chickens was somewhat less during the spring of 1966, during which nine females were tracked for an average of 35 days, and only two were located for less than 12 days. Three of six females radio-tagged by Cebula (1966) were tracked for less than 12 days, and the average tracking period for females during the spring of 1965 was 24 days.

Since there was no way of determining the reason for loss of radio contact with a tagged bird unless it was subsequently recaptured or observed at close range, the extent of predation on radio-tagged prairie chickens could not be determined, and observed mortality of radio-tagged birds represented minimal losses. In many cases, predators may have broken the wire leads incorporated in the harness between the battery package and the transmitter. Predation losses could perhaps be more readily detected by including the battery package alongside the transmitter, within an epoxy covering, and by including in the harness a section of material which could be readily broken by a predator, thus maintaining electrical contact and allowing the transmitter to continue operating. In this manner, the cause of death could perhaps be determined by field sign, and the extent of loss by predation of radio-tagged birds more readily determined. One disadvantage of such a system would be that balance of the bird would be altered, perhaps causing a temporary loss of equilibrium by radio-tagged birds. Another disadvantage of a break-away type harness, is that it might be torn off a male bird during the intense fighting which occurs on the booming grounds. However, even if lost from a bird, the transmitter would continue to operate and therefore could be recovered.

Only one prairie chicken nest was discovered during the 1967-1968 phase of the study, and it had been destroyed by fire when found. The use of a bird dog in nest searches during 1967 was not successful, nor was early morning observation of feeding areas known to have been used by nesting females during past years (Silvy, 1968:81). Females were observed to use the feeding area under observation, but evasive flights and hilly topography prevented the observation of the females when they returned to their nests. As previously noted, extremely poor success in radio-tracking female prairie chickens was experienced during the nesting season of 1968, and as a result, no nests were found by that means.

Silvy (1968:83) described in detail the use of Rustrak recording thermistor charts in interpreting the activities of nesting females.

Comparisons of ambient temperature with the temperature in the nest allowed the determination of the presence and absence of the nesting female. During periods when the female was present on the nest, the temperature recorded in the nest remained nearly constant at approximately 104^{o}F, whereas the ambient temperature followed the normal diurnal temperature curve. The nest temperature coincided with the ambient temperature when the hen was absent, but rose sharply when she returned, and dropped sharply when she departed (Plate V).

Vegetation density indices were obtained by the vision-obstruction method of Briggs (1968:17) for each season of the 1967-1968 phase of the study, and were combined with Briggs' data collected during the 1966-1967 phase to determine whether relationships existed between seasonal or annual vegetation densities of three range sites on the study area and habitat preferences of radio-tagged prairie chickens tracked during the 2-year period.

In order to test the assumption that Briggs' method provided an accurate estimate of vegetation density, seventeen 20-meter transects were selected which presented visibly different vegetation densities, distributed along a scale from the lowest to the highest on the area, and which contained different proportions of plants of several life forms. Each transect was first sampled by the method of Briggs (1968:17), and then vegetation from ten 0.10 square-meter plots located at alternate meters along each transect were clipped to within 0.5 decimeter of ground level, collected and oven dried at 60^{o}C for 48 hours before weighing. Density indices were plotted against total oven dry weight of vegetation clipped from each transect (Fig. 9). A significant (at the $P>0.5$ level) oositive correlation ($r = 0.958$) was found to exist between the indices and the vegetation weight. The regression equation ($Y = 0.10 + 0.0084X$) indicated that the method of Briggs (multiplied by a factor of 100) closely approximated the oven-dry weight of clipped vegetation.

Mobility Studies

Monthly Ranges

Viers (1967:34) found that radio-tagged juvenile prairie chickens exhibited a period of low mobility immediately after radio-transmitters were attached, and Marshall (1964) reported similar findings for juvenile ruffed grouse. Viers (1967:34) also noted that male prairie chickens did not return to fall booming grounds after initial capture and radio-tagging. Silvy (1968:83) found that only males which were captured and radio-tagged during the height of the spring booming season did not exhibit a short period of low-mobility after being captured and radio-tagged. A similar period of 3 to 5 days of little movement of newly-tagged birds was observed during the current phase of the study. For this reason, to eliminate bias in movements due to initial effects of handling, only those birds for which 15 or more locations were recorded were used in calculating average monthly ranges.

Silvy (1968:84) pointed out that the term "monthly range" was more nearly correct for purposes of this study than "monthly home range" since, by definition (Burt, 1940:25) home range includes the area traversed by an animal during its normal activities of food gathering, mating and caring for young. For greater prairie chickens, these activities encompass a period of at least one year. For this reason, the term "monthly range" was used by Silvy (1968:84) to describe the area within a polygon formed by connecting the outermost points of location of a given bird for at least 15 days during any month.

The monthly ranges obtained during each of the four phases of the study since 1964 reveal few clear trends in the size of monthly ranges for any sex and age class when considered individually, since sample sizes were often relatively small or nonexistent for certain periods for a given sex and age class of birds. For this reason, statistical comparisons between and within sex and age classes, months, or years were not possible. When the data collected during the 1967-1968 phase were combined with those of Cebula (1966), Viers (1967) and Silvy (1968), mean monthly ranges for the entire study began to show discernible trends (Fig. 10, Table 9).

The summer ranges of adult males were largest in June, smaller in July, and smaller yet in August (Table 9). The size of ranges of adult males increased during the fall, reaching a maximum of 744±385 acres in November. The mean range in December was slightly smaller than that of November, while the range for February was 871±217 acres. The ranges of adult males increased to 1,267±365 acres in March, then showed a sharp decrease in size, with a mean area of 266±105 acres calculated for April, and 91±46 acres for May.

Sufficient data were available to calculate mean ranges of adult females for the months of March through September only (Fig. 10, Table 9). Summer ranges of adult females remained nearly constant during June and July, averaging 479±177 acres in June and 473±107 in July. August and September ranges showed a decline in size, averaging 326±203 and 90±69 acres, respectively. Spring ranges were larger than fall ranges, with March, April and May averaging 450±43, 475±92, and 577±269 acres, respectively.

Mean monthly ranges of juvenile prairie chickens followed an annual cycle similar to that observed for adult males (Fig. 10, Table 9). No data were obtained for juveniles during June or July, since no juveniles were available which were large enough to successfully carry radio transmitters. The mean

Table 9. Summary of entire study mean monthly range areas for male, female and juvenile prairie chickens. Number in brackets represents the number of prairie chickens radio-tracked.

Month	Mean Locations for Monthly Ranges			Mean Area of Monthly Ranges*		
	Adult Male	Adult Female	Juvenile	Adult Male	Adult Female	Juvenile
January	- - -	- - -	50 {1}	- - -	- - -	440**
February	21 {2}	- - -	23 {9}	871±217	- - -	834±332
March	34 {4}	20 {2}	35 {2}	1267±365	450±43	938±242
April	26 {2}	26 {7}	51 {1}	266±105	475±92	459**
May	61 {3}	28 {9}	44 {1}	91±46	577±269	89**
June	37 {7}	26{10}	- - -	262±136	479±177	- - -
July	37 {5}	29 {3}	- - -	132±40	473±107	- - -
August	35 {7}	27 {3}	18 {5}	79±28	326±203	136±24
September	33 {4}	20 {2}	29 {3}	200±78	90±69	178±39
October	32 {2}	- - -	25 {2}	387±64	- - -	444±165
November	26 {2}	- - -	27 {2}	744±385	- - -	935±27
December	30 {1}	- - -	24 {5}	701**	- - -	795±150

* All ranges in acres; means ± one standard error.

**Standard errors not calculated.

range for all juveniles during August was slightly larger than that of adult males. Average fall ranges of all juveniles increased in size during each successive month of the fall. A decrease in the mean range of juveniles was noted during December and January, with ranges averaging 795±150 and 440* acres, respectively. February ranges showed an increase to 834±332 acres. Spring ranges of juveniles showed first a continued increase in March with a mean range of 938±242 acres, then a decline to 459* acres in April, and 89* acres in May.

Mean Daily Movements

Viers (1967:39) stated that the mean distance of movements between successive daily locations appeared to be more useful than monthly ranges for comparing movements between sex and age classes. Reliable ranges can be calculated only if a comparatively large number of locations are made for an individual bird, however, the distance between each consecutive daily location can be used as an index to bird mobility even if only a few data are available. Daily movement data greatly increases sample size and quantity of data for comparisons between seasons and sex- and age-classes of birds.

Mean daily movements follow the same general pattern as mean monthly ranges, but as noted by Viers (1967:39), the greater amount of movement data appeared to give a clearer indication of trends in activity than did the less complete mean monthly range data. Each daily location was used in calculating mean daily movements, except that on days on which more than one location was made for a given bird, the point selected to represent that day's movement was randomly selected.

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*$S_{\bar{x}}$ not calculated

Summer movements of adult males were the least extensive of the year-round period (Fig. 11 and Table 10). The beginning of the lowest portion of the annual movement cycle followed the end of active spring booming, and declined to the annual low in August. Though histological examination of testes was not attempted, behavioral observations indicated that the period of least movement may have coincided with the "regeneration" or refractory period of the annual reproductive cycle. During the summer months, adult males became more solitary, and molting was evident. According to Marshall (1961:317), sexual behavior during the regeneration phase is minimal, and the postnuptial molt begins and proceeds strongly. At the same time, food in the form of native seeds becomes readily available to molting males, and apparently energy requirements for the molt could be met within a small area by making short movements. Marshall (1961:315) assumed that the late summer and autumn sexual displaying of birds marked the end of the regeneration phase of species which exhibit such behavior.

Accordingly, the mean daily movements observed for the fall months showed an increase which corresponded to the increase in fall booming activity of males. The mean daily movement of adult males began to increase in September and continued to increase through November. The fall booming season is presumed to mark the beginning of the "acceleration" phase of the annual sexual cycle (Marshall, 1961:16). According to Marshall, the acceleration phase spontaneously follows the regeneration phase and once it is reached, the neuroendocrine machinery of males becomes again responsive to external factors such as light and temperature which may further accelerate or inhibit sexual activity. During the fall period, time spent in grain fields was increasing (Fig. 7). It seemed, therefore, that an increase in sexual behavior coupled with the location of the feeding areas (Fig. 1) accounted

Table 10. Summary of entire study mean monthly movement distances between successive daily locations for male, female and juvenile prairie chickens. Number in brackets represents the number of prairie chickens radio-tracked.

Month	Number of Movements			Mean Distance of Daily Movements*		
	Adult Male	Adult Female	Juvenile	Adult Male	Adult Female	Juvenile
January	6 {2}	- - -	35 {2}	735(163)	- - -	624(107)
February	46 {3}	8 {1}	68 {4}	1121(128)	391(93)	969(100)
March	119 {9}	46 {9}	50 {2}	920(61)	499(67)	1018(125)
April	44 {6}	152{14}	24 {1}	678(98)	928(45)	499(102)
May	91 {6}	188{11}	21 {1}	450(42)	428(37)	298(73)
June	129{10}	159{12}	- - -	392(26)	423(47)	- - -
July	102 {6}	106 {5}	- - -	338(22)	417(33)	- - -
August	136 {7}	71 {5}	70 {6}	320(22)	465(43)	297(30)
September	91 {4}	31 {2}	53 {3}	378(34)	322(28)	378(45)
October	71 {4}	- - -	38 {3}	614(58)	- - -	639(77)
November	69 {7}	- - -	65 {6}	697(82)	- - -	838(90)
December	39 {3}	- - -	101 {6}	593(104)	- - -	705(80)

*All movements in yards; means (one standard error) for the increased distance of mean daily movements during the fall months, with the further increases which occurred from December through February being a reflection of sexual activity and decreased food abundance.

Mean daily movements of adult males during December showed a slight decrease in length from those of late fall. An average daily movement of 593 (104)[1/] yards was recorded for December, as compared to 697 (82) yards in November. January movements averaged 735 (163) yards, and increased to 1121 (128) yards in February. February movements were longest of any month of the year. Again the movement pattern observed during the winter months may have been influenced by the sexual cycle of adult males. According to Marshall (1961:316), the inhibitory effect of cold weather accounts for the termination of fall displaying of several species of temperate zone birds. The photoperiod also reached the annual minimum in mid-December, which if not inhibitory, would certainly not have been expected to have any stimulatory effect. Volumes of testes of 15 male prairie chickens collected by Schwartz (1945:61) indicated that a slight increase in testicular volume may have occurred in the fall, though his data were far too few to provide any conclusive evidence of an early winter leveling-off or decrease in testicular volume. It is the opinion of this investigator that the December depression in the mean daily movement occurred because of the inhibitory effect of winter weather on sexual activity, resulting in a period during which males temporarily ceased to visit the booming grounds except during periods of mild weather. Winter visits of males to booming grounds during mild weather apparently are not uncommon (Yeatter, 1943:384; Schwartz, 1945:44; Hamerstrom, 1939:105).

[1/] Numbers in parentheses are standard errors ($S_{\bar{x}}$), see page 49

The increase in length of mean daily movements observed in January and February coincided with the earliest visits of the "spring" booming season. It may be valid to assume that this period includes the last portion of the acceleration phase of the sexual cycle as described by Marshall (1961:316). During January and February the photoperiod increases, thus increasing the force of the major external stimuli for sexual activity. Yeatter (1943:385) stated that cold, stormy weather delayed the start of the mating season in Illinois, and that such weather may later cause a temporary halt of sexual activity and even a return to winter flocking habits. Yeatter's observation seemed to confirm the inhibitory effect of cold weather on sexual activity of prairie chickens. While renewed photoperiodic stimulation may account for the return to the booming grounds as early as January, it should be noted that January and February also represented a period of diminishing food supply, with native and agricultural seed availability at an annual low, and green spring growth not yet present to any extent. Thus, the annual high in mean daily movements exhibited by birds during February may represent the division of activity between food-seeking and sexual display which has begun in earnest by late February.

A decline in mean daily movements was observed for each successive month during spring. Mean daily movements for March averaged 920 (61) yards, decreased to 678 (98) yards in April, and then to 450 (42) yards in May. The greater abundance of succulent growth near the booming grounds as the spring progressed may have resulted in less movement away from the booming ground for the birds to obtain necessary food. The spring months also contained the peak of the booming season, during which most matings occurred. This marks the "culmination" phase of the annual sexual cycle as described by Marshall (1961:317), during which insemination and ovulation occur.

The mean daily movements of juvenile prairie chickens (Fig. 11, Table 10) showed patterns similar to those of adult males. The daily movements of all juveniles were least extensive during August, when they averaged 297 (30) yards. During the fall and winter, mean daily movements of juveniles increased gradually, reaching a peak of 1018 (125) yards in March (Table 10). Winter movements of juveniles showed a pattern similar to that of adult males, except that the decline in movement noted in December continued into January (Fig. 11). The delay in the winter decline in daily movement may have been due to a slight lag in the sexual cycle of juvenile males.

February exhibited an increase in mean daily movements of juvenile males but the annual peak in movement occurred during March, with an average daily movement of 1018 (125) yards. This lag in the high peak of mean daily movement by juvenile males may indicate a lag in sexual development in comparison to adult males, but such a conclusion certainly should not be drawn in the absence of histological evidence. April and May movements showed similar decreases to those of adult males, with a mean movement of 499 (102) yards recorded for April, and 298 (73) yards in May.

The movement patterns of adult females differed markedly from those of either adult males or juvenile males during the February through September period (Fig. 11, Table 10).

The least extensive movements of females were in September, a month later than the period of lowest mobility of males. However, the mean daily movement of females during September was nearly the same as the August average of adult males and juveniles. The delay in what may be assumed to be the period of lowest mobility may perhaps be explained by the delay in entering the regeneration phase by females. Though females which did not renest probably entered the regeneration phase earlier, and thus began the postnuptial molt earlier, many females on the study area did renest and probably did not begin to molt until late August or early September.

February and March movements of adult females were markedly shorter than those of adult or juvenile males (Fig. 11, Table 10). A sharp increase in mobility of females occurred in April and coincides with the peak of mating activity on the booming grounds. Such extensive movements may reflect the activities of females seeking out booming grounds, possibly moving between booming grounds as observed by Silvy (1968:44), and searching for suitable nest sites. The lag in the spring increase in mobility of females may be accounted for in part by a lag in the annual sexual cycle of the female. Marshall (1961:316) noted that following the acceleration phase of the cycle, "the accessory sexual organs of the female have been enlarging, but still lag behind the male in gametogenic development. Further special environmental influences including those of the mate are necessary before there begins the final swift oocyte development that ends in ovulation and egg deposition". In the case of greater prairie chickens, the stimulus provided by the combined booming and displaying of males on booming grounds is necessary to bring about the final stages of the female sexual cycle (Robel, 1967:113).

Mean daily movements of female prairie chickens remained about constant for the period from May through August. Average movements between locations for the four months ranged from 417 (33) yards in July to 465 (43) yards in August. The similar mean movements obtained for the late spring and summer period may reflect the fact that females were undergoing different physiological phases of the sexual cycle. Some of the females radio-tracked during this period were nesting, others were rearing broods, and still others were renesting or had completed their last nesting attempt and were beginning the postnuptial molt. The effect of pooling all such movements may have resulted in concealing individual movement patterns of nesting, rearing young, and molting.

Reproductive Studies

Booming ground attendance by male prairie chickens observed during the spring booming season of 1968 was similar to that reported by Robel (1967:111) and Hamerstrom (1941:24), with the greatest numbers of males present early in the season, with a gradual decrease in numbers as the season progressed.

Data of particular interest were obtained during the spring booming season of 1968 on the attendance of females on booming grounds located on a burned and an unburned area. The area presumed to have comprised most of the "sphere of influence" of the north booming ground was intentionally burned by Simpson Ranch personnel on 18 April 1968. The north booming ground was located approximately in the center of the burned area, which included about 2,000 acres. The central booming ground was approximately 1.5 miles from the north ground, and was within an unburned area. Fig. 4 shows the cumulative freguency of females visiting both booming grounds.

Robel (1967:112) observed that peaks of matings occurred during two periods, one during mid- to late April, and another in late May. Matings during the later period were believed to represent renesting attempts.

Examination of the female attendance data for the two booming grounds showed that the first peak in numbers of females visiting the grounds occurred on both grounds between 1 and 15 April. During that period, a total of 59 females were observed on the central ground on 10 mornings, for an average of 5.9 females per morning. A total of 90 hens were counted on the north ground during 8 mornings, for an average of 11.3 females per morning. It was not intended to imply that the total numbers of females represented different birds, since totals obviously represent returns by several of the same birds to the grounds. A second peak in female attendance was observed on both booming grounds during the last three weeks of May, though numbers on the central ground could hardly be designated a "peak", since only one bird was observed on the central ground during each of four mornings. The late peak in female attendance on the burned north ground showed markedly greater numbers of visits and greater numbers of females per visit. An average of 2.3 females visited the north ground on each of 15 mornings observations were made. No successful matings were observed on the central booming ground during the late period, but 18 copulations were observed on the north ground during the later period.

The foregoing data seem to indicate that controlled burning resulted in the destruction of a number of first nests of female prairie chickens, in the vicinity of the north booming ground (reflected by their return in large numbers to the booming ground). Two nests were known to have been destroyed as a direct result of the fire. The fact that females continued to visit the north booming ground until, and even after, male booming activity ceased perhaps indicated that the burn indirectly resulted in losses of second nests. It should be noted that females could be attracted to the north ground by broadcasting recorded vocalizations of displaying males long after males had stopped coming to the ground. One female (AF102) was trapped in a mist net on 21 June on the north booming ground and subseguently radio-tracked. Baker (1953:24) stated that both sexes seemed to become physiologically incapable of breeding shortly after the first of June. The late visits of females attracted to the grounds by recorded vocalizations may have indicated that, within certain limits, females which have experienced unsuccessful nesting attempts will continue to visit the booming grounds as long as the stimulus of male booming continues.

Data from dummy nest studies conducted during the summer of 1967 seemed to indicate that 1) nests located in the limestone breaks range site were less likely to be lost to predation, 2) cattle affected the success of nests, and 3) human influence apparently had little effect on the "success" of dummy nests.

Results of more extensive dummy nest studies undertaken during the spring and summer of 1968 tended to reinforce these conclusions, and provided further information. Results of the 1968 study indicated that losses of artificial nests were significantly lower for all sites and treatments during the earliest (May 2-24) experimental setting, than for either the mid- or late-season (3-25 June and 7-29 July) settings of artificial nests (Table 5). These findings for artificial nests were in accord with the observations of Lehmann (1941:15) and Baker (1953:28), both of whom believed that early nests accounted for the production of most young prairie chickens. However, Yeatter (1943:392) reported that in Illinois, clutches laid early in the season suffered high losses from predators, while those begun later in the nesting season had fewer losses.

All four of the natural nests which hatched successfully during the entire study were begun between 18 and 26 Aoril. Of 11 natural prairie chicken nests destroyed by predators during the entire study, only two were begun in April, one was begun during the first week of May, seven were begun during the last two weeks of May, and one was begun during the first week of June.

For all three time periods, dummy nests marked with surveyor's flags sustained significantly greater losses than those checked daily from a vehicle (designated "drive"), by approaching on foot ("walk") or the control nests, which were not visited until the end of each 21-day period. No significant differences could be detected between the latter three treatments. Losses of dummy nests marked by surveyor's flags were primarily due to trampling by cattle, which accounted for 82 percent of flag-marked nests destroyed during all three experimental periods.

The burned sites sustained significantly greater losses of dummy nests than the claypan, shallow, or limestone breaks range sites. No significant differences between the numbers of nests destroyed in the latter three sites could be detected. The higher losses of artificial nests in the burned sites, may have reflected a similar loss of natural nests and thus been the cause of more renesting activity around the north booming ground (burned area) than around the central booming ground (unburned area) as evidenced by the large number of females visiting the north booming ground late in the booming period.

Treatment (visitation method) differences in dummy nest "success" for the three periods were not consistent from period to period (Table 5). During the May period, numbers of control nests destroyed were significantly greater than those in the "walk" category, but neither differed significantly from those marked with surveyor's flags or those in the "drive" treatment category. During the June period, significantly fewer control nests were destroyed than those marked with flags, but neither treatment differed significantly from the walk or drive categories. No significant differences between treatments could be detected for the July period.

Site comparisons also varied from series to series. For the May period, significantly more nests in the burned sites were destroyed than in the shallow site, but neither differed significantly from the claypan or limestone breaks sites. During the June period, significantly more of the nests located in burned sites were destroyed than those in the limestone breaks site, but neither suffered significantly different losses than the shallow or claypan sites.

No significant site differences between nests destroyed could be detected for July. Cattle accounted for most of the losses of dummy nests during the three time periods combined. Of 117 dummy nests destroyed during the three time periods, 75 were destroyed by cattle, 14 by striped skunks, 9 by undetermined agencies, 9 by coyotes, 7 by crows, 2 by badgers, and one was accidentally destroyed by the research vehicle.

If destruction by cattle was excluded, the monthly trend in numbers of nests destroyed was reversed from the overall pattern, with 18 losses in May, 16 in June, and only 8 in July. Cattle accounted for most of the losses of dummy nests located on burned sites (67 percent) and of nests marked with flags on all sites (82 percent). Higher losses to cattle of dummy nests on burned sites and those marked by flags might be due to the tendency of cattle to congregate around foreign objects (blinds, fence posts, piles of stones, etc.) erected in a pasture. Both the surveyor's flags and the white domestic chicken eggs probably acted to attract the attention of cattle, particularly on burned sites where generally less cover was available. Even though the dummy nests were placed in unburned patches of cover, they were susceptible to destruction as cattle tended to bed down in these unburned areas.

Destruction of dummy nests by cattle followed the same pattern during each of the experimental periods. Sixty-two percent of 13 nests in burned areas that were destroyed during May were destroyed by cattle, and 64 percent of 11 nests on all sites that were marked with flags were destroyed by cattle during the same period. Forty-seven percent of 15 nests destroyed in burned areas during June were trampled by cattle, as were 8D percent of the 15 flag-marked nests destroyed on all sites. During July, 93 percent of the destructions in the burned area were attributed to cattle and 100 percent of 14 destroyed nests that were marked by flags were also trampled by cattle.

Six of 7 nests that were destroyed by crows were located in the burned sites, and the seventh in an unburned site, was marked with a flag. No other clear-cut associations of destructive agencies with sites or treatments were apparent.

Silvy (1968:60) reported the results of monitoring nesting activity of three female prairie chickens with Rustrak thermistor recorders for a total of 738 hours during the 1967 nesting season. He found that the average time spent on the nest by laying females was 3.25 hours for each egg, and that laying periods ranged from 1.5 to 8.75 hours in duration. With one exception, eggs in all nests monitored were laid at the rate of one egg per day. This finding was in agreement with that of Baker (1953:25), though Gross (Bent, 1932:248) reported that eggs of captive prairie chickens and one wild bird were laid at the rate of one egg every other day.

Silvy (1968:60) also noted that female prairie chickens normally left their nests twice each day during incubation, once in the early morning, and once in the late afternoon or evening. He found that the average length of the morning absence was 1.35 hours, and the evening period averaged 1 hour.

An additional 302 hours of nesting activity data were collected by use of a Rustrak thermistor recorder during the latter part of the 1967 nesting season. The one nest so monitored was the second renest (third nest) of female AF70. Attendance and laying data from her first two nests were reported by Silvy (1968:58).

Oata from the third nest of AF70 were combined with those collected by Silvy (1968:60) in order to estimate the mean duration of morning and evening absences during incubation. For the combined data, morning absences averaged 1.3 hours for 29 such absences. No morning departure was noted on four mornings, and two absences were recorded on each of three mornings. The range in length of morning absences was from 0.5 to 3.6 hours, and 83 percent of the absences occurred between 0600 and 1100 hours.

Evening absences during incubation averaged 1.1 hours in length and ranged from 0.3 to 2.2 hours in duration. Evening absences were recorded during each of 34 full days of incubation, and two absences were recorded during five evenings. Thirty of 34, or 88 percent of the evening absences occurred between 1600 and 2200 hours.

Broods

All broods observed during the summers of 1967 and 1968 were found in or near grain fields, field borders, or old fields. Viers (1967:33) found that the requirements of hens with broods less than two weeks of age were satisfied by ravines, but he gathered no data on brood movements after young had reached the age of two weeks. During the 1967-1968 phase of the study, only broods more than four weeks of age were observed with one exception. Since movements of young broods (zero to two weeks old) were restricted to grassy ravines and older broods (four to ten weeks old) were more closely associated with agricultural and disturbed areas, a change in habitat requirements must occur as the brood grows older. Brood observations during the 1967-1968 phase of the study were in accord with those reported by Schwartz (1945:68). He found that about two weeks after hatching, hens with broods began to range further from their nests toward higher areas and fields of small grain, often visiting dusting spots in grain fields, cattle trails, paths, and other spots of bare ground. He noted that broods in Missouri continued to use grain fields until late June or July.

Jones (1963:772) found that areas in .. broods were found generally had mr.. forbs than occurred on adjacent ar where broods were encountered les. frequently. Similarly, he f nd more b ods in areas supporting large insect populations than in areas with low insect populations. Though quantitative data were not obtained during this study, superficial observation revealed that sites in which broods were found provided much greater insect availability than surrounding unbroken grassland. Also field borders provided dusting areas for both young and adult prairie chickens.

An additional reason for movements of females with broods to disturbed areas may have involved shade requirements. Lehmann (1941:21) found that broods of Attwater's prairie chickens moved toward areas of surface water in which there was considerable vegetation of types that provided shade for the young birds. During the summers of 1967 and 1968, females with and without broods, and to a lesser extent males, were observed to seek shade under thickets of wild plum, dogwood, aromatic sumac, and in strips of tall forbs such as sunflowers and giant ragweed along field borders.

Data obtained by radio-tracking three members of one brood between 10 and 14 weeks of age indicated that dispersal did not begin earlier than 12 weeks after hatching, and that young occasionally rejoined the remainder of the brood after initially departing. During the first week of the observation period, when the brood was 11 weeks old, a radio-tagged female (AF102) which had not successfully brought off a brood joined the young birds and remained with them for four days. It was not known whether the mother hen was with the brood during the four-day period.

The above observations differed somewhat from those of Schwartz (1945:69), who stated that greater prairie chicken chicks between 8 and 10 weeks of age were seldom found with hens, and that family groups gradually dispersed after chicks reached that age. Lehmann (1941:19) reported that family groups of Attwater's prairie chickens began to break up when chicks reached 6 to 8 weeks of age, but that all young did not leave the hen at the same time, and some remained with hens well into the fall. Lehmann believed that young prairie chickens at the age of 6 weeks were as capable of foraging and resisting adverse weather as were adults.

Mortality

Sufficient evidence was available to verify the death of 34 individual prairie chickens during the entire study. Of 70 different prairie chickens radio-tagged during four years, 21 (30 percent) were known to have died. This minimal percentage was half that observed by Marshall (1964) for radio-tagged ruffed grouse, that is, 12 of his 20 (60 percent) died during his studies in Minnesota.

During the entire study, six prairie chickens were observed to fly into power lines or fences. Two birds died as the result of such accidents. One additional radio-tagged bird was believed to have been lost as a result of flying into a barbed-wire fence at night, but no confirming evidence could be obtained. The importance of overhead wires as a mortality factor in prairie chickens was noted by Leopold (1931:185), who reported that the pinnated grouse was more prone to fly into overhead wires than any other game bird. He also reported that prairie chickens sometimes died after flying into ordinary barbed-wire fences. Schorgen (1943:7) reported that prairie chickens were frequently killed by flying into telegraph wires in the Chicago area. Schwartz (1945:89) similarly reported that prairie chickens were occasionally killed or injured by flying into telephone wires or fences.

Two radio-tagged prairie chickens were killed and recovered by hunters during the entire study, and a third apparently died as a result of a gunshot wound. Marshall (1964:9) reported detection of one crippling loss of a radio-tagged ruffed grouse. Silvy (1968:107) stated that radio-telemetry techniques may prove valuable in determining the extent of crippling losses in the future.

Silvy (1968:107) pointed out that trapping injuries and deaths represent a problem always encountered in live-trapping birds. Only 7 of 177 prairie chickens (including predation in traps) during the entire study were killed as a direct result of trapping, and two were seriously injured. Of the seven trapping deaths, five occurred during the 1967-1968 phase of the study, and all could have been avoided. Of the five deaths which occurred during the 1967-1968 phase of the study, two occurred as the result of leaving mist nets stretched flat on the booming ground overnight, a practice which was immediately discontinued; one adult male and one female were killed in walk-in traps by predators as the result of omitting regular trap checks; and an adult female captured in a walk-in trap died as a result of being restrained in a heavy jacket during warm weather. It is the opinion of this investigator that, with reasonable care and additional experience, the numbers of deaths caused by trapping can be further reduced.

During the entire study, three adult male prairie chickens were found dead from unknown causes. Two of these deaths from unknown causes were observed during the 1967-1968 phase of the study. The intact skeleton, transmitter, and decomposed carcass of bird AM40 was found in an intermittent stream on 28 June 1968, and no cause of death could be determined. The intact carcass of another adult male, AM44, was found on 3 May 1968 on a hillside approximately 500 yards from the central booming ground. The carcass was taken to the Kansas State University Veterinary Diagnostic Center, but decomposition was too far advanced to determine the cause of death.

Silvy (1968:107) reported the death of a 7-week old juvenile prairie chicken which he attributed to the added weight of a radio-transmitter. He pointed out the need for determining the minimum age at which a juvenile prairie chicken could successfully carry a radio-transmitter, and theorized that birds 10 to 11 weeks old might be able to do so. This hypothesis was borne out during the 1967-1968 phase of the study, when three 10- to 11-week old juveniles were successfully tagged and radio-tracked for nearly four weeks. With the exception of one young bird which was fitted with a too-large transmitter harness, the transmitters were apparently carried with little difficulty.

Habitat Preference

Vegetation Density

Comparisons of vegetation densities with percentages of radio-telemetry locations of prairie chickens for each season on the three major range sites of the study area revealed that significant correlation existed only for the claypan site. Correlation coefficients (r) for the claypan, limestone breaks, and shallow range sites were 0.78, 0.23, and 0.11, respectively. Availability of each site was not considered in making comparisons.

High percentages of locations in the claypan site (Fig. 7) occurred during the spring and summer months, and much smaller percentages during the fall and winter months. Increased use of the claypan site by prairie chickens occurred just after the end of the spring booming seasons. All booming grounds were located in the claypan site, and increased use indicated that the birds stayed near the booming grounds for some time after regular booming activities had ceased. The increased use of the claypan site also occurred during the time when food in the form of green vegetation, particularly forbs, was still readily available in the more heavily-grazed claypan site.

The foregoing factors may have influenced the degree of use of the claypan site more than vegetation density, but it was noted that during the summer of 1966, when density indices for the claypan site were low because of drought conditions, utilization by prairie chickens was also low. Wheat fields were used to a greater extent than the claypan site, perhaps because they provided better food and cover than the dry claypan sites.

Habitat Relationships

Comparison of site-location data obtained during the 1967-1968 phase of the study with those of Briggs (1968) for the 1966-1967 phase indicated that year-to-year differences in seasonal habitat preference apparently occurred. Briggs' discussion and data included only the south half of the study area as described herein (Fig. 1), and proportions of the area in cropland and the three major range sites changed somewhat when the entire area was considered. However, changes in proportion of each range site did not account for differences noted in proportions of prairie chicken locations in each site. Weighted mean habitat preference indices were utilized to take into account the proportion of the study area in each site, as well as the proportion of prairie chicken locations on the site.

Of the three major range sites described by Briggs (1968:11), the shallow site provided the largest habitat preference index, averaging 2.3 for all seasons (Table 7). An index value of 1.0 would indicate that the number of locations on a site was directly proportional to the percentage of the study area in that site. Briggs (1968:47) believed that the relatively low density of vegetation found in the shallow site most closely approximated the optimum cover requirements of greater prairie chickens. He also noted that the shallow site was always gently sloping and near the crest of a ridge, essentially a narrow strip of varying width between the limestone breaks site on the steeper hillsides and the relatively flat claypan site on top. Briggs (1968:47) believed that the gentle slopes provided an attractive force for prairie chickens.

Seasonal trend in preference for the shallow site could be detected, though a rather abrupt droo in the preference index occurred during the winter of 1967-1968. Figure 7 shows that the decrease in use of the shallow site was apoarently accompanied by increased use of grain sorghum fields, and to some extent the limestone breaks site. Harsh weather could have accounted for such a change from one winter to the next, though examination of climatological data revealed no marked difference in amount of snowfall, snow on ground, or average minimum temperature which might have accounted for the increased use of feeding areas and protected areas such as the limestone breaks provided.

The weighted mean habitat preference index for the claypan site was 0.7. The positive correlation between the vegetation density indices and the proportion of bird locations on the claypan site were discussed earlier, though it was not meant to imply that the relationship was one of cause and effect. Other factors such as a carry-over period after the end of the booming season, or food requirements may well have accounted for the patterns of use observed for the claypan site. Occurrence of orairie chickens on the claypan site showed approximately the same patterns for each of the three daily time periods (Fig. 8, Table 8).

The limestone breaks site covered more than 50 percent of the study area, and accounted for only 22 percent of all prairie chicken locations for the entire two-year period, giving an average preference index of 0.3. Briggs (1968:47) reported that the vegetation of the limestone breaks site was typified by taller grass species than the shallow site, and that vegetation density indices were consistently higher for the limestone breaks site than the shallow site. As noted previously, no significant correlation between vegetation density indices and percentages of prairie chicken locations could be detected for the limestone breaks site.

Briggs (1968:48) observed that the occurrence of prairie chickens in the limestone breaks site increased sharply during the mid-day period in the summer of 1966. Such a mid-day increase in percentage of locations was not noted during the summer of 1967, though the data for the summer of 1968 revealed a slight increase (Fig. 8). Briggs believed that movements to the limestone breaks in summer resulted from shade requirements for loafing. Lehmann (1941:30) noted that heavy cover was used for shade by Attwater's prairie chickens during summer, and Baker (1953:17) reported that male prairie chickens in Kansas used loafing cover in the shade of shrubs and tall grass. During the summers of 1967 and 1968, female prairie chickens, both with and without broods were frequently located in the shade of shrubs and tall forbs. Field borders provided some such areas, but most were in the wetter limestone breaks sites.

Booming grounds provided a weighted mean preference index of 11.1 for all seasons, indicating extensive use of a small proportion of the study area. As might have been expected, use of booming grounds was greatest during the early morning period in the spring of the year. During the 2-year period, the summer of 1966 was the only season during which prairie chickens were not located on the booming grounds. This was perhaps because the 1966-1967 phase of the study was not begun until 16 June 1966, after booming activities for that season had ceased. As previously noted, all booming grounds were located on claypan sites, and except for the activity classification, could as well be classified as claypan site locations.

Wheat and oats fields accounted for 7 percent of the bird locations for the 2-year period, and provided a mean preference index of 3.2. Briggs (1968:45) noted that use of wheat and oats fields was greatest during summer and fall, when waste grain was available. He reported that wheat fields were used most heavily during the evening in summer, and that birds occasionally roosted in grain stubble. Similar observations were made during the 1967-1968 phase of the study (Table 8). Briggs (1968:45) further reported that wheat fields were frequented by prairie chickens during winter and spring when green wheat was available, though to a lesser extent than during summer and fall.

Grain sorghum fields accounted for 8 percent of all locations for the 2-year period, and the weighted mean preference index was 7.1. Greatest use of grain sorghum was in winter during each of the two years, with preference indices of 7.0 for winter 1966-1967, and 70.0 for the winter of 1967-1968. The large increase reflects the much smaller proportion of the area in grain sorghum during the 1967-1968 phase of the study. Use of grain sorghum fields was approximately egual during each of the three daily time periods, with the morning and evening periods showing slightly more use than the mid-day period (Fig. 8, Table 8). Weather conditions and numbers of birds tracked were approximately egual during the winters of 1966-1967 and 1967-1968, though one of the fields contained only volunteer growth during the second winter. The fact that less grain was available in the same area may have accounted for the larger proportion of locations in grain sorghum fields during the second winter.

CONCLUSIONS

In the opinion of the author, the following conclusions are justified by the data collected to date in the entire study:

1. The mean distance between daily radio-telemetry locations provided a better index to movement activity of greater prairie chickens than do mean monthly ranges or total home ranges, since fewer data were required to make reliable estimates.

2. The movement activity of greater prairie chickens on the study area followed similar seasonal patterns during each year, and the movement patterns were determined by the proximity of different types of required habitat. The interaction of energy requirements and sexual behavior apparently accounted for the seasonal shifts in mobility patterns.

3. Spring burning of pastureland destroys prairie chicken nests and decreases the likelihood of prairie chicken renesting attempts being successful. Thus, sound economic range management practices in the region of the study area are not necessarily beneficial to prairie chickens.

4. Variation of vegetation density did not fully explain the changes in habitat use by greater prairie chickens during the study period. Obviously, other parameters of the habitat must be evaluated to more fully account for habitat utilization patterns of greater prairie chickens.

5. Dummy nest studies indicated that early nesting attempts of prairie chickens contribute more to the annual production than do later ones. Natural nest data showed that early nests had larger average clutches and greater hatching success.

6. Human disturbance apparently had little effect on the success of dummy nests, except those marked by flags, and presumably did not account for the low percentage (20 percent) of natural nests that hatched successfully during the entire study.

7. More study is needed to: 1) obtain data on movement patterns of female greater prairie chickens, particularly during the winter period, 2) determine brood movement and dispersal patterns, 3) establish the role of extensive movements of juvenile males in the gene pool of prairie chicken populations, and 4) the influence of trapping and handling on mortality, particularly of female prairie chickens.

SUMMARY

In 1963, a 6-year study of the ecology of greater prairie chickens was initiated in the Flint Hills region of northeastern Kansas. This thesis includes findings concerning daily and seasonal movement patterns, monthly ranges, and reproduction of greater prairie chickens during the 1967-1968 phase of the study, as well as a discussion of the combined findings from the entire study. Mobility data were obtained by use of the radio-telemetry system developed by Marshall (1960), adapted for greater prairie chicken studies by Cebula (1966), and modified by Silvy (1968).

Live-trapping methods included mist nets, a drop net, bow nets, cannon nets, walk-in traps and a hand dip-net. Tape recorded vocalizations and female decoys mounted in a receptive position aided in trapping success. Telemetry equipment included miniature radio-transmitters, portable receivers, and portable receiving antennas. Nest attentiveness data were obtained by use of a thermistor probe recorder. Dummy nest studies were conducted during

the summers of 1967 and 1968. Brood searches and nest searches were conducted during the spring and summer months of 1967 and 1968.

Vegetation density indices were sampled at the end of each season by the vision-obstruction method of Briggs (1968). Nineteen transects were located in unburned sites and 12 were located in burned sites. Oven-dry weights of vegetation clipped from ten 0.1 M^2 plots along seventeen 20-meter transects were highly correlated with density indices obtained by Briggs' method.

A total of 176 prairie chickens was trapped during the entire study, 47 of which were taken during the 1967-1968 phase. One hundred and twelve birds were banded, of which 29 were marked during the 1967-1968 phase. Sixty-four birds were recaptured during the entire study, and 16 were recaptured during the 1967-1968 phase.

During the entire study oeriod, 100 transmitters were placed on 70 different prairie chickens, and 25 were placed on 23 birds during the 1967-1968 phase. A total of 2,229 days of location data were collected during the entire study, 701 of which were collected during the current phase. An average of 32 days of location data per bird was obtained for the entire period, with an average of 31 days of data per bird during the 1967-1968 phase. A total of 3,214 locations of 70 different prairie chickens was obtained during the entire study, with an average of 46 locations per bird. During the 1967-1968 phase, a total of 873 locations of 23 birds was obtained, giving an average of 38 locations for each bird.

Mean monthly ranges and mean distances between daily locations for each month of the 1967-1968 phase of the study were combined with those from earlier phases (Cebula, 1966; Viers, 1967; Silvy, 1968) to determine seasonal patterns.

In general the patterns of mean monthly ranges and mean distance between daily locations for each month were similar for adult males and juveniles. The largest mean ranges for adult and juvenile males were recorded in March, with a sharp decline in the area traversed in April and May. A slight increase in the range of adult males occurred during June, followed again by a decrease in mean range to the annual minimum in August. No data were obtained for juveniles during June and July, since no juvenile birds were large enough to carry radio transmitters during that period. The mean August range of juveniles was larger than the May range, though the latter was calculated from only one bird and may not have been representative of the entire population. Mean monthly ranges of both adult males and juveniles increased with each successive fall month, and declined slightly in size in December. The range of juveniles continued to decrease in January and an increase in size of ranges of both juvenile and adult males resumed in February, and the annual maximum was reached in March.

Sufficient data were available to calculate mean ranges for adult females for the months of March through September only. Mean monthly ranges of adult females differed markedly from those of adult and juvenile males. Ranges remained nearly constant in area from March through July. Female mean monthly ranges began to decrease in August, and the smallest mean monthly range was recorded in September.

Mean daily movements of adult males reached an annual maximum in February, and decreased in length during each successive spring and summer month until August, during which the shortest movements of the year-round period were recorded. An increase in the distance of mean daily movement occurred with each successive fall month, followed by a decline in December and a resumed increase in January. The longest mean daily movements of the year occurred during February.

Movements of juvenile males were similar to the pattern exhibited by adult males from December through May although a one-month lag in the annual peak and the winter decrease appeared to occur. The mean daily movements of juveniles from August through December also appeared to follow a pattern similar to that of adult males. Mean daily movements of juvenile males for the period from August through December were consistently shorter than those of juvenile females.

Mean daily movements of adult females remained nearly constant from February through September, with the exception of a sharp increase in mean daily movements in April, the month which contained the height of the breeding season. A slight decrease in mean daily movement was noted in September, which may have marked the period when most females were in the postnuptial molt.

It appeared that the proximity of different types of required habitat determined the length of daily movements, and that the interaction of sexual behavior and energy requirements influenced the timing of the movement cycle.

Dummy nest studies indicated that: 1) early nests had the greatest chance of survival, 2) marking nests with surveyor's flags significantly increased the chance of nest destruction, and 3) burning large expanses of rangeland increased the likelihood of destruction of nests located in small unburned areas. No significant differences in the chances of survival of nests due to site influences or human visitation could be detected. Cattle were responsible for the destruction of 75 of 117 dummy nests, skunks 14, undetermined agencies 9, coyotes 9, crows 7, badgers 2, and vehicles 1.

More than 1,040 hours of nesting activity of three female prairie chickens were monitored by use of thermistor recorders during the nesting season of 1967. Approximately 302 hours of these data were obtained during the 1967-1968 phase of the study. The average time spent on the nest by laying females was 3.25 hours for each egg, and laying periods ranged from 1.50 to 8.75 hours in duration. With one exception, eggs in all nests were laid at the rate of one per day. For all nests, morning absences of females during incubation averaged 1.31 hours, and evening absences averaged 1.05 hours.

All 12 broods observed during the 1967-1968 phase of the study were found in or near grain fields, field borders or old fields. Only one of the broods observed was believed to be less than four weeks of age. Earlier observations of movements of broods up to two weeks of age were confined to grassy ravines.

Three members of one brood were radio-tagged at approximately 10 weeks of age, and were successfully tracked until the age of 14 weeks. Observations indicated that dispersal of the brood did not begin until young were more than 12 weeks of age, and that departures from the family group were temporary between 12 and 14 weeks.

A total of 34 prairie chickens were known to have died during the course of the entire study. Twenty-one (30 percent) of 70 prairie chickens that were radio-tagged during the entire study were known to have died. Seventeen of 34 fatalities resulted from predation. Evidence indicated that eight birds were killed by coyotes, four by great horned owls, four by hawks, and one by a skunk. Of the deaths not caused by predation, five were caused by trapping, four by hunting, two by accidents, and five from unknown causes.

Of the three major range sites on the study area, the shallow site contained the greatest proportion (44 percent) of prairie chicken locations.

The shallow site provided a weighted mean habitat preference index of 2.3 (obtained by dividing the percentage of bird locations in a site by the percent of the area occupied by the site). The limestone breaks site contained 22 percent of the 2,019 locations, with a mean preference index of 0.4, and 10 percent of the locations were in the claypan site which had an overall preference index of 0.7.

Booming grounds accounted for 9 percent of the locations with a mean preference index of 11.1, wheat and oats fields 7 percent with an index of 3.2, and grain sorghum fields 8 percent with an index of 7.1. Year-to-year differences in occurrence of prairie chickens were apparent, but could not be explained solely on the basis of vegetation density. Grain sorghum fields and the claypan site were the only sites that appeared to be used approximately the same during the two years.

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LITERATURE CITED

Adams, L. 1965. Progress in ecological biotelemetry. BioSci. 15(2):83-86.

Ammann, G. A. 1957. The prairie grouse of Michigan. Game Div. Mich. Dept. of Cons. Lansing. 181pp.

Anderson, A. 1963. Patagial tags for waterfowl. J. Wildl. Mgmt. 27(2): 284-288.

Anderson, B. K. 1965. Mating behavior of the greater prairie chicken in Wisconsin. 8pp. IN Proc. VI Conf. Prairie Grouse Tech. Council, Warroad, Minnesota. 38pp.

_____, and Frances Hamerstrom. 1967. Trapping cock prairie chickens on booming grounds with hen decoys. J. Wildl. Mgmt. 31(4):829-832.

Anderson, K. L. 1961. Common names of a selected list of plants. Tech. Bull. No. 117. Kans. Agr. Expt. Sta., Kans. St. Univ., Manhattan. 59pp.

_____, E. F. Smith, and C. E. Owensby. 1968. Burning bluestem range. Unpublished manuscript 38pp. Typewritten.

Baker, M. F. 1953. Prairie chickens of Kansas. Univ. of Ks. Mus. Nat. Hist. State Biol. Surv. Misc. Publ. No. 5. 66pp.

Baldwin, S. P. and S. C. Kendeigh. 1927. Attentiveness and inattentiveness in the nesting behavior of the house wren. Auk 44(2):206-216.

Bennitt, R. and W. O. Nagel. 1937. A survey of the resident game and furbearers of Missouri. U. of Mo. Studies 12(2):1-215.

Bent, A. C. 1932. Life histories of North American gallinaceous birds. U. S. Nat. Hist. Mus. Bull. 162:242-285.

Bidwell, O. W. 1960. Soil survey of Geary County, Kansas. U.S.D.A. Soil Cons. Service and Ks. Agr. Expt. Sta. 35pp.

Blair, W. F. 1953. Population dynamics of rodents and other small mammals. Advances in Genetics 5:1-41.

Briggs, J. N. 1968. Vegetation and occurrence of greater prairie chickens (Tympanuchus cupido pinnatus) on three range sites in Geary County, Kansas. M. S. Thesis. Kansas State Univ., Manhattan. 59pp.

Burt, W. H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. U. of Mich. Misc. Pub. Zool. 45. 58pp.

Cebula, J. J. 1966. Radio-telemetry as a technique used in greater prairie chicken (Tympanuchus cupido pinnatus) mobility studies. M. S. Thesis. Kansas State Univ., Manhattan. 61pp.

Christisen, D. M. 1967. A vignette of Missouri's native prairie. Missouri Historical Review 61(2):166-186.

Cook, W. W. 1888. Report on bird migration in the Mississippi Valley in the years 1884 and 1885. U.S.D.A. Div. Econ. Orn. Bull. 2. 313pp.

Copelin, F. F. 1963. The lesser prairie chicken in Oklahoma. Okla. Wildl. Cons. Dept. Tech. Bull. No. 6. 37pp.

Einarsen, A. S. 1956. Determination of some predator species by field signs. Oregon State U. Monogr. 10:1-34.

Grange, W. B. 1948. Wisconsin grouse problems. Federal Aid in Wildlife Restoration Proj. No. 5R. Pub. 328. Wisconsin Cons. Dept. Madison. 318pp.

Gross, A. O. 1930. Progress report of the Wisconsin prairie chicken investigation. Wisc. Cons. Comm., Madison. 112pp.

Hamerstrom, F. N., Jr. 1939. A study of Wisconsin prairie chicken and sharptailed grouse. Wilson Bull. 51:105-120.

_____, 1941. A study of Wisconsin prairie grouse--breeding habits, winter food, endoparasites, and movements. Ph.D. Dissertation, Univ. of Wisconsin, Madison. 140pp.

_____, and O. E. Mattson. 1964. A numbered, metal color-band for game birds. J. Wildl. Mgmt. 31(1):124-141.

_____, _____, and Frances Hamerstrom. 1957. A guide to prairie chicken management. Wisconsin Cons. Dept. Tech. Bull. 15. 128pp.

_____, and Frances Hamerstrom. 1949. Daily and seasonal movements of Wisconsin prairie chickens. Auk 66(4):313-337.

_____, and _____. 1955. Population density and behavior in Wisconsin prairie chickens (*Tympanuchus cupido pinnatus*). Proc. XI Internat'l. Orn. Cong. Basel, 1954. pp. 459-466.

_____, and _____. 1960. Comparability of some social displays of grouse. Proc. XII Internat'l. Orn. Cong., Helsinki, 1958. pp. 274-293.

Hartesvelt, R. J. 1951. A simple technique for den-use study. J. Wildl. Mgmt. 15(1):105-106.

Herbel, C. H. and K. L. Anderson. 1959. Response of true prairie vegetation on major Flint Hills range sites to grazing treatment. Ecol. Monogr. 29:171-186.

Horak, G. J. 1967. Population dynamics of prairie chickens in grassland and cropland areas. Completion Report, Job No. D-3-5, P-R Proj. W-23-R-5. Kansas Forestry, Fish and Game Comm., Pratt. 20pp. Multilith.

_____, and W. C. Peabody. 1966. Effects of availability of cultivated acreage on the pooulation dynamics of the greater prairie chicken, Kansas Forestry, Fish and Game Comm., Pratt. 5pp. Mimeo.

Heezen, K. L., and J. R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. J. Wildl. Mgmt. 31(1):124-141.

Jacobs, K. F. 1958. A drop-net trapping technique for greater prairie chickens. Okla. Acad. Sci. 68:314-322.

Jackson, W. 1967. Seasonal movements of prairie grouse in South Dakota. M. S. Thesis, South Dakota St. Univ., Brookings. 47pp.

Jones, R. E. 1963. Identification and analysis of lesser and greater prairie chicken habitat. J. Wildl. Mgmt. 27(4):757-778.

Kessler, F. W. 1960. Egg temperatures of the ring-necked pheasant obtained with a self-recording potentiometer. Auk 77(3):330-336.

Ko, W. H. 1965. Progress in miniaturized biotelemetry. 8ioSci. 15(2): 118-121.

Komarek, E. V., Sr. 1966. The meteorological basis for fire ecology, Proc. 5th Tall Timbers Fire Ecol. Conf. 5:85-126.

Korschgen, L. J. 1962. Food habits of the greater prairie chicken in Missouri. Am. Midl. Nat. 68(2):307-318.

Lehmann, V. W. 1941. Attwater's prairie chicken, its life history and management. North Am. Fauna, No. 57. U.S. Fish and Wildl. Service, Washington, O. C. 63pp.

Leopold, A. 1931. Report on a game survey of the north central states. Sporting Arms and Ammunition Mfrs. Institute. Madison, Wisconsin. 299pp.

Main. J. S. 1937. The dance of the prairie chicken. Wilson Bull. 49(1): 37-42.

Marshall, W. H. 1960. Development and use of short wave radio transmitters to trace animal movements. Univ. Minnesota. 27pp. Mimeo.

_____, 1964. Progress report: Studies of movements, behavior and activities of ruffed grouse using radio telemetry techniques. Univ. Minnesota. 12pp. Mimeo.

Marshall, A. J. 1961. Biology and comparative physiology of birds. Vol. II. Academic Press, N. Y. and London. 468pp.

Mohler, L. L. 1952. Fall and winter habits of prairie chickens in southwest Nebraska. J. Wildl. Mgmt. 16(1):9-23.

_____, 1963. Winter surveys of Nebraska prairie chickens and management implications. J. Wildl. Mgmt. 27(4):737-738.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. Am. Midl. Nat. 37(1):223-249.

Ostle, B. 1963. Statistics in research. Iowa St. Univ. Press, Ames. 585pp.

Pienkowski, E. C. 1965. Predicting transmitter range and life. BioSci. 15(2):115-118.

Rearden, J. D. 1951. Identification of waterfowl nest predators. J. Wildl. Mgmt. 15:386-395.

Robel, R. J. 1964. Quantitative indices to activity and territoriality of booming Tympanuchus cupido pinnatus in Kansas. Trans. Kans. Acad. Sci. 67(4):702-712.

_____, 1967. Significance of booming grounds of greater prairie chickens. Proc. Am. Philos. Soc. 111(2):109-114.

Sanderson, G. C. 1966. The study of mammal movements--a review, J. Wildl. Mgmt. 30(1):215-235.

Schmidt, F. J. W. 1936. Winter food of the sharp-tailed grouse and pinnated grouse in Wisconsin. Wilson Bull. 48(3):141-160.

Schwartz, C. W. 1945. The ecology of the prairie chicken in Missouri. Univ. of Missouri Studies. 20(1):1-99.

Seton, E. T. 1909. Life histories of northern animals. Charles Scribner's Sons, New York. Vol. I. 693pp.

Silvy, N. J. and R. J. Robel. 1967. Recordings used to help trap booming greater prairie chickens. J. Wildl. Mgmt. 31(2):370-373.

_____, and _____. 1968. Mist nets and cannon nets compared for capturing prairie chickens on booming grounds. J. Wildl. Mgmt. 32(1):175-178.

_____. 1968. Movements, monthly ranges, reproductive behavior, and mortality of radio-tagged greater prairie chickens (Tympanuchus cupido pinnatus). M. S. Thesis, Kansas State Univ., Manhattan. 135pp.

Siniff, D. B. and J. R. Tester. 1965. Computer analysis of animal movement data obtained by telemetry. BioSci. 15(2):104-108.

Slade, N. A., J. J. Cebula, and R. J. Robel. 1965. Accuracy and reliability of biotelemetric instruments used in animal movement studies in prairie grasslands of Kansas. Trans. Kansas Acad. Sci. 68(1):173-179.

Slater, L. E. 1963. Biotelemetry. Proc. Interdisciplinary Conf. Pergamon Press, New York. 372pp.

Smith, L. S. 1962. A report on a cannon net trap workshop held at Swan Lake National Wildlife Refuge, Oct. 4-5, 1962. U.S. Fish and Wildl. Serv., Branch of Wildl. Refuges, Boston, Mass. 12 pp. Mimeo.

Snedecor, G. W. 1956. Statistical methods, Iowa State Univ. Press. Ames, Iowa. 534pp.

Stemple, M. E. and S. Rodgers, Jr. 1961. History of prairie chickens in Iowa. Proc. Iowa Acad. Sci. 68:314-322.

Stoddard, H. L. 1932. The bobwhite quail - its habits, preservation, and increase. Charles Scribner's Sons, New York. 559 pp.

Tester, J. R. and D. B. Siniff. 1965. Aspects of animal movement and home range data obtained by telemetry. Trans. N. Am. Wildl. Conf. 30:379-392.

Viers, C. E. 1967. Home range and movements of the greater prairie chicken (Tympanuchus cupido pinnatus) with notes on activities. M. S. Thesis. Kansas State Univ., Manhattan. 78pp.

Yeatter, R. E. 1943. The prairie chicken in Illinois. Illinois Nat. Hist. Surv. Bull. 22(4):377-416.

Zwickel, F. C. and A. N. Lance. 1965. Renesting in blue grouse. J. Wildl. Mgmt. 29(2):402-404.

APPENDIX

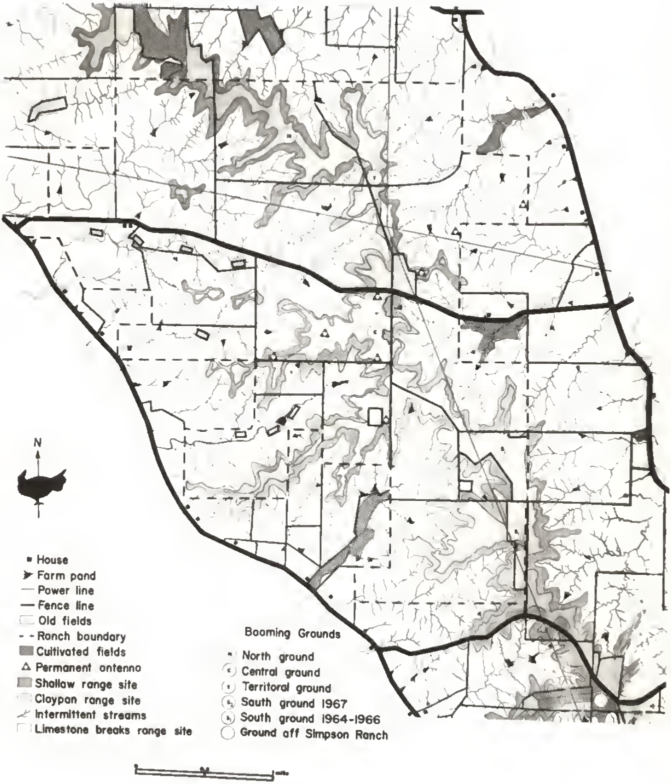


Fig. 1. Map of the Simpson ranch study area.

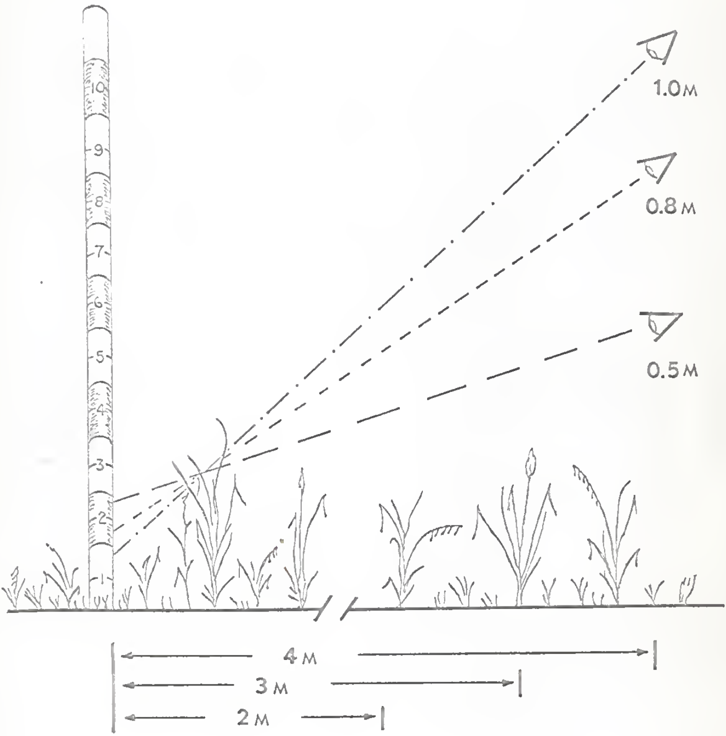


Fig. 2. Diagrammatic sketch of apparatus and technique used in sampling vegetation density. Readings were taken at each of the three heights at 2, 3, and 4 meters from the pole when the pole was placed at each alternate meter along a 20-meter transect (from Briggs, 1968).

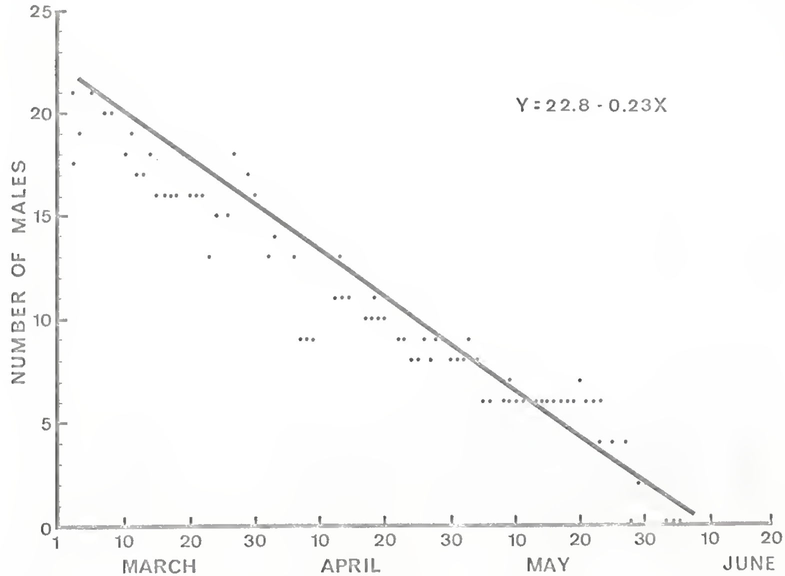


Fig. 3. Numbers of booming male prairie chickens present on the central booming ground during the spring booming season, 1968.

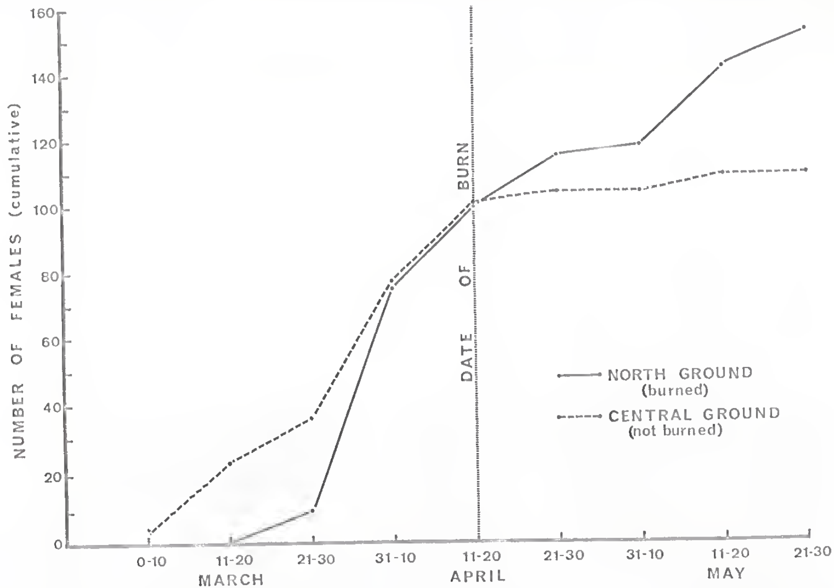


Fig. 4. Cumulative frequency of visits of female prairie chickens to booming grounds in burned and unburned areas during the spring booming season of 1968.

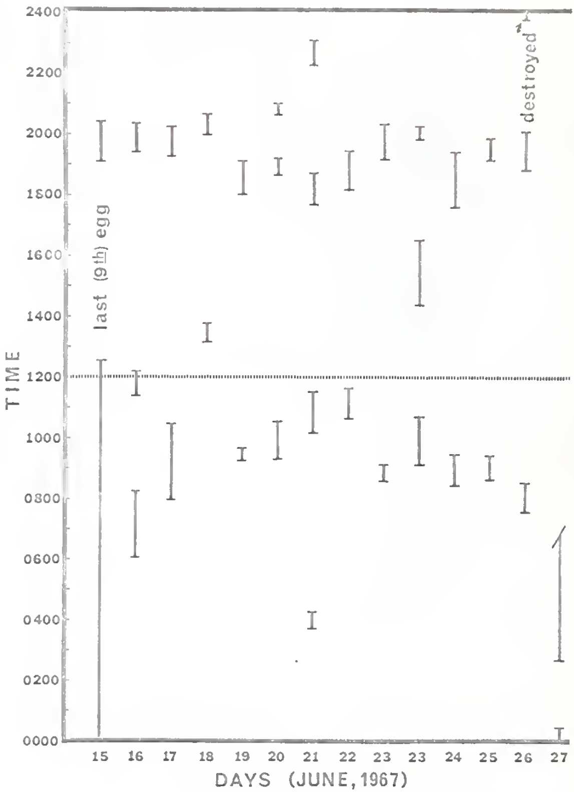


Fig. 5. Record of attentiveness and inattentiveness for the second renest of bird AF70, obtained by use of the Rustrak dual-probe thermistor recorder. Solid lines indicate periods when the female was absent from the nest.

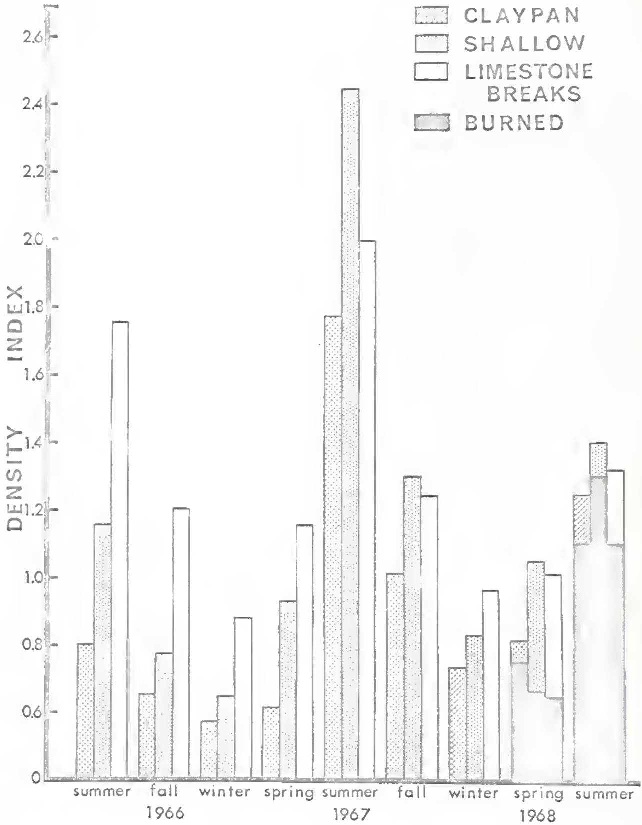


Fig. 6. Annual and seasonal variation in vegetation density on the three major range sites of the study area from summer 1966 through summer 1968.

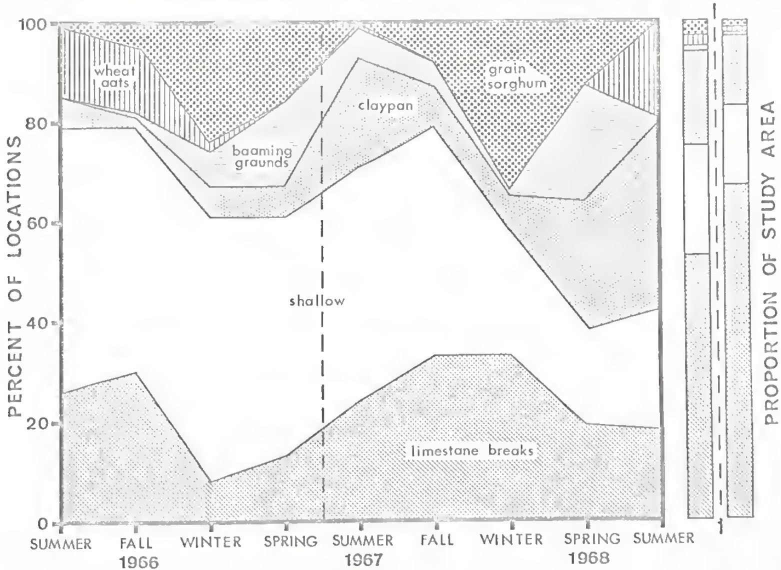


Fig. 7. Seasonal site distribution of 2,019 radio-telemetry locations of greater prairie chickens tracked between 16 June 1966 and 30 August 1968.

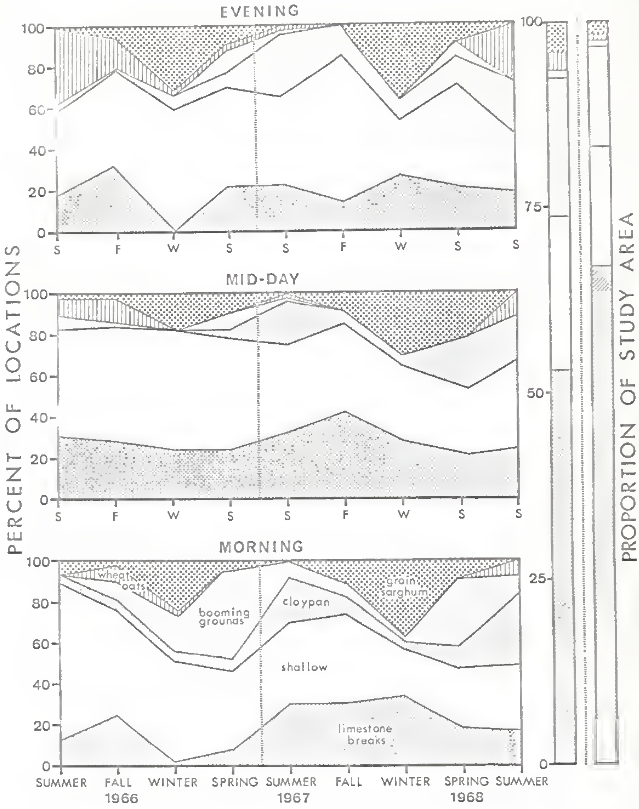


Fig. 8. Timewise site distribution of 2,019 radio-telemetry locations of greater prairie chickens tracked between 16 June 1966 and 30 August 1968.

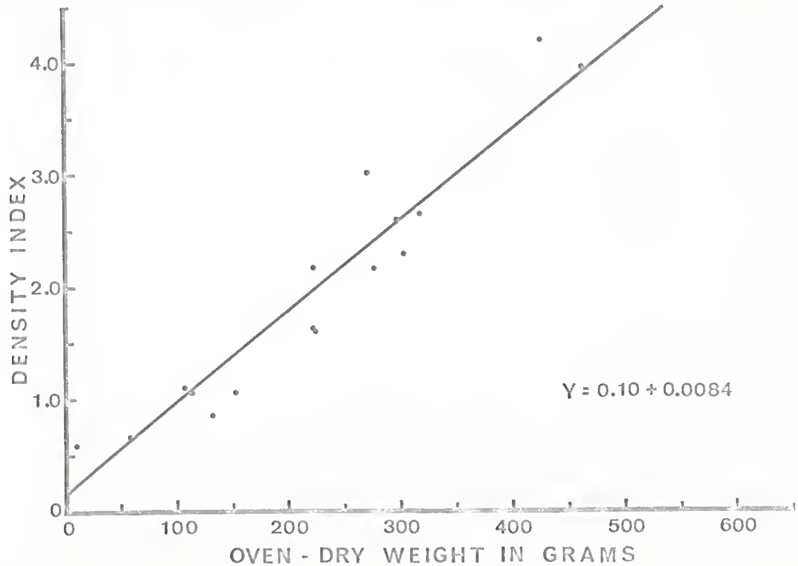


Fig. 9. Relationship between vegetation density indices determined by the method of Briggs (1968) and oven-dry weight of vegetation clipped from ten 0.1 M^2 plots along the same 20-meter transects.

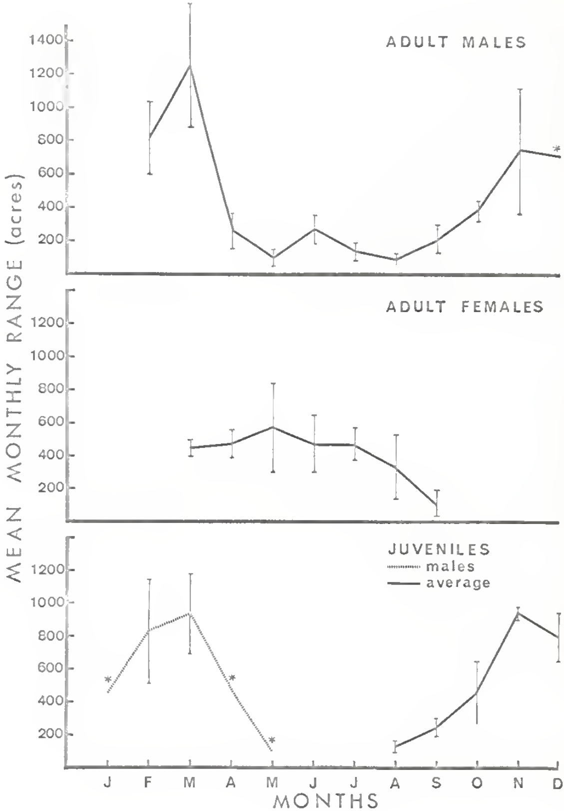


Fig. 10. Mean monthly ranges of 70 radio-tagged greater prairie chickens tracked during the period 1964-1968. Vertical lines indicate a span of plus or minus one standard error ($S_{\bar{x}}$). Asterisks indicate sample sizes too small for calculation of standard errors.

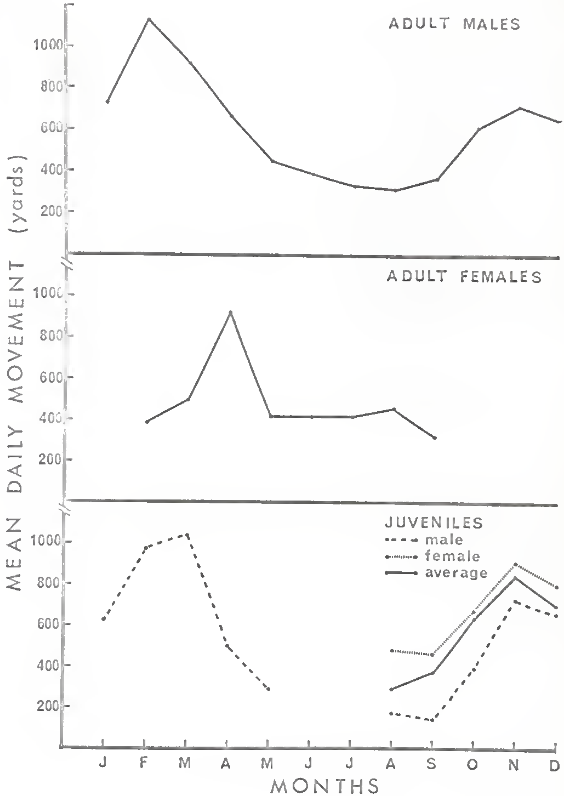


Fig. 11. Mean distances between daily locations of 70 greater prairie chickens radio-tracked between 1964 and 1968. Standard errors of the means are given in table 10.

EXPLANATION OF PLATE I

Fig. 1. Diagrammatic sketch of erected mist net. Supports (A) and (A') are 14-inch surveyor's arrows and (B) is a standard electric wire fence post. The elevated edge of the net should face the main path of approaching birds (from Silvy and Robel, 1968).

Fig. 2. View of cocked bownet with female decoy in position. Net and frame were covered with litter for concealment when bownet was used. Sensitive trigger engages bow frame at lower left.

PLATE I

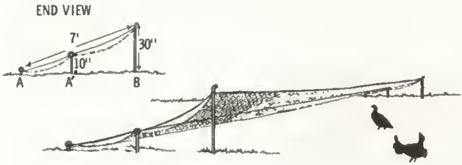


Figure 1.

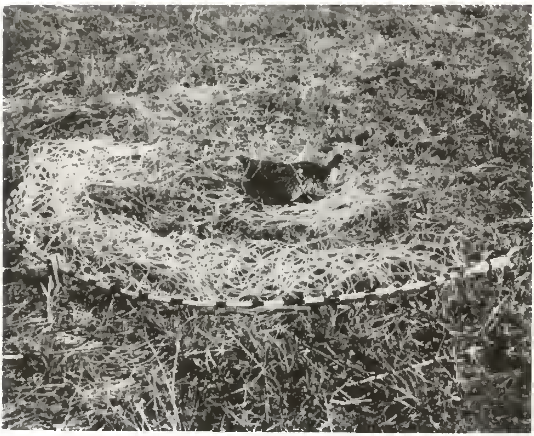


Figure 2.

EXPLANATION OF PLATE II

Fig. 1. A view of transmitters with single (left) and double (right) battery packs. Note plastic "snap cap" with center brass contact.

Fig. 2. Closeup of portable receiver, showing canvas carrying case and strap. Base of permanent antenna is seen at upper right.

PLATE II

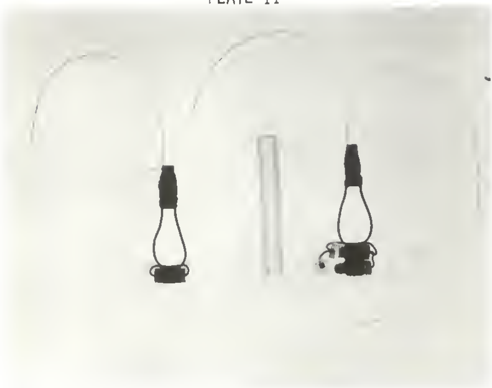


Figure 1.

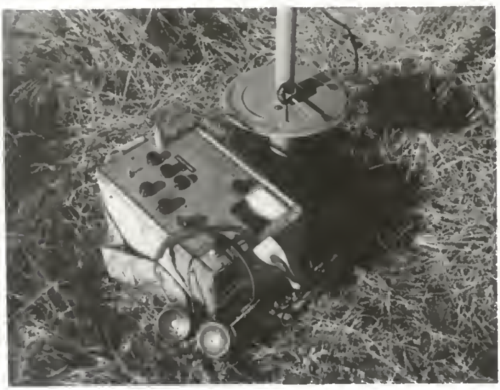


Figure 2.

EXPLANATION OF PLATE III

Fig. 1. View of the mobile receiving antenna mounted on a pickup truck.

Fig. 2. A hand-held directional antenna being used to locate a radio-tagged prairie chicken.

PLATE III

Figure 1.

Figure 2.

EXPLANATION OF PLATE IV

Fig. 1. View of prairie chicken nest showing Rustrak thermistor probe.

Fig. 2. Closeup of Rustrak thermistor recorder housed in plastic container.

PLATE IV

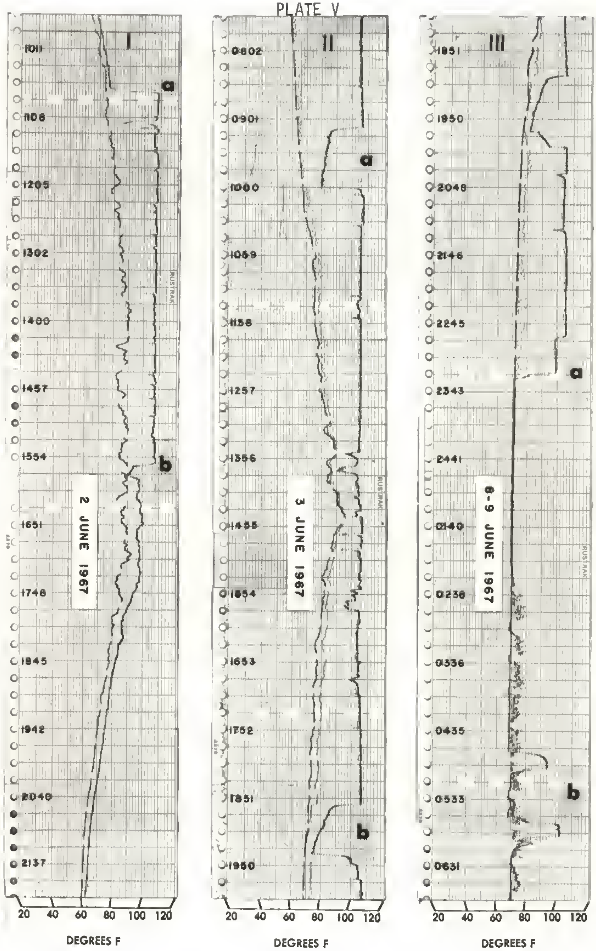
Figure 1.

Figure 2.

EXPLANATION OF PLATE V

Fig. 1. View of three Rustrak chart tracings. Broken lines show temperatures recorded in an artificial nest, and solid lines show temperatures in the actual nest. Chart I shows the arrival (a) and departure (b) of a female prairie chicken during the morning laying period. Chart II shows morning (a) and evening (b) feeding periods of an incubating female. Chart III shows time female was flushed prior to nest destruction (a) and two subsequent revisits (b) by the female before the nest was abandoned.

PLATE V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MOBILITY PATTERNS, HABITAT RELATIONSHIPS AND REPRODUCTIVE SUCCESS OF GREATER PRAIRIE CHICKENS (TYMPANUCHUS CUPIDO PINNATUS) IN NORTHEASTERN KANSAS

by

PHILIP G. WATT

B. S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Zoology

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1969

ABSTRACT

In 1963, a 6-year study of the ecology of greater prairie chickens was initiated on a 6,000 acre study area in the Flint Hills region of northeastern Kansas. Mobility patterns, habitat relationships and factors affecting reproductive success were investigated between 16 June 1967 and 30 August 1968. Mobility data were obtained by use of a radio-telemetry system developed by Marshall (1960).

Live-trapping methods included mist nets, a drop net, bow nets, cannon nets, walk-in traps and a hand dip-net. Tape recorded vocalizations and female decoys mounted in a receptive position aided in trapping success. Telemetry equipment included miniature radio transmitters, portable receivers and portable receiving antennas. Nest attentiveness data were obtained by use of a thermistor probe recorder. Dummy nest studies, brood searches and nest searches were conducted during the spring and summer months.

Vegetation densities on 31 permanent transects were sampled at the end of each season by the vision-obstruction method devised by Briggs (1968). Density indices obtained by Briggs' method were highly correlated ($r = 0.958$) with the oven-dry weight of vegetation clipped from 17 transects.

Mobility data were combined with the cumulative findings thus far in the 6-year study. Mean daily movements and monthly ranges showed similar annual patterns. The most extensive movements of adult and juvenile males were in February and March, respectively, and movements of both became shorter during each successive month from March through the summer months, reaching an annual minimum in August. Monthly ranges and daily movements increased from September until November for both juveniles and adult males. A decrease in ranges and length of movements occurred in December, followed by a resumed

increase in adult male movements, but movement of juveniles continued to decline until January. A sharp increase in movement of both adult and juvenile males occurred in February, followed by a slight increase in March for juveniles, and a decline in movements of adult males. The spring decline in movements of juveniles did not begin until April.

Mean daily movements of adult females remained nearly constant from February through September, with the exception of a sharp increase in April, the month which contained the height of the breeding season. A slight decrease in movements was noted in September, when most females were molting. Mean monthly ranges of adult females showed no significant differences from March through July, and began to decrease in August and September.

The proximity of different types of required habitat apparently determined the length of movements and the size of monthly ranges. The interaction of energy requirements and sexual behavior appeared to have influenced the timing of the annual movement cycle.

Dummy nest studies indicated that: 1) early nests had the greatest chance of survival, 2) marking nests with surveyor's flags significantly increased the chance of nest destruction, and 3) burning large expanses of rangeland increased the likelihood of destruction of nests located in small unburned areas. No significant difference in the chances of survival of nests due to site influences or human visitation could be detected.

The average time spent on the nest by laying females was 3.25 hours for each egg, and laying period ranged from 1.5 to 8.75 hours in duration. With one exception, eggs in all nests were laid at the rate of one per day. For all nests, morning absences of females during incubation averaged 1.31 hours, and evening absences averaged 1.05 hours.

All 12 broods observed during the 1967-1968 phase of the study were found in or near grain fields, field borders, or old fields. Only one brood was believed to be less than four weeks of age. Movements of broods up to two weeks were confined to grassy ravines (Viers, 1967).

Dispersal of one brood began when the young birds were about 12 weeks of age, and departures from the family group were temporary between 12 and 14 weeks.

Thirty-four prairie chickens were known to have died during the course of the entire study. Twenty-one (30 percent) of 70 prairie chickens that were radio-tagged during the study were known to have died. Seventeen of 34 fatalities resulted from predation.

Of the three major range sites on the study area, the shallow site contained the greatest proportion (44 percent) of prairie chicken locations. The shallow site provided a weighted mean habitat oreference index of 2.3. The limestone breaks site contained 22 percent of the 2,019 locations, with a mean preference index of 0.4, and 10 percent of the locations were in the claypan site which had an overall preference index of 0.7.

Booming grounds accounted for 9 percent of the locations with a mean preference index of 11.1, wheat and oats fields 7 percent with an index of 3.2, and grain sorghum fields 8 percent with an index of 7.1. Year-to-year differences in habitat preference of prairie chickens were apparent, but could not be explained solely on the basis of vegetation density. Grain sorghum fields and the claypan site were the only sites that appeared to be used approximately the same during the two years.