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Harold H. Prince
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HABITAT SELECTION AND REPRODUCTIVE SUCCESS OF SICHUAN PHEASANTS IN MICHIGAN

By

Paul Irving Padding

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ABSTRACT

HABITAT SELECTION AND REPRODUCTIVE SUCCESS OF SICHUAN PHEASANTS IN MICHIGAN

By

Paul Irving Padding

Habitat selection and reproductive success of female Sichuan pheasants (*Phasianus colchicus strauchi*) released in southeastern Michigan were studied in 1987. The objectives of this study were to document the nesting ecology and evaluate habitat preferences of females and to estimate survival of their chicks. This was accomplished by monitoring a sample of radio-tagged females on a daily basis.

Nest initiation began in early April and continued through early July. Prior to nest incubation, females preferred idle agricultural fields and wooded wetlands, but upland scrub-shrub was the preferred cover type for initial nesting attempts. Nest success was 40%, and appeared to be related to diversity of vegetative structure at nest sites. Females with broods preferred idle agricultural fields, upland herbaceous, upland scrub-shrub, and emergent wetland cover types. Daily survival probabilities for chicks were 0.9747 for the first 4 weeks after hatch and 0.9916 for the following 8 weeks.

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INTRODUCTION

The state-sponsored introduction of ring-necked pheasants (*Phasianus colchicus*) to Michigan began in 1918 (McCabe et al. 1956, MacMullan 1957). Michigan held its first pheasant hunting season in 1925 (MacMullan 1957), and the species soon became the most popular upland game bird in the state (McCabe et al. 1956). Pheasant populations in Michigan, as well as throughout the United States, increased to all-time highs in the mid 1940's, and then underwent general and sometimes drastic declines during the subsequent decades.

Many factors have contributed to the decline of pheasants, including changes in agricultural land use patterns, the advent of herbicides and pesticides, climate, and predation. Clean farming, which entails the use of all available land by the farmer, led to the elimination of fencerows and draining of potholes, decreasing winter cover (Labisky 1976, Warner and David 1982). Fall plowing became more widespread, further reducing winter cover and food available to pheasants. Optimal nesting and brood cover declined as farmers shifted from production of small grains and forage crops to row crops, and put fallow fields into production (Leedy and Dustman 1947, Warner 1979, Warner et al. 1984). This loss of adequate cover made pheasants more vulnerable to predation (Dumke and Pils 1973) and increased the probability of death from starvation or exposure during harsh winters (McClure 1948, Kopischke and Chesness 1967). The negative impacts of biocides on reproduction and survival of birds have been shown by several investigators (Adams and Prince 1972, Stromborg 1977, 1979, Bennett and Prince 1981).

Although many studies have demonstrated the impacts of individual factors on pheasant populations, an integrated overview of the interactions of various factors and the mechanisms involved has not been formed. As a result, state agencies attempting to restore pheasant populations may lack information vital to the success of their management plans. In fact, there is no certainty that ring-necked pheasants can ever make a substantial recovery.

An alternative to reestablishment of ring-necked pheasant populations being pursued by Michigan's Department of Natural Resources (MDNR) is the introduction of Strauch's pheasant (P. c. strauchi), called the Sichuan pheasant by the MDNR. This subspecies of common pheasant appears to occupy a different niche than the subspecies originally introduced into North America (P. c. torquatus). The Sichuan pheasant inhabits the mountainous pine (Pinus spp.) and oak (Quercus spp.) forest in the northeast region of Sichuan Province, People's Republic of China. It is hypothesized that Sichuan pheasants will occupy the brushy nonagricultural habitats in southern Michigan and therefore may offer better hope for rehabilitation of pheasant populations.

In 1987, the MDNR initiated a long-term project to introduce the subspecies and monitor its response to Michigan habitats. As part of that project, the study discussed herein examined reproductive and post-reproductive activities and productivity of purebred female Sichuan pheasants released in southeast Michigan in spring, 1987. The objectives were:

1) to determine nest initiation dates, clutch sizes, nest attentiveness, fertility, hatchability, renest intervals, and nesting success,
2) to describe nest sites selected by females,
3) to evaluate habitat selection by females and broods, and,
4) to estimate chick survival.

BACKGROUND

A pilot study was done in Huron and Tuscola counties of Michigan in spring and summer, 1986 (Prince et al. 1986). The study was undertaken to monitor the response of introduced Sichuan X ring-necked pheasant hybrids and to test equipment and techniques in preparation for future Sichuan pheasant introductions. Two hundred forty two hybrids, including 65 radio-tagged birds (45 females and 20 males), were released at 2 sites. Birds were monitored daily by radio-telemetry from late March through early September.

Reproductive response of the hybrid females differed, in some respects, from that reported for ring-necked females. Clutch size, fertility, hatchability, brood habitat use, and offspring survival were within the ranges reported for ring-necked pheasants (Kabat et al. 1955, Trautman 1982, Castillo et al. 1984). However, 75% of the hybrids' nesting attempts were successful, whereas ring-necked pheasant nest success has been documented at 15-49% during other studies (Baskett 1947, Buss and Swanson 1950, Dumke and Pils 1979, Castillo et al. 1984). The higher success rate may have been due in part to nest site selection. The hybrids nested primarily in wooded and other nonagricultural areas, whereas ring-necks often nest in agricultural fields, and are therefore more susceptible to nest destruction due to farming practices (Olsen 1977). A high incidence of renesting after hatching a clutch of eggs was observed for the hybrids, whereas ring-necked pheasants rarely exhibit this behavior (Dumke and Pils 1979). Because Sichuan pheasants had not been released in Michigan habitats at that time, it was not possible to determine the genetic origins of these phenotypic expressions.

Survival of the hybrids' chicks increased with later hatch dates through June, but this may have been influenced by weather conditions in the region in 1986.

A concurrent breeding study of captive purebred Sichuan pheasants was done at the Mason Wildlife Facility in Mason, Michigan (Prince et al. 1986). Results showed that the mean clutch size of 1-year-old Sichuan females was smaller than those reported for adult ring-necks. Additionally, some individuals did not become involved in reproductive activities.

STUDY AREA

MDNR biologists evaluated potential release sites according to 6 criteria (P. Squibb, pers. commun.). Areas selected should: 1) contain < 60% cultivated lands; 2) include < 15% urban and suburban development; 3) receive < 152 cm mean annual snowfall; 4) include $\geq$ 777 km^2 of diverse, well interspersed vegetation cover types; 5) have no local ordinances that would prohibit hunting when pheasant populations attain huntable numbers; and 6) have public support for the Sichuan pheasant introduction project and for temporary curtailment of pheasant hunting to allow establishment of self-sustaining populations. Putnam Township in Livingston County, southeastern Michigan was selected as the initial release site (Fig. 1).

Land use in Putnam Township (based on aerial photographs taken in 1985) is 31% cropland, 4% residential and developed, and 3% lakes, ponds, and reservoirs. Vegetation cover types include deciduous forest (22%), nonforested upland types (21%), wetlands (17%), and coniferous forest (2%). In 1987, Livingston County's agricultural lands consisted of corn (38%), hay (23%), wheat (7%), other crops (10%), and idle (22%) fields (L. Young, U. S. Agric. Stabil. and Conserv. Serv., pers. commun.).

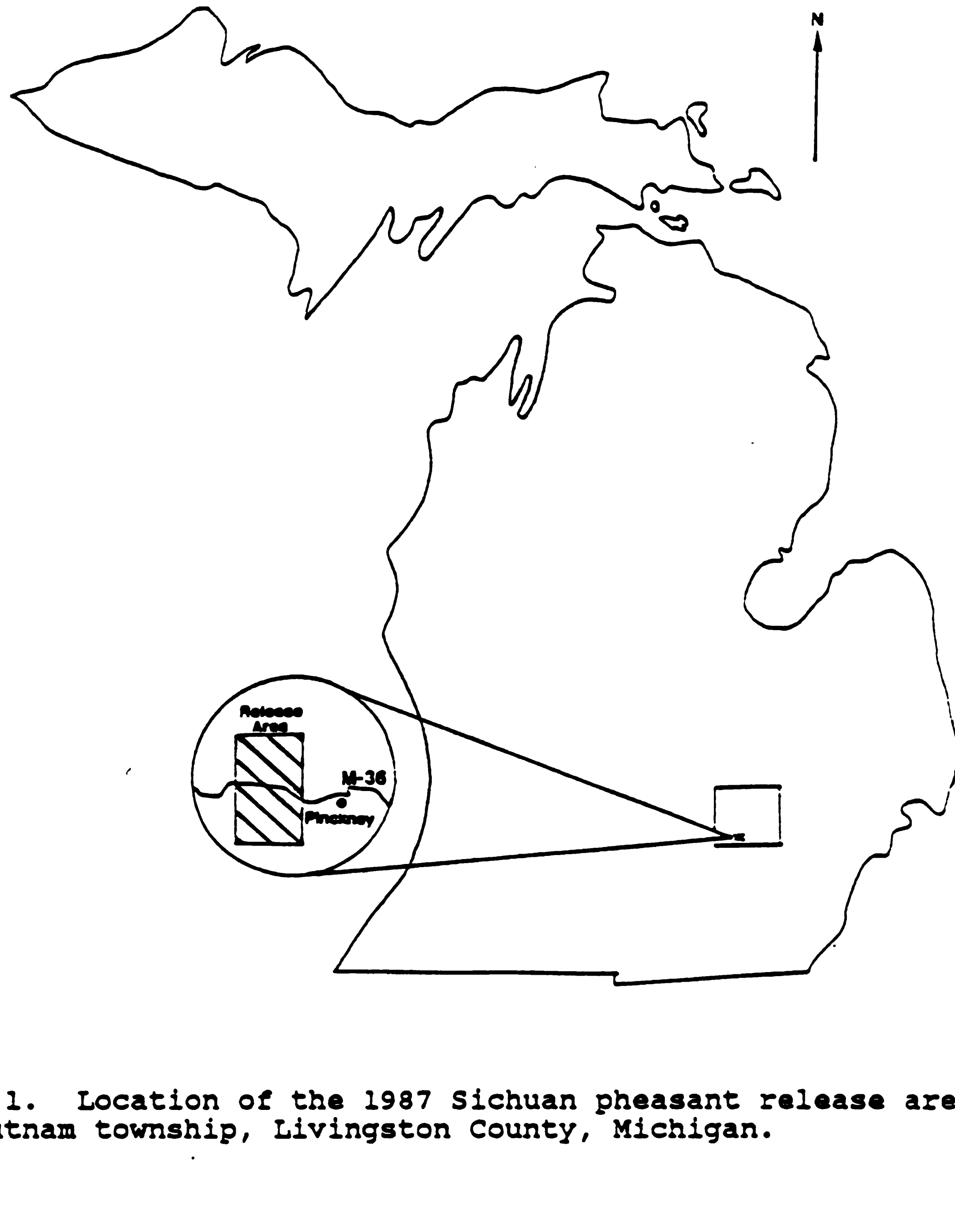

Fig. 1. Location of the 1987 Sichuan pheasant release area in Putnam township, Livingston County, Michigan.

Fox-Boyer-Oshtemo and Fox-Boyer-Oshtemo-Houghton associations are the dominant soil types in Putnam Township, but Spinks-Oakville-Boyer-Oshtemo and Carlisle-Houghton-Gilford associations are also present (Engberg and Austin 1974). These associations range from very poorly drained soils on nearly level outwash plains to well drained soils on hilly moraines (Engberg and Austin 1974).

Mean annual precipitation in Livingston County is 85.3 cm, with 59% of this falling in April through September (Engberg and Austin 1974). Snowfall averages 108 cm annually, but variability among years is high. Winter temperatures are $\leq$ -17.8°C an average of 5 days per year, and summer temperatures reach $\geq$ 37.8°C an average of 10 days per year. Mean dates of last freezing temperature in spring and first freezing temperature in fall are 10 May and 6 October, respectively (Engberg and Austin 1974).

METHODS

Radio telemetry was used to monitor the movements of 87 radio-tagged Sichuan females. A sealed radio transmitter (Telonics, Mesa, AZ) with a 28-cm external antenna was attached to each bird with loops of black, 0.48-cm wide, tubular teflon ribbon (Bally Ribbon Mills, Bally, PA) around the lower neck and each wing, backpack style. The birds were then kept in a holding pen for approximately 2 weeks to condition them to the radio packages prior to release.

Fifty Sichuan pheasants, including 26 radio-tagged females, were released in Putnam township on 16 March, 1987. On 8-9 April, 1987, 272 more birds, including the remaining 61 radio-tagged females, were released at 6 other locations in Putnam township. All released birds were 36-40 weeks old.

Monitoring

Portable TR2 receivers and hand held 2-element Yagi antennas (Telonics, Mesa, AZ) were used to monitor radio-tagged pheasants. Standard triangulation techniques were used to locate birds daily during the initial 2-week dispersal period. Azimuths taken from compass readings were plotted on cover maps upon which a 4-ha grid system was superimposed. To minimize error polygons, only azimuths intersecting at 60-120 degree angles were used (Heezen and Tester 1967), and the birds' locations were recorded as being in given cells on the grid. After the initial 2 weeks, each radio-tagged female was located daily during 1 of 3 time periods: sunrise - 3 hrs after sunrise, 3 hrs after sunrise - 3 hrs before sunset, and 3 hrs before sunset - sunset. The time periods were designed to ensure that birds were located throughout the day, and sampling time was allocated equally among the 3 periods.

From 2 weeks post-release to the end of the study, a different method of location was used to provide more accurate information on habitat selection. An observer approached each radio-tagged pheasant on foot and moved in a semicircle around the bird until its location could be pinpointed visually or through telemetry. Grid cell and cover type within the cell were recorded for the location.

Mapping System

Recent (1985) Geographic Information System (GIS) maps that classified land use into defined cover types were provided by the Land and Water Management Division, MDNR. These maps provided a means for quantifying the composition of the habitat in the entire study area as well as the composition of subunits within the study area. This allowed evaluation of the habitat preferences of female Sichuan pheasants based on selection (as determined from telemetry locations) versus availability (obtained from the GIS maps).

The resolution of the GIS maps was limited to blocks of cover that were $\geq$0.81 ha in size. Therefore, pheasant locations in strip cover, small potholes and sloughs, and other cover types in small amounts were not always accurately represented by the cover types indicated on the maps. Furthermore, because of annual variation in farming activities, the mapping system was not able to distinguish between cropland in production and temporarily idle or recently retired fields. Despite these drawbacks, cover types in which pheasants were located were recorded in accordance with the type indicated on the cover maps so that selection and availability data were consistent.

Nesting

Any radio-tagged bird showing little or no movement for 2 or 3 consecutive days was tracked on foot to check its status. Consequently, nests were generally located when females began to incubate. Incubating females were also located daily. When females were not at their nest sites, nests were approached for observation and the eggs were counted. The average laying rate (1 egg/1.3 days) and incubation period (23 days) reported by Trautman (1982) for ring-necked pheasants were used to estimate nest initiation date. Unhatched eggs from successful, destroyed, or abandoned nests were examined for fertility, and embryos from unsuccessful nests were aged to obtain accurate initiation date estimates. Destroyed nests and the areas surrounding them were inspected in an attempt to identify nest predators.

Four methods were used to evaluate nest success: apparent percent success, the Mayfield model (Mayfield 1961, 1975), the product method (Klett and Johnson 1982), and the Pollock model (Pollock and Cornelius 1987). Apparent percent success only reports the percent success of nests under observation. Cornelius and Pollock (1987) reviewed the inadequacies of this method in a modelling context.

The Mayfield model corrects for failures of unobserved nests during the laying segment of the nest period. Relatively few nests were discovered before incubation, so nests that failed during egg-laying went largely undetected. Nest success as reported by the apparent percent success method was therefore overestimated.

A potentially restrictive assumption of the Mayfield model is that the daily survival rate must be constant over the entire nest period. The product method may alleviate this problem if daily survival rates are constant within distinct segments of the nest period. Survival probabilities are calculated for each segment, then multiplied to produce the overall probability of nest success. In this study, the nest period was divided into 3 segments: laying, the first half of incubation (days 1-11), and the second half of incubation (days 12-23). The duration of the laying segment (12 days) was derived from mean clutch size. A z-test described by Hensler and Nichols (1981) was used to test the null hypothesis that daily survival probabilities for the 3 periods were equal.

The Pollock model is a distribution-free model that does not require that the daily survival rate be constant. It also allows estimation of survival probability from nest initiation to hatching, whereas the Mayfield and product models are based on time of first discovery of the nest. As in the other methods, the Pollock model assumes that observed nests represent a random sample in terms of survival, and that visits by observers do not affect the probability of a nest's survival. It also assumes that encounter probabilities are not related to nest success. In telemetry studies, encounter probability generally is not dependent on visibility of the nest, so this assumption was probably not violated.

Habitat Selection

Prenesting. The prenesting period was 21 days prior to incubation of the eggs, and habitat selection by each female that made a nesting attempt was evaluated. Availability and selection of cover types during the prenesting period were determined from telemetry locations.

Two methods for defining available habitat were evaluated. The first was the minimum area polygon method (Mohr 1947), in which available habitat is considered only that area known to be used by the bird. In the alternative method, the smallest circle encompassing 50% of a bird's locations during the 21-day period was considered the bird's center of activity for that period. A line was then drawn from the focal point of the activity center to the bird's outermost location during the period. This line became the radius for a larger circle that defined the area termed available habitat. The second method, although also constrained by known locations of the bird, is less likely to ignore little used or avoided cover types.

A Digi-pad digitizer (GTCO Corp., Rockville, MD) was used to measure the area of each cover type within a bird's available habitat. Cover types in which the bird was located during the period were termed selected habitat. Seven cover type categories were analyzed: agricultural, upland herbaceous, upland scrub-shrub, deciduous forest, wooded wetlands, emergent wetlands, and other (Table 1). Aquatic bed wetlands, open water, urban development, and other unsuitable cover types were not included as available habitat in the category termed " other ".

Availability and selection of cover types were calculated separately for each bird and the results pooled. The null hypothesis that all cover types were selected in

Table 1. Description of defined cover types available to radio-tagged female Sichuan pheasants released in Livingston County, Michigan, 1987.

Cover Type	Description
Agricultural	cropland currently in production of cash crops and hay, and idle agricultural fields
Upland herbaceous	nonforested land dominated by grasses, forbs, and legumes
Upland scrub-shrub	nonforested land dominated by native shrubs and low woody plants
Deciduous forest	upland and lowland deciduous woodlots such as: beech/maple, oak/hickory, lowland hardwood, and aspen stands
Emergent wetland	wetlands dominated by erect, rooted, perennial, herbaceous hydrophytic plants
Wooded wetland	forested and scrub-shrub wetlands
Other	rural residential, coniferous forest, orchards, ornamental horticulture areas, and miscellaneous agricultural lands

proportion to availability was tested by both the nonparametric Friedman (1937) 2-way analysis of variance and a 1-sample Hotelling T^2 test described by Johnson (1980). Application of the Friedman test and, when the null hypothesis was rejected, of Fisher's least significant difference (LSD) procedure for multiple comparisons followed the methods described by Alldredge and Ratti (1986). The Waller-Duncan multiple comparison procedure suggested by Johnson (1980) was used when results of Hotelling T^2 tests were significant ($P < 0.05$). These 2 methods of analysis were selected based on the results of Monte Carlo simulations reported by Alldredge and Ratti (1986). They showed that by using sample size, number of cover types, and number of observations as criteria for selecting a method, Type I and Type II errors can be minimized.

Agricultural fields in which birds were located were classified as active (currently in production) or idle. Because availability of active and idle fields could not be determined from the GIS maps, farming activity in the study area was assumed to be similar to that in Livingston County as a whole. The U. S. Agric. Stabil. and Conserv. Serv. (USASCS) records for Livingston County indicated that 78% of the agricultural land was in production and 22% was idle in 1987 (L. Young, pers. commun.). Using these data as the basis for estimating availability, the hypothesis that

females selected active and idle agricultural cover types in proportion to availability was tested with Chi-square.

Initial Nesting Attempts. Initial nest sites were studied on both macro- and microhabitat scales. The macrohabitat measures taken were: 1) cover type; 2) distance to the nearest manmade edge, such as a building, road, or agricultural field; 3) distance to the nearest natural edge, where a change in vegetation type occurred; and 4) area of the contiguous block of cover type in which the nest was located.

Cover types selected by radio-tagged females for initial nest attempts were analyzed in terms of availability versus selection. A map of the nest locations was used to place boundaries around an area that encompassed all nests observed. This area was then expanded 0.8 km in all directions, and the area within the resulting boundaries was termed available habitat. Total area of each cover type (based on the GIS maps) within the available habitat was provided by the Land and Water Management Division, MDNR. Each nest site was categorized according to the cover type indicated on the GIS maps. The various cover types were then combined into 5 major groups: wetlands, forest, agricultural, upland herbaceous, and upland scrub-shrub. The null hypothesis that the 5 major cover type groups were selected for nesting in proportion to availability was evaluated with a Chi-square test. The contribution of each cover type to the overall Chi-square statistic (i.e. partial Chi-square) (Freeman 1987) was used to determine which cover types were preferred or avoided.

Agricultural cover types selected for nesting were classified as active or idle. The estimates of availability derived from 1987 USASCS data for Livingston County were then used in a Chi-square test of the hypothesis that females selected both classes of agricultural cover types in proportion to availability.

On the microhabitat scale, stem density, overhead cover, and vertical cover measures were taken. Eight vegetation categories were evaluated: 1) trees >7.6 cm dbh; 2) trees 2.5-7.6 cm dbh; 3) tall (>1 m) woody stems <2.5 cm dbh; 4) intermediate (0.5-1 m) woody stems <2.5 cm dbh; 5) short (<0.5 m) woody stems <2.5 cm dbh; 6) tall (>1 m) herbaceous vegetation; 7) intermediate (0.5-1 m) herbaceous vegetation; and 8) short (<0.5 m) herbaceous vegetation.

Stem density around the nest site was measured in nested square plots centered on the nest. Corners of the plots were oriented in the cardinal directions. Plot sizes for the various vegetation categories were: category 1, 10 m X 10 m; category 2, 5 m X 5 m; categories 3, 4, 6, and 7, 1 m X 1 m; and categories 5 and 8, 0.1 m X 0.1 m. Two 0.1-m X 0.1-m plots were established in randomly selected corners of each 1-m X 1-m plot. Overhead cover was quantified as percent canopy, using a spherical densiometer

(Lemmon 1956). Densiometer readings were taken from inside the nest bowl and from 1 m above the nest. A vertical obstruction board was used to estimate percent vertical cover at 5 height strata, from 0-2.5 m in 0.5-m intervals. Two estimates were taken from opposite directions, at a distance of 5 m, and then averaged for each nest site.

A subset of these measures was used to find distinct groups of structurally similar nest sites based on horizontal and vertical cover components. The variable subset was selected using descriptive statistics, principal components analysis, and Spearman rank correlation to eliminate redundant variables and measures that would not help discriminate groups. Cluster analysis was then used to help determine structurally different groups of nest sites (Anderberg 1973, Everitt 1980). To ensure independence of observations, only the first known nest of each female was used in this analysis.

Euclidean distance with both single and average linkage were used in hierarchical clustering. The nonhierarchical procedure used the $\underline{k}$-means approach. Results of analyses of the raw data were compared to results obtained from standardized and ranked data. As further checks of robustness, certain variable(s) and/or case(s) were removed from the data set and the cluster analyses repeated. Groups that appeared repeatedly in the results of the various analyses were considered robust.

Renesting. Initial nest sites as well as renest sites were classified according to cover type during on-site inspections. The binomial test (Siegel 1956) was used to test the hypothesis that renesting females selected the same cover types that they had selected for previous nest attempts. For those females that selected different cover types for renest attempts, the McNemar test for the significance of changes (Siegel 1956) was used to test the hypothesis that the probability of changing from nonagricultural to agricultural cover types was equal to the probability of changing from agricultural to nonagricultural cover types.

Brood Rearing. Habitat selection was evaluated for 3 21-day brood rearing periods: the first 3 weeks of brood rearing (brood period 1); weeks 4-6 of brood rearing (brood period 2); and weeks 7-9 of brood rearing (brood period 3). Brood rearing periods were chosen on the basis of size of the chicks and pheasant food habits described by Loughery and Stinson (1955). They reported that juvenile ring-necked pheasants feed primarily on animal matter during their first 3 weeks of life. As the chicks approach adult size they gradually select more plant matter and eat primarily plant matter upon reaching adult size. This suggests that habitat selection by females with broods may change over time as the nutritional requirements change and the size of the chicks increases.

Methods used to quantify and analyze habitat selection during brood rearing periods were identical to those used for the prenesting period.

Chick Survival

Chick survival was determined from brood counts that were obtained by flushing radio-tagged females with broods at regular intervals. Broods were intentionally flushed for the first time at age 4 weeks ($\pm$ 4 days), and were subsequently flushed every 2 weeks ($\pm$ 4 days) until age 12 weeks. The 9-day flushing period allowed observers to choose opportune times to flush broods. Accuracy of the brood counts was influenced by habitat condition, because observers were more likely to flush entire broods from more open areas than from heavy cover. The interval also allowed observers to flush broods more than once to obtain accurate biweekly counts. Occasionally this was necessary when counts were suspected to be incomplete. Broods were not flushed under adverse weather conditions or when predators were observed nearby.

Difficulties inherent to the study of pheasant chick survival have been noted by many authors. Potential problems include brood mixing (Errington and Hamerstrom 1937, Kozicky 1951, Wagner et al. 1965), survival of chicks after the female dies (Baxter and Wolfe 1973, Gates and Hale 1975), loss of entire broods (Baxter and Wolfe 1973, Gates and Hale 1975), and varying degrees of difficulty associated with flushing complete broods in different age classes (Baxter and Wolfe 1973, Warner et al. 1984). Therefore, analysis of brood counts to estimate offspring survival required certain assumptions.

First, it was assumed that the number of chicks gained by radio-tagged females through brood mixing was equal to the number of chicks lost by radio-tagged females through brood mixing. Gates and Hale (1975) stated that in years when they noted high frequencies of recognizable brood mixing (i.e., broods consisting of different-age chicks), they assumed that frequencies of same-age brood mixing were also high. Because no instances of recognizable brood mixing were observed in this study, this assumption seems reasonable.

Second, it was assumed that chicks flushed with radio-tagged females during late brood counts were also associated with those females during earlier flushing attempts. For example, flushes of female 0.480's brood at ages 6, 8, and 10 weeks resulted in counts of 1, 3, and 6 chicks, respectively. For analysis, female 0.480 was assumed to have had 6 chicks at each of the stated intervals.

A third assumption dealt with brood hen mortality. If chicks were <4 weeks old when their brood hen died, it was assumed that none survived; if they were ≥ 4 weeks old, their survival rate was assumed to be equal to that of chicks with brood hens. At age 4 weeks, pheasant chicks no longer require body temperature control provided by hens (D. Dorn, Mason Wildlife Facility, pers. commun.), but still benefit from the protection a hen provides. On the other hand, some abandoned chicks <4 weeks old probably survive. The errors associated with this assumption were assumed to be equal and offsetting.

The final assumption was that flushing did not increase a brood's vulnerability. No evidence of mortality related to disturbance by observers was noted for adults or chicks throughout the study, but the validity of this assumption was not evaluated.

Two models were used to estimate chick survival: a modified Mayfield model proposed by Miller and Johnson (1978) and the exponential growth model, $N_t = N_o e^{rt}$. The Mayfield model (Mayfield 1961, 1975) estimates survival probability from the number of days each individual was at risk (exposure days) during a specified interval and the number of individuals that died during the interval. Miller and Johnson (1978) noted that if the interval between observations is long and death is subsequently observed, only 40% of the days in the interval should be considered exposure days. Hensler and Nichols' (1981) z-test was used for pairwise comparisons of the various interval survival probabilities. In the exponential growth model, r is a measure of chick mortality (negative growth rate), and thus represents the daily mortality rate when *t* is in units of days. Therefore, 1 + *r* represents daily survival rate. Both models assume a constant daily survival rate.

RESULTS

Nesting

Fifty three nests, representing the reproductive effort of 36 radio-tagged females, were observed. Of these, 34 were probably initial nest attempts and 19 represented renest efforts. The earliest known nest initiation date was 10 April (Fig. 2). This nest was established by a female released on 16 March. For birds released on 8 April, the first observed nest was initiated on 12 April, just 4 days after release. The peak of the nesting effort occurred in the latter half of April, but renest attempts continued through 6 July.

Daily monitoring of radio-tagged birds resulted in 681 locations of incubating females. Incubating females were located off their nests 60 times (8.8%). A Chi-square test, based on 1 hour periods from 0600 - 2100 hrs, indicated that nest attentiveness was not equal during all daylight hours ($\underline{P} < 0.05$). Females left their nests most frequently during the mid-afternoon and evening hours, but were usually at the nest sites in the morning and early afternoon (Fig. 3).

Of the 34 observed initial nest attempts, 20 (59%) were successful, 10 (29%) were destroyed, and 4 (12%) were abandoned (Table 2). Renest attempts were less successful,

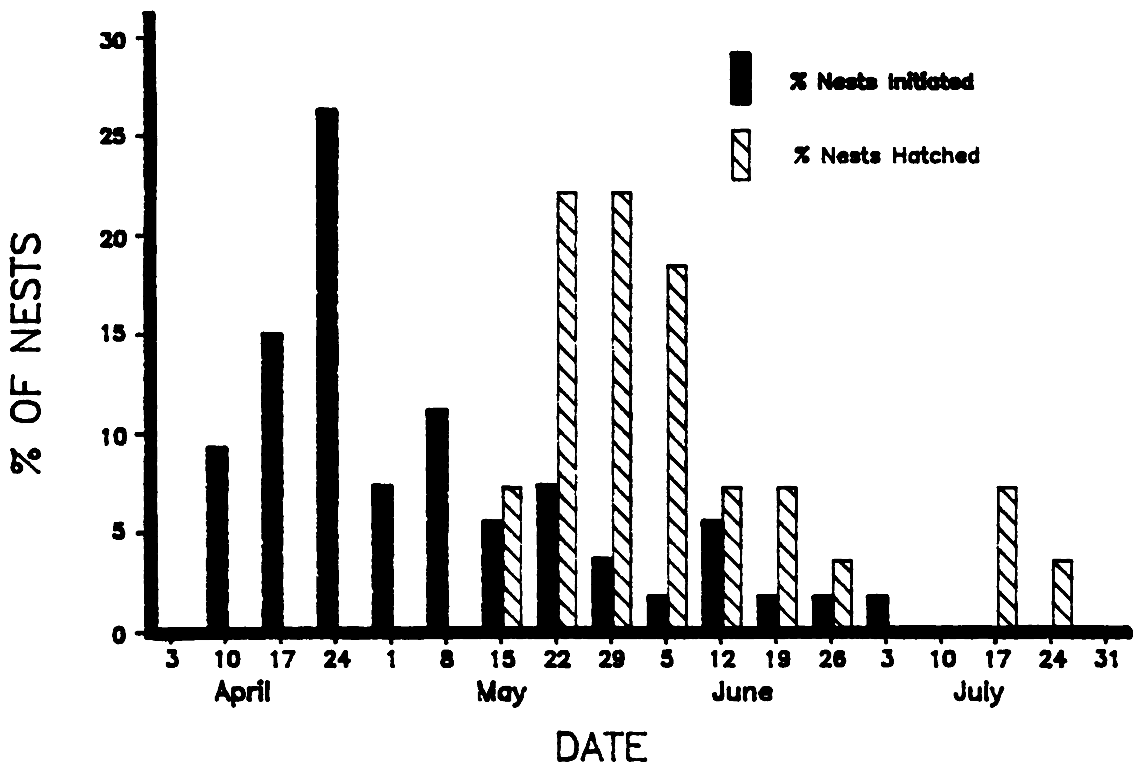

Fig. 2. Distributions of nest initiation and hatch for radio-tagged female Sichuan pheasants released in Livingston County, Michigan, 1987.

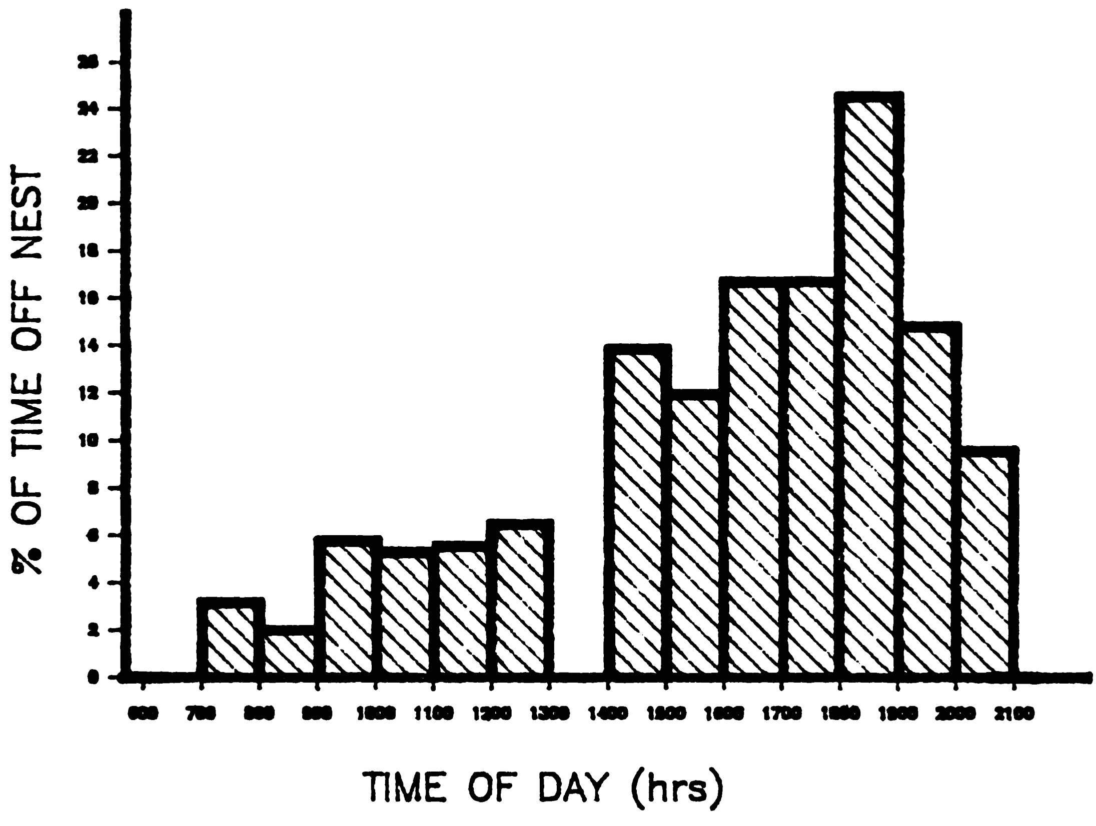

Fig. 3. Frequency distribution of nest inattentiveness (based on 15-99 locations of incubating females per 1-hr interval, n = 681 locations) by 36 radio-tagged Sichuan pheasants in Livingston County, Michigan, 1987.

Table 2. Results of 53 nesting attempts made by 36 radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987.

Nest Attempt	Hatched	Destroyed (Predation)	Destroyed (Farming)	Abandoned	Total
First	20 (59) a/	9 (26)	1 (3)	4 (12)	34
Second	5 (36)	6 (43)	3 (21)	0 (0)	14
Third	2 (40)	1 (20)	2 (40)	0 (0)	5
Total	27 (51)	16 (30)	6 (11)	4 (8)	53

a/ Percent of row total in parentheses.

with 7 of 19 nests (37%) producing chicks. Twenty six (72%) of the 36 radio-tagged females known to be involved in the reproductive effort ultimately had successful nests. One female hatched 2 nests. Active and idle agricultural lands contained the highest number of nests, followed by upland herbaceous, upland scrub-scrub, wetland, strip cover, and forested cover types (Table 3). Nest success was greatest in wetlands and upland scrub-shrub cover types and lowest in active and idle agricultural lands (Table 3).

Predation was the primary cause of nest destruction. Opossum (Didelphis virgianus) was the only positively identified nest predator, but other potential nest predators in the study area were raccoon (Procyon lotor), red fox (Vulpes vulpes), gray fox (Urocyon cinereoargenteus), striped skunk (Mephitis mephitis), mink (Mustela vison), 13-lined ground squirrel (Citellus tridecemlineatus), American crow (Corvus brachyrhynchos), and dogs.

Six nests were destroyed by farming activities: 5 by hay mowing and 1 by plowing. Haying began during the first week of June. Although eggs in 2 nests destroyed by mowing were crushed, eggs from the remaining 3 mowed nests were retrieved and hatched artificially. Additionally, 1 hayfield nest was successful because the farmer agreed to delay mowing the field until after the chicks hatched. This nest was considered successful in nest success analyses.

Table 3. Nest success of radio-tagged female Sichuan pheasants by cover type in Livingston County, Michigan, 1987.

Cover Type	Total Number of Nests	Number Successful	Percent Successful
Active agricultural	12	4	33
Idle agricultural	10	3	30
Upland herbaceous	9	4	44
Upland scrub-shrub	8	6	75
Wetlands	7	7	100
Strip cover	5	2	40
Deciduous forest	2	1	50
Total	53	27	51

Nest success as calculated by the apparent percent success method was 51%, however the Mayfield and Pollock methods produced estimates that were lower (40% and 41% respectively) (Table 4). The product method estimate was the lowest (28%), probably because a small sample size negatively biased the survival probability estimate for the egg laying period. No significant differences among daily survival probabilities for the 3 periods used in the product method calculations were found ($\underline{P} > 0.10$). Therefore, the Mayfield assumption of constant daily survival probably was not violated, and the Mayfield estimate is believed to be more accurate than the product method estimate.

Mean clutch size, based on incubated clutches only, was 9.0 $\pm$ 1.7 (SD) eggs per clutch. Mean clutch size decreased with successive renest attempts, but fertility and hatchability remained high for renest attempts (Table 5).

Renest intervals, ranging from 2-18 days, were related to the number of days destroyed or abandoned nests were incubated. The average renest interval for females whose previous nests were not incubated was 5.4 days ($\underline{n} = 5$). For all other females, the mean renest interval was 3.45 days plus 0.44 days for each day the previous nest was incubated ($\underline{r} = 0.54$, $\underline{n} = 11$, $\underline{P} < 0.10$). Only 1 instance of renesting after hatching a clutch of eggs was observed, and this occurred after all chicks from the female's first successful nest had disappeared.

Table 4. Estimates of nesting success of radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987. Nest survival probabilities were calculated from 4 alternative models.

Model	Survival Probability Estimate	Standard Error
Apparent a/	0.509	0.069
Mayfield b/	0.403	0.080
Product c/	0.278	0.103 d/
Pollock e/	0.410	0.146

a/ Apparent percent success (percent success of observed nests).

b/ Mayfield (1961, 1975).

c/ Klett and Johnson (1982).

d/ Standard error formula from Hensler (1985).

e/ Pollock and Cornelius (1987).

Table 5. Clutch sizes, percent fertility, and percent hatchability of radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987.

	Nest Attempt			
Nesting Parameter	First	Second	Third	Total
Clutch Size a/				
No. of nests	25	7	2	34
Eggs/nest (mean)	9.3	8.6	6.0	9.0
Standard deviation	1.5	1.0	1.0	1.7
Fertility b/				
No. of eggs examined	223	74	15	312
Percent fertile	93.7	93.2	93.3	93.7
Standard error	1.6	2.9	6.5	1.4
Hatchability c/				
No. of fertile eggs	184	38	7	229
Percent hatched	94.6	92.1	100.0	94.3
Standard error	1.7	4.4	0.0	1.5

a/ Includes only complete clutches.

b/ Includes undamaged eggs from unsuccessful nest attempts.

c/ Includes only eggs from successful nest attempts.

Although the mean hatch date was 9 June, the hatch distribution peak occurred at the end of May (Fig. 2). This peak represented the results of initial nest attempts. Successful females produced 8.15 ± 2.05 (SD) chicks ($\underline{n}$ = 27). Other indices of productivity often reported include percentage of females observed with broods during brood surveys. As of 27 June, when 89% of the successful nests were hatched, 18 of 28 (64%) surviving radio-tagged females had broods. On 4 August, 8 weeks after the mean hatch date, 13 of 18 (72%) surviving radio-tagged females had broods.

Habitat Selection

Prenesting. Evaluation of habitat selection by 18 females during the prenesting period was based on 18 observations/bird. The mean area of available habitat as calculated by the minimum area polygon method was 34.0 ± 6.5 (SE) ha, whereas the mean area based on circles around activity centers was 167.8 ± 78.2 (SE) ha.

The Friedman and Johnson analyses produced conflicting results when the circle method was used to calculate habitat availability. According to the Friedman analysis, the most preferred cover types during prenesting were agricultural and wooded wetlands (Table 6). Females had intermediate preference for emergent wetlands, "other", and deciduous forest cover types and low preference for upland scrub-shrub

Table 6. Order of preference of cover types selected by radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987 a/.

Rank of Preference	Activity Period b/							
	Prenesting		Nesting		Brood 1		Brood 2	
1	Agricultural	a	Upland scrub-shrub	a	Agricultural	a	Upland herbaceous	a
2	Wooded wetlands	ab	Upland herbaceous	b	Upland scrub-shrub	a	Agricultural	ab
3	Emergent wetlands	bc	Agricultural	b	Emergent wetlands	ab	Upland scrub-shrub	bc
4	Other	bc	Wetlands	b	Upland herbaceous	ab	Emergent wetlands	bcd
5	Deciduous forest	bc	Forest	c	Other	abc	Other	cd
6	Upland scrub-shrub	c			Wooded wetlands	bc	Wooded wetlands	de
7	Upland herbaceous	c			Deciduous forest	c	Deciduous forest	e

a/ Preferences for cover types followed by the same letter were not significantly different ($P > 0.05$).

b/ Prenesting = 21-day period prior to incubation, brood 1 = days 1-21 of the brood rearing period, brood 2 = days 22-42 of the brood rearing period. Preference ranks for the nesting period are based on selection of nest sites.

and upland herbaceous cover types. The Johnson analysis did not result in rejection of the null hypothesis that selection of all cover types was proportional to availability. Neither analytical method found significant differences in cover type preferences when habitat availability was based on minimum area polygons.

Within the agricultural category, females preferred idle fields over active cropland (Chi-square = 17.32, 1 df, $P < 0.01$). Of 157 locations in agricultural cover types, 59 (38%) were in idle fields and 98 (62%) in active cropland.

Initial Nesting Attempts. Selection of cover types for initial nest attempts by radio-tagged females was not proportional to availability (Chi-square = 12.13, 4 df, $P < 0.025$). Although wetland, upland herbaceous, and agricultural types were selected roughly in proportion to availability, percent selection of upland scrub-shrub was significantly greater than percent availability (partial Chi-square = 6.34, $P < 0.05$) (Table 7). Conversely, percent selection of forest cover types for first nest attempts was less than percent availability (partial Chi-square = 5.26, $P < 0.05$) (Table 7). The hypothesis that active cropland and idle fields were selected for nesting in proportion to availability was not rejected (Chi-square = 2.75, 1 df, $P > 0.05$).

Eighteen (50%) of the first known nest attempts ($n = 36$) were located < 10 m from an edge, whereas 3 (8%)

Table 7. Availability and selection of cover types for initial nest attempts by radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987.

Cover Type	Ha Available (%)	Number of Nests (%)
Wetlands	1124 (18.1)	6 (17.6)
Emergent	468 (7.5)	2 (5.9)
Wooded	656 (10.6)	4 (11.8)
Forest	1612 (25.9)	2 (5.9)
Deciduous	1479 (23.7)	2 (5.9)
Coniferous	133 (2.2)	0 (0.0)
Agricultural	1938 (31.1)	11 (32.4)
Upland Herbaceous	818 (13.2)	6 (17.6)
Upland Scrub-shrub	730 (11.7)	9 (26.5)
Total	6222 (100)	34 (100)

were > 50 m from the nearest edge (Fig. 4). Distance to the nearest edge was significantly correlated ($r = 0.57$) with total area of the block of cover in which a nest was located. Twenty three (64%) of the nests were established in small blocks of cover (< 5 ha), whereas 3 (8%) were established in very large blocks (> 50 ha) (Fig. 5).

Seven structural component measures were selected as the subset of variables used to describe microhabitat features at the nest sites: 5 total stem count (woody + herbaceous stems) variables representing horizontal cover and 2 percent-canopy measures (Table 8). These variables were independent and had high variance (relative to their means), indicating that they were all potentially good discriminators of distinct groups.

Although hierarchical and nonhierarchical cluster analyses of the raw, ranked, and standardized data produced similar results, group size and group membership were not identical. Differences in plot size, scale, and variance caused some variables (e.g. number of stems < 2.5 cm dbh and 0.5-1 m tall) to be more heavily weighted than others (e.g. number of stems > 7.6 cm dbh) when raw data were used. Additionally, many nest sites had zero counts for some variables (Table 8), so that ranking the data resulted in many ties. Therefore, groups derived from the standardized data were considered to be the best representation of the data.

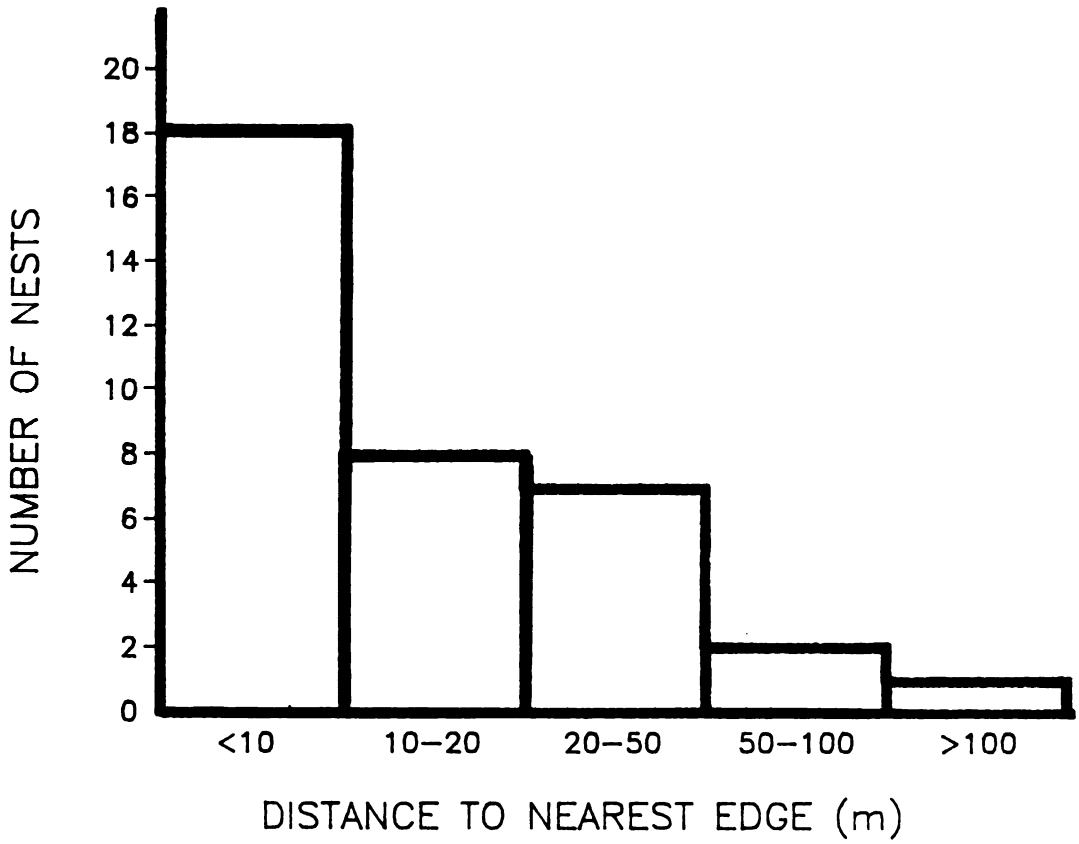

Fig. 4. Distance from nest site to the nearest natural or manmade edge (change of cover type) for nests of 36 radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987.

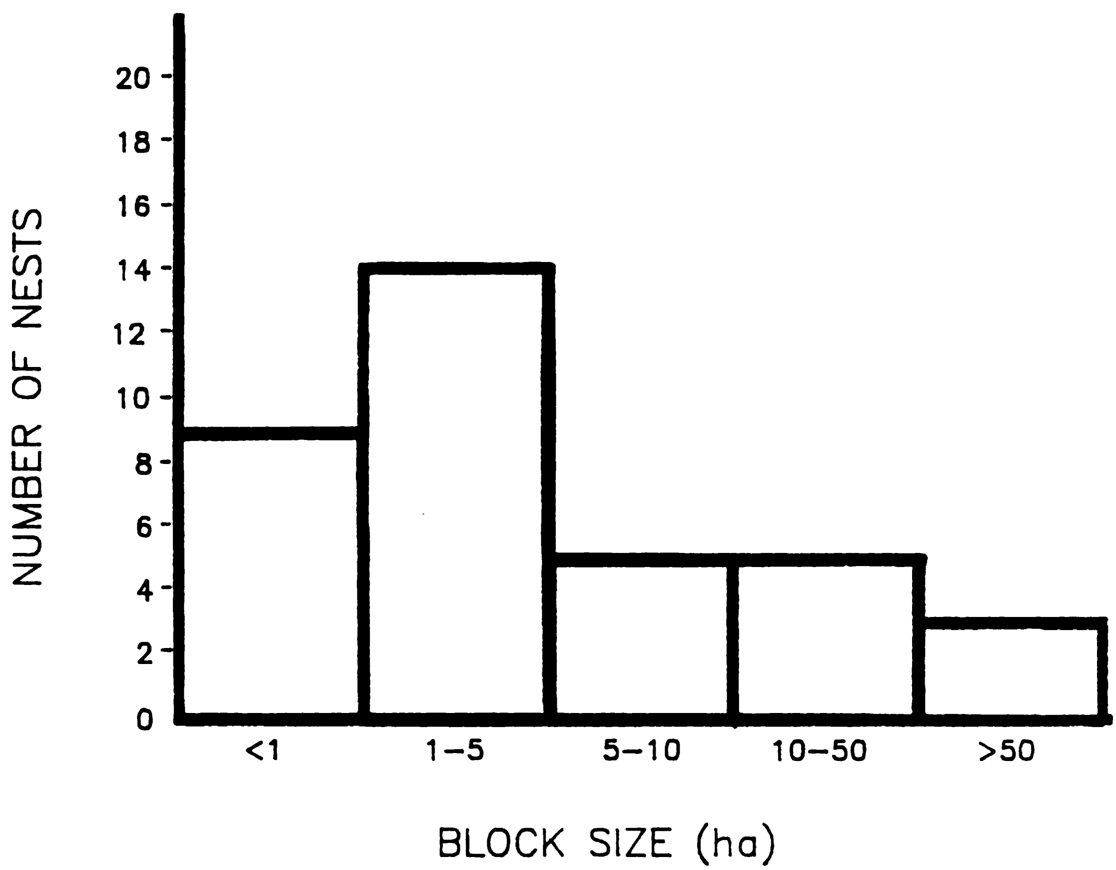

Fig. 5. Areas of contiguous blocks of cover types selected for nesting by 36 radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987.

Table 8. Structural characteristics of vegetation around nest sites selected by female Sichuan pheasants in Livingston County, Michigan, 1987.

Variable	n a/	Mean	SD b/	Frequency of zero counts
No. of stems > 7.6 cm dbh	36	0.8	1.5	25
No. of stems 2.5-7.6 cm dbh	36	0.7	1.5	26
No. of stems < 2.5 cm dbh and > 1 m tall	36	13.1	30.3	15
No. of stems < 2.5 cm dbh and 0.5-1 m tall	35	162.9	288.8	3
No. of stems < 2.5 cm dbh and < 0.5 m tall	34	18.3	10.9	0
Percent canopy over nest bowl	34	78.4	17.8	0
Percent canopy > 1 m above nest bowl	35	34.4	39.3	14

a/ Number of nest sites.

b/ Standard deviation.

Hierarchical cluster analysis was used to help set *k* (the number of clusters) for nonhierarchical cluster analysis. Results of hierarchical clustering of the standardized data indicated that 7 clusters should be generated by the nonhierarchical method. The 7 clusters produced by nonhierarchical analysis include 5 groups and 2 outliers (Table 9). Outliers were defined as clusters consisting of < 3 members. Horizontal cover at nest sites in group 1 (n = 3) was dominated by woody vegetation > 2.5 cm dbh (Table 9). Understory cover was sparse, but canopy cover was abundant. The nests were located in a quaking aspen (*Populus tremuloides*) clone (1 nest), hardwood strip cover (1 nest), and upland scrub-shrub (1 nest), and all were successful. Group 1 is robust, with membership remaining intact for most methods.

No vegetation > 1 m tall was present at nest sites in group 3 (n = 3) (Table 9). High stem densities in the 0.5-1 m tall class provided abundant horizontal cover, but canopy cover at the nest level was relatively sparse. These nests were located in high quality hay (75-100% alfalfa) (2 nests, both successful) and an idle agricultural field (1 nest, unsuccessful). Group 3 is also robust.

Group 5 nest sites (n = 5) had relatively sparse horizontal cover except in the <0.5 m height class, moderate canopy cover at the nest level, and little canopy cover more than 1 m above the nest (Table 9). Nests were

Table 9. Structural characteristics (mean ± standard deviation) for 7 groups determined by cluster analysis of nest sites selected by female Sichuan pheasants in Livingston County, Michigan, 1987.

	Group Number						
Variable a/	1	2	3	4	5	6	7
n	3	2	3	2	5	8	13
Dbh > 7.6	3.7 ± 2.5	0.5 ± 0.7	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.4	1.8 ± 1.5	0.2 ± 0.8
Dbh 2.5-7.6	5.3 ± 0.6	1.0 ± 1.4	0.0 ± 0.0	0.0 ± 0.0	0.6 ± 0.5	0.4 ± 0.5	0.0 ± 0.0
Dbh < 2.5 A	1.0 ± 1.0	130.0 ± 15.6	0.0 ± 0.0	0.0 ± 0.0	7.0 ± 12.3	9.0 ± 11.9	7.8 ± 9.5
Dbh < 2.5 B	19 ± 11	141 ± 11	850 ± 304	1015	54 ± 34	84 ± 150	66 ± 66
Dbh < 2.5 C	17.0 ± 7.0	7.5 ± 6.4	9.0 ± 11.4	41	34.4 ± 7.9	10.8 ± 6.0	17.4 ± 6.8
Canopy 1	89 ± 8	93 ± 5	54 ± 15	86	83 ± 9	94 ± 3	66 ± 16
Canopy 2	83 ± 10	52 ± 52	0 ± 0	0 ± 0	29 ± 34	83 ± 9	4 ± 8

a/ n = number of nests in the group; Dbh > 7.6 = number of stems > 7.6 cm dbh; Dbh 2.5-7.6 = number of stems 2.5-7.6 cm dbh; Dbh < 2.5 A = number of stems < 2.5 cm dbh and > 1 m tall; Dbh < 2.5 B = number of stems < 2.5 cm dbh and 0.5-1 m tall; Dbh < 2.5 C = number of stems < 2.5 cm dbh and < 0.5 m tall; Canopy 1 = percent canopy over the nest bowl; Canopy 2 = percent canopy > 1 m above the nest bowl.

located in upland scrub-shrub (1 nest), hay (1 nest), upland herbaceous (1 nest), scrub-shrub strip cover (1 nest), and an ornamental conifer planting (1 nest). Two of these 5 nests were successful. Members of this group often appeared in group 7 (and vice versa) when other clustering methods were used. Therefore, group 5 is not considered robust.

Nest sites in group 6 ($\underline{n}$ = 8) were associated with trees > 7.6 cm dbh, moderate stem densities in the <2.5 cm classes, and abundant canopy cover at both the nest level and 1 m above the nest (Table 9). These nests were located in scrub-shrub wetlands (3 nests), hardwood strip cover (2 nests), upland scrub-shrub (2 nests), and lowland hardwoods (1 nest). Six of the 8 nests in this group were successful. Membership was nearly identical for most clustering methods, therefore group 6 is considered robust.

The largest group (group 7, $\underline{n}$ = 13 nest sites) was characterized by little or no woody vegetation > 2.5 cm dbh, stem densities in the <2.5 cm classes that were generally less than the means for all nest sites, and relatively sparse canopy cover (Table 9). Nest sites in this group were located in several cover types, including upland herbaceous (4 nests), idle agricultural fields (4 nests), hay (2 nests), upland scrub-shrub (2 nests), and emergent wetland (1 nest). Five of these 13 nests were successful. Because the membership and size of this group varied when other methods of cluster analysis were used, group 7 is considered the least robust of the 7 clusters.

The 2 remaining groups, each with 2 members, are outlier clusters (Table 9). The nest sites in group 2 were located in emergent wetlands dominated by reed canary grass (Phalaris arundinacea). High stem densities in the $\geq$ 0.5 m tall classes and relatively abundant canopy cover characterized the group. Group 2 was consistently an outlier group with the same 2 members. Group 4 nest sites were located in a sedge (Carex sp.) wetland and a high quality hayfield. Counts of stems < 2.5 cm dbh and percent canopy above the nest bowl were not obtained for the hayfield nest because the field was mowed during the incubation period. Missing data for this nest site caused it to be placed in several different groups when other methods were used, but the sedge wetland nest site was a consistent outlier, usually in a group by itself. One of 2 nests was successful in both outlier groups.

Renesting. Eight renesting females selected the same cover types that they had selected for previous nest attempts, whereas the remaining 9 birds selected different cover types. There was also no evidence that unsuccessful females shifted from nonagricultural to agricultural cover types for renest attempts (Chi square = 0.143, 1 df, $P > 0.5$).

Brood Rearing. Analysis of habitat selection by 13-19 females during the 3 brood rearing periods was based on 18 observations/bird (Table 10). Mean areas of available habitat, as calculated by the minimum polygon method, ranged from 25.2 ha for brood period 1 to 43.9 ha for brood period 3. Mean areas produced by the alternative method based on circles around activity centers were 3-4 times greater in size (Table 10).

The Friedman analysis found significant differences in preferences for cover types during brood periods 1 and 2 when the circle method was used, but was significant only for brood period 2 when the minimum area polygon method was used. No differences in preference for cover types during brood period 3 were found. The Johnson analysis did not find significant differences for any brood rearing period.

During brood period 1, females had high preference for agricultural fields and upland scrub-shrub, intermediate preference for emergent wetlands, upland herbaceous, "other", and wooded wetlands, and low preference for deciduous forest (Table 6). Within the agricultural category, females preferred idle fields over active cropland ($\underline{n}$ = 110 locations, Chi-square = 7.87, 1 df, $\underline{P}$ < 0.01).

Results derived from the circle and minimum area polygon methods for brood period 2 were nearly identical. Females had high preference for upland herbaceous, agricultural, and upland scrub-shrub cover types, intermediate preference for emergent wetlands, and low preference for "other", wooded wetlands, and deciduous

Table 10. Number of birds (n), mean number of observations per bird, and mean area of available habitat for radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987.

Activity Period	n	Observations Per Bird	Mean Area (ha ± SE)	
			Polygons a/	Circles b/
Brood 1 c/	19	18.3	25.2 ± 2.1	77.3 ± 11.3
Brood 2	16	18.3	42.4 ± 6.2	181.3 ± 1.9
Brood 3	13	17.5	43.9 ± 7.5	139.9 ± 26.8

a/ Area within minimum area polygon (Mohr 1947).

b/ Area within circle with radius from center of activity for the period to the outermost location during the period.

c/ Three-week brood rearing periods (Brood 1 = days 1-21, Brood 2 = days 22-42, Brood 3 = days 43-63).

forest (Table 6). Selection of idle fields (49%, 44 of 90 locations) was significantly greater than availability, whereas selection of active cropland (51%, 46 of 90 locations) was less than availability (Chi-square = 29.58, 1 df, $\underline{P} < 0.01$).

Although no cover types were significantly preferred during brood period 3, the order of selection of cover types was similar to those found for brood periods 1 and 2. Agricultural, emergent wetlands, upland herbaceous, and upland scrub-shrub cover types were selected most often (relative to availability), and "other", wooded wetlands, and deciduous forest were selected least often. Of the agricultural cover types, idle fields were preferred over active cropland ($\underline{n}$ = 73 locations, Chi-square = 17.87, 1 df, $\underline{P} < 0.01$).

Chick Survival

Estimates of chick survival derived from the modified Mayfield and exponential growth models were similar. Because survival appeared to be much lower during the first 4 weeks post-hatch than after 4 weeks, separate survival rates were calculated for the 2 periods. The exponential growth model estimate for daily survival probability over the first 4 weeks post-hatch was 0.9747, and the Mayfield estimate was 0.9740 $\pm$ 0.0025 (SE). The low survival rate during this period was primarily a result of losses of entire broods ($n = 10$) following deaths of brood hens.

Survival probability was significantly greater after 4 weeks post-hatch ($P < 0.001$). The exponential growth model estimated daily survival probability for weeks 5-8 at 0.9916 ($n = 13$ broods). The calculation included only chicks whose brood hens were still alive after 8 weeks post-hatch.

The Mayfield model allowed use of all available brood count data from 4-12 weeks post-hatch. The Mayfield model estimated daily survival probability at 0.9912 ± 0.0016 (SE). Equations derived from Mayfield estimates were used to produce survival probability curves for early and late brood periods (Fig. 6).

Mean brood size decreased over time due to mortality and partial disbanding of broods. Mean brood size was 8.15 chicks ($n = 27$) at hatch, 6.50 chicks ($n = 16$) at age 4 weeks, 5.69 chicks ($n = 16$) at age 6 weeks, 5.54 chicks ($n = 13$) at age 8 weeks, 4.67 chicks ($n = 9$) at age 10 weeks, and 3.86 chicks ($n = 7$) at age 12 weeks. Possible causes of chick mortality include disease, exposure, farming activities, and predation.

Chick survival was greatest for broods hatched in the first third of the hatch and decreased progressively through the hatching period (Table 11).

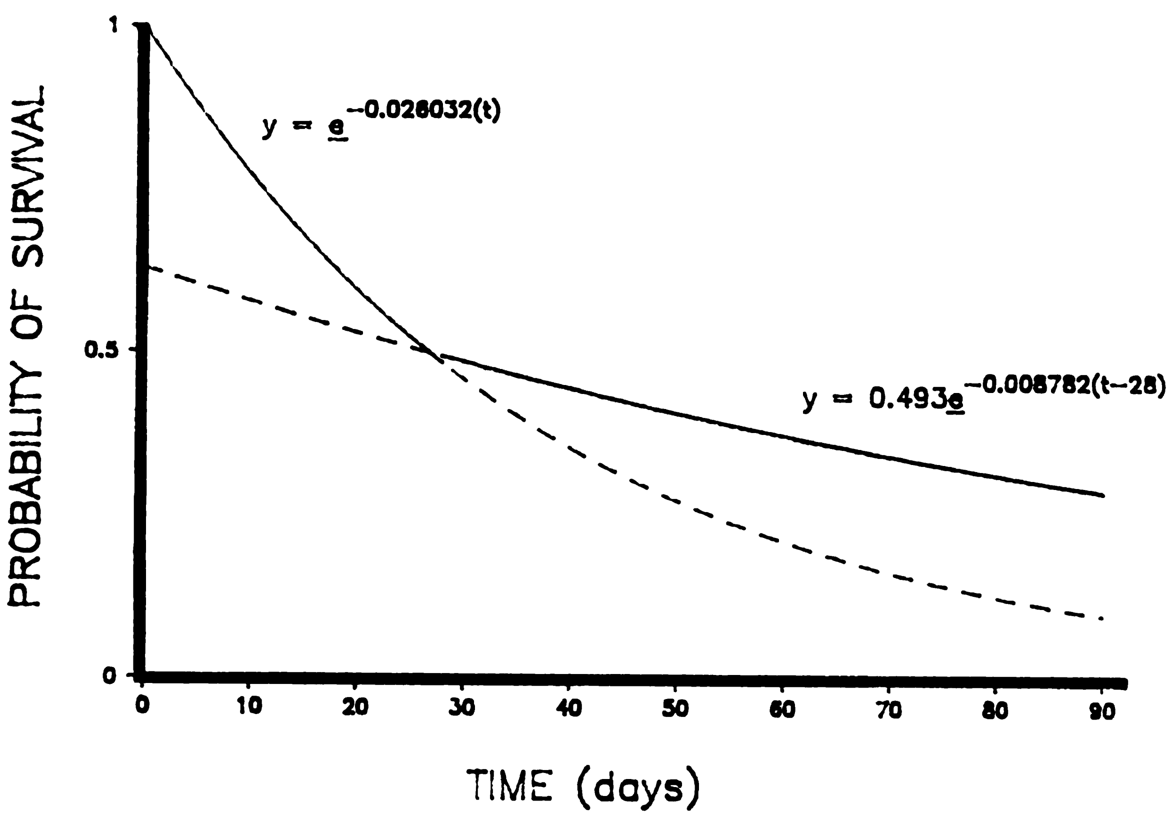

Fig. 6. Mayfield survival probability curve (solid line) for chicks of radio-tagged female Sichuan pheasants released in Livingston County, Michigan, 1987. The curve derived from the equation $y = e^{-0.026032(t)}$ represents survival for days 1-28, and the curve derived from $y = 0.493e^{-0.008782(t-28)}$ represents survival for days 29-84. Dashed lines are extensions of the 2 significantly different ($P < 0.001$) curves.

Table 11. Survival of chicks of radio-tagged female Sichuan pheasants in Livingston County, Michigan, 1987 a/. Percent survival in parentheses.

Hatch Date	Age of Chicks (Weeks) 0	4	6	8
17 May-6 Jun	134 (100) b/	71 (53)	67 (50)	58 (43)
7 Jun-27 Jun	60 (100)	29 (48)	20 (33)	20 (33)
28 Jun-25 Jul	17 (100)	4 (24)	4 (24)	3 (18)

a/ Survival of 2 abandoned broods > 6 weeks old was projected from a Mayfield (1961, 1975) survival probability estimate for all chicks > 4 weeks old.

b/ Status of 9 chicks unknown due to failure of brood female's transmitter.

DISCUSSION

Nesting chronology, nesting behavior, and productivity of Sichuan pheasants was similar to that of ring-necked pheasants throughout midwestern United States. Nest initiation began in early April and continued through mid-July. The same egg production dates have been reported for ring-necked pheasants in Iowa (Baskett 1947), Michigan (Shick 1952), and Nebraska (Baxter and Wolfe 1973). The hatch distribution and mean hatch date (9 June) were similar to those for ring-necked pheasants in Michigan (Blouch and Eberhardt 1953), Wisconsin (Wagner et al. 1965, Gates and Hale 1975), and Nebraska (Baxter and Wolfe 1973).

Mean clutch size (9.0 eggs/nest), fertility (93.7%), and hatchability (94.3%) were within the ranges reported for ring-necked pheasants. Trautman (1982) summarized 17 studies that reported mean clutch sizes ranging from 8.6-12.6 eggs/nest. Because egg production increases in the second reproductive year (H. Prince, pers. commun.), the relatively low mean clutch size for females in this study may have been related to age at release (36-40 weeks). Gates and Hale (1975) cited 8 studies that reported fertility (89-95%) and hatchability (85-96%) rates for ring-necked pheasants.

Nest attentiveness was similar to that described in other studies. Incubating females were located away from their nests most frequently in the afternoon and evening. Klonglan et al. (1956) noted that inattentive periods for most females were from 1500-1800 hrs. Four females observed by Kuck et al. (1970) left their nests daily for about 1 hr during late afternoon, and 1 female left her nest each day for 1 hr at approximately 1000 hrs. Kessler (1962) found that females frequently left their nests at 1600-1800 hrs, but also reported 0700-0930 hrs as a common inattentive period.

Apparent nesting success of 51% was adjusted to 40% and 41% by the Mayfield and Pollock estimators, respectively. These estimates compare favorably with nest success reported for ring-necked pheasants. In 18 studies (1939-1964) summarized by Gates and Hale (1975), apparent nest success for ring-necked pheasants ranged from 13-46%. More recent studies have reported apparent nest success rates of 31% in Wisconsin (Dumke and Pils 1979) and 15-49% in Oregon (Castillo et al. 1984).

Renest intervals of 3.45 days plus 0.44 days per day of incubation of the previous nest were similar to the 4.9 days plus 0.49 days per day of incubation of the previous nest reported by Dumke and Pils (1979). Seubert (1952) found that each day of incubation resulted in a 0.34-day increase of the renest interval.

Females preferred upland scrub-shrub cover types for initial nest attempts. Wetland, agricultural, and upland herbaceous types were selected in proportion to availability, whereas deciduous forest types were avoided. In contrast, most investigators have reported that ring-necked pheasants select agricultural cover types, principally hayfields and small grains, and emergent wetlands most often (eg. Eklund 1942, Baskett 1947, Baxter and Wolfe 1973, Whiteside and Guthery 1983). Those studies generally were conducted in areas where nonagricultural cover types were not abundant.

Selection of cover types for renesting was not significantly related to the locations of previous unsuccessful nest attempts. Some females selected the same cover types, but others shifted to different types. There was no tendency for females that shifted to move from nonagricultural to agricultural cover types. In contrast, hayfields and small grains become more attractive to ring-necked pheasants for nesting cover as the growing season progresses. Females in Wisconsin selected permanent cover types for initial nest sites, but shifted to hayfields and small grains for renest attempts (Gates 1966, 1971; Gates and Hale 1975). Strip cover and upland herbaceous types were selected for early nesting attempts in Pennsylvania (Randall 1940). Dumke and Pils (1979) stated that idle cropland, wetlands, strip cover, and hayfields were preferred cover types for initial attempts in Wisconsin, but Gates and Hale (1975) found that selection of hayfields for initial attempts was less than expected based on availability.

The Sichuan pheasant's preference of upland scrub-shrub cover types for initial nest sites is the only apparent departure from preferences of the ring-necked pheasant. This may be a characteristic unique to the subspecies. Alternatively, upland scrub-shrub types may have been uncommon or absent in areas in which many earlier studies were conducted.

Overall nest success was highest in wetlands (100%) and upland scrub-shrub cover types (75%) and lowest in active and idle agricultural types (33% and 30%, respectively). Nest success in wetlands is also high for ring-necked pheasants (Gates 1971, Baxter and Wolfe 1973). Low success is typical in active cropland because of farming practices (Klonglan 1955, Gates 1966), but other investigators have noted high success in idle or retired cropland (Gates and Hale 1975, Dumke and Pils 1979).

Meyers (1984) stated that structural components of the microhabitat are important in the dynamics of nest site selection. He found that vegetation height and density were related to both nest site selection and nest success. Bowman and Harris (1980) demonstrated that increased complexity of vegetative structure led to less predation of ground nests. In Wisconsin, sites with diverse plant communities were favored by pheasants for initial nest attempts (Dumke and Pils 1979). Canopy cover is also an important factor in nest site selection (Dumke and Pils 1979). Matulich et al. (1983) stated that 50-90% canopy cover was preferred by pheasants for nest sites.

Horizontal and vertical components of the vegetative structure at nest sites were measured in this study. Of the 7 distinct groups of nest sites suggested by cluster analysis, 2 (11 nests) were closely associated with trees. The high success rate (72%) for these nests is attributed to their structural complexity and abundant canopy cover. Although structural complexity was relatively low for 3 groups (7 nests), high densities of herbaceous stems > 0.5 m tall and adequate canopy provided enough cover to allow intermediate nest success (57%). Nest success was low (39%) for 2 groups (18 nests), with low to moderate stem densities in all categories resulting in relatively low structural complexity of the vegetation.

The groups suggested by cluster analysis generally included nest sites found in several different cover types. Furthermore, nest sites in certain cover types, notably upland scrub-shrub, appeared in several different groups. This indicates that structural components of the vegetation as well as cover types should be examined when an area is evaluated as nesting habitat.

Home range sizes (calculated from minimum area polygons) during 3-week activity periods were somewhat larger than those reported for ring-necked pheasants, but similar patterns were observed. Home ranges during brood period 1 (25.2 ha) were smaller than during prenesting (34.0 ha), and the largest home ranges occurred during brood periods 2 (42.4 ha) and 3 (43.9 ha). Kuck et al. (1970) reported that prenesting home ranges averaged 12.5 ha. One-week brood ranges in relatively diverse farming systems in Illinois increased from approximately 5.5 ha for 1-3 week old broods to approximately 15 ha for 4-6 week old broods and 40 ha for 7-9 week old broods (Warner 1984).

During the prenesting period, females preferred idle agricultural and wooded wetland cover types. These cover types probably provided the most dense residual cover available in early spring. In Wisconsin, strip cover, emergent wetlands, wooded wetlands, and wooded uplands were the only cover types preferred by ring-necked pheasants during prenesting (Dumke and Pils 1979). This was attributed to the dense residual cover available in those types.

Habitat preferences remained constant throughout the 3 brood rearing periods studied. Idle agricultural fields, upland herbaceous, upland scrub-shrub, and emergent wetlands were consistently the most preferred and deciduous forest, types categorized as "other", and wooded wetlands the least preferred cover types. The most preferred types probably provided the moderately dense herbaceous cover that Matulich et al. (1983) recommended as optimal brood habitat. Similar preferences have been noted for ring-necked pheasant broods. Wheat stubble, pasture, noncultivated lands, hayfields, small grains, and strip cover have been reported as preferred brood habitat (Kozicky 1951, Baxter and Wolfe 1973, Hanson and Progulske 1973, Warner 1979).

Optimal nesting cover for ring-necked pheasants also provides good brood cover (Matulich et al. 1983). This was partially true for Sichuan pheasants in this study. Upland scrub-shrub cover types preferred for nesting were also used heavily during brood rearing. In contrast, wooded wetlands produced 11.1% of the successful nests, but were not preferred cover types during brood rearing periods. Chicks are probably more vulnerable to mortality when broods move long distances. Nesting cover in close proximity to brood cover would reduce the frequency of such moves.

Chick survival was lowest during the first 4 weeks after hatching, primarily as a result of losses of entire broods during that period. Although survival to age 8 weeks (38%) was lower than most reported survival rates for ring-necked pheasant chicks, those estimates were not adjusted for losses of brood hens or entire broods (eg. Anderson 1964, Gates and Hale 1975).

Despite possible differences among mean numbers of chicks hatched per nest, mean brood size is a more accurate measure for comparisons of survival between Sichuan and ring-necked pheasant chicks. Mean brood sizes of ring-necked pheasants at age 4-6 weeks generally ranged from 6-7 chicks per brood from the 1940's through the 1960's (Baskett 1947, Kozicky 1951, Baxter and Wolfe 1973, Gates and Hale 1975). In Illinois, Warner et al. (1984) reported a trend of declining chick survival during the past 30 years that coincides with the general decline of pheasant numbers throughout most of the United States. Although the mean number of chicks hatched per nest did not decrease significantly from 1954 through 1981, mean brood sizes (chicks per brood at age 5-6 weeks) gradually declined from 6.7 during the late 1940's and early 1950's to 4.6 during 1975-1981. The mean brood size at age 6 weeks in this study (5.7 chicks per brood) indicates that survival of Sichuan pheasant chicks in 1987 was similar to that of ring-necked pheasant chicks from the 1940's through the 1960's.

Although this study found that Sichuan and ring-necked pheasants are similar in many ways, several apparent differences suggest that Sichuan pheasants are better suited to some Michigan habitats than ring-necks. At this point, those differences cannot be confirmed. Future research should include studies of Sichuan and wild ring-necked pheasants on the same study area(s). This would allow direct comparisons of nest site preferences, nest success, chick survival, and other parameters to determine whether differences are significant and to predict the impacts of future releases of Sichuan pheasants on pheasant populations in Michigan.

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