GRAY PARTRIDGE ECOLOGY IN SOUTHEAST-CENTRAL WISCONSIN

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ABSTRACT

Observations on the ecology of the gray partridge *(Perdix perdix)* recorded incidential to a study of ring-necked pheasants *(Phasianus colchicus)* in south east-central Wisconsin from 1959 to 1966 revealed that pheasants were most strongly associated with wetland habitat and partridge, with areas largely devoid of such cover. This possibly represented selective use of upland habitat by partridge, or avoidance of areas of higher pheasant density. Egg-laying by partridge began in early May and reached a peak near the middle of the month. Preferred nesting sites consisted of roadsides, hayfields and fencelines, in which nest success averaged 40, 10 and 8 percent, respectively. The overall rate of hatching success was 16 percent. Successful clutches averaged 12.5 chicks per brood. The mean size of all broods consisting of young at least half grown was 8.3 chicks, indicating a minimum juvenile loss of 34 percent.

Partridge populations increased nearly 5-fold between 1960 and 1965. Most of the increase occurred in 1963 as the result of an unusually high rate of spring-to-fall gain. Rates of spring-to-fall gain throughout the study were unrelated to the percentage of pairs producing young, but showed a significant correlation with average brood size. It was concluded that juvenile survival was the principal determinant of population trend, and that temperature and precipitation during the early stages of brood-rearing were ultimately responsible for yearly differences in juvenile mortality. Winter weather had no apparent effect on population fluctuation.

Rates of juvenile survival, although variable between years, were not inordinately low, and rates of over-winter loss were generally light. The principal long-term depressant on partridge abundance was high nest mortality. With only 16-percent hatching success, and infrequent renesting, no more than 20 percent of the pairs were believed capable of producing broods in an average year. Only a low density population apparently could be maintained with this low level of reproductive success.

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By

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INTRODUCTION

Information on habitat selection, reproduction and mechanisms of short-term population change by gray partridge* was obtained during a study of ring-necked pheasant ecology in east-central Wisconsin from 1959 to 1966. Since the early field studies of Yeatter (1934) in Michigan and McCabe and Hawkins (1946) in Wisconsin, little has been published on the ecology of the gray partridge in the north-central states. Nowhere throughout this region does the partridge currently rank as an important game bird; however, it seems much better adapted to intensive agriculture than the pheasant and conceivably could become increasingly important in the years ahead.

**Also called the Hungarian partridge.*

STUDY AREA

The Waupun Study Area, 42 square miles in size, is situated in southwestern Fond du Lac County and adjacent portions of Green Lake and Dodge Counties, Wisconsin. The area's topography is level to gently undulating, with approximately 78 percent of the land area under cultivation. Major crops were corn, oats and hay, and these comprised 31, 20 and 18 percent, respectively, of the area under investigation. Wetlands made up 10 percent, of the study area, permanent pastures 7 percent and woodlots less than 1 percent. The most prevalent forms of wetland vegetation were sedges (principally *Carex stricta),* canary grass *(Phalaris arundinacea)* and shrubs *(Salix* spp., *Cornus* spp.). The principal agricultural enterprise in the area was dairy farming, with cash-cropping and other livestock production representing secondary sources of farm income.

During this investigation, the Waupun Study Area supported a moderately dense pheasant population (25-30 hens per square mile in spring as a 1959-1966 mean), but rated no better than second-rate or marginal as partridge habitat. The most recent analysis of gray partridge distribution in Wisconsin (Besadny, 1964) shows the area belonging to the lowest of three density categories based on the estimated kill per square mile during the 1950-55 hunting seasons. Highest partridge densities in Wisconsin currently exist in counties bordering Lake Michigan between Milwaukee and Green Bay. Compared with the Waupun Study Area, this region has more woodlots (11 percent), hayfields (23 percent), pasture (17 percent) and small grains (23 percent), but typically has smaller acreages of corn (13 percent) and wetlands (8 percent) (Besadny, 1964). Pheasant densities in the lake counties are also considerably lower.

METHODS

NEST–SEARCHING

Nest-searching was carried out on two subdivisions of the Waupun Study Area. The Alto Area (7 square miles) was sampled during 1959-1964 and the Mackford Area (5 square miles) during 1960-64. Nest-searching was conducted according to a stratified random design in which all potential nesting cover was sampled for both partridge and pheasant nests. In most years, approximately 16 percent of the wetland acreage was examined, as was 25 percent of the strip cover (roadsides, fencelines and ditchbanks),

Nest-searching.

25 percent of the hayfields, 10 percent of the small grains and 16 percent of the peas.

Nests were also encountered outside of the 2 study plots. These nests were not used in determining cover preferences, but were tallied with the number of nests found on the study plots to determine hatching success.

DETERMINING POPULATION SIZE

Roadside counts of gray partridge were made at two seasons of the year, both in conjunction with pheasant population surveys:

(1) During 1 April to 15 May, partridge observations were recorded incidental to a search of the study area for back-tagged pheasants. All roads on the study area were driven by a single observer at least twice weekly; observations were made between sunrise and 7:00 a.m. (CST) or 8:00 a.m. (CDT). Counts were restricted to mornings without precipitation, with wind velocities less than 10 mph and with temperatures above 25 F. Only birds identified while driving, and without optical aids, were included in the morning's total. Nearly all partridge encountered at this season were paired.

(2) Between 15 July and 31 August, the same roads were driven again at least once weekly in search of pheasant and partridge broods. Observations began at 6:00 a.m. and terminated before 9:00 a.m. (CDT). All adult and young partridge originally sighted without use of optical aids were recorded; binoculars and spotting scopes were used only to determine brood size and to distinguish between adult and juvenile birds. Family groups were flushed only when complete counts could not otherwise be obtained. Observations were generally restricted to mornings of moderate to heavy dewfall and clear skies.

Odometer readings were recorded at the start and conclusion of each count. The number of adult patridge observed per 100 miles of driving between 1 April and 30 April served as a spring index to population density. A late-summer (postbreeding) index was calculated from the total number of adult and juvenile partridge observed per 100 miles of driving between 1 August and 31 August. Family groups encountered outside this period, or incidental to other field work, provided additional information on brood size, but were not included in the August population index.

GENERALIZED HABITAT SELECTION

Ten percent of the Waupun Study Area consisted of some form of wetland vegetation; however, the western half contained very little wetland cover. While this upland area supported below-average pheasant densities, it was the most preferred partridge habitat. Of all partridge observed in April and August, 81 percent were seen in this area, as were 75 percent of all coveys observed in winter.

Whether the general pattern of partridge distribution at Waupun represented selective use of upland habitat, or purposive avoidance of areas of higher pheasant density, cannot be stated. Partridge did not nest in wetlands, and even during periods of maximum snow cover, were rarely found in the vicinity of wetland vegetation. Leopold, (1931) stated that "the best Hungarian range is never the best pheasant range," and several authors have mentioned, or at least alluded to, the possibility of direct interference of pheasants with partridges (Jenkins, 1961; Westerskov, 1964; and Green and Hendrickson, 1938). Whatever the explanation, partridge at Waupun clearly attained highest densities in areas of minimum wetland acreage where pheasants were least numerous.

No partridge nests were found in wetlands–the cover type most attractive to pheasants.

In contrast to pheasants, partridge did not exhibit major shifts in population distribution between winter and summer range. In most winters, pheasants abandoned nearly all upland portions of the study area and concentrated in wetland sites where the heaviest winter cover was available. Partridge, on the other hand, tended to remain year-long on the uplands, apparently finding adequate winter shelter in open fields and in the few brushy thickets present along fencelines and roadsides. At least in winter, it was evident that partridge were much better adapted to near-absence of permanent cover than pheasants.

PHENOLOGY OF CLUTCH ESTABLISHMENT AND RENESTING

Seasonal trends in nest establishment were based on 31 completed clutches backdated to the date of first-egg laying (Fig. 1). In backdating, I assumed a laying rate of 1.1 days per egg and a 25-day incubation period (McCabe and Hawkins, 1946).

The average date of clutch initiation was 26 May. The earliest known nesting attempt was established on 2 May and the latest on 17 July. First-egg dates thus spanned a 2.5 month period; however, 81 percent of all clutches were begun during the month of May. McCabe and Hawkins (1946) also found that the peak of partridge nesting in Wisconsin occurred during the middle of May.

The resurgence in nest-starting dates in early July (Fig. 1) constituted evidence that some renesting occurred. However, in view of the low rate of nest success (16 percent) experienced by partridge (Table 1), the magnitude of the secondary peak seemed inordinately small, implying a comparatively low level of renesting activity. Although no information was available on the actual percentage of unsuccessful pairs that renested, it was clear that renesting among partridge was far less prevalent than among pheasants. The average rate of nest success for pheasants was 30 percent (Gates, 1971), almost double the rate of nest success for partridge (Table 1), and even though the percentage of pheasant hens available for renesting was correspondingly lower, the configuration of the nest-establishment curve (Fig. 1) indicated considerably greater renesting activity. Based on the present study, partridge appear to be much less persistent renesters than pheasants. In Washington, Yocom (1943) also commented on the infrequency of renesting by partridge demonstrated by the shape of the nest-establishment curve.

NEST LOCATION

Only three cover types contained appreciable numbers of partridge nests—fencelines, roadsides and hayfields (Table 1). No nests were discovered in wetlands or in peas, only 1 nest was found in ditchbanks and only 2 nests, in small grains. Fencelines contained 17 percent of the total number of nests, roadsides 18 percent and hayfields 58 percent. In Michigan, 20 percent of the nests studied by Yeatter (1934) were located in small grains, as were 11 percent of the nests observed by McCabe and Hawkins (1946) in Wisconsin. Apart from the lower use of small grains, the distribution of partridge nests at Waupun was generally similar to previous studies, demonstrating what appeared to be preferential use of both strip cover and hayfields. The fact that small grains were so little used at Waupun probably resulted from the extremely large acreages of hay that were available to nesting hens (18 percent of the land area).

Of the total hayfield acreage searched for partridge nests, 179 acres consisted of unmowed fields temporarily retired from crop production under the U.S. Department of Agriculture Feed Grain Program. Most of this acreage was left unharvested 2 or more years in succession and thus afforded dense stands of residual cover in spring. Only a single nest was found in this subsample, suggesting that heavy stands of unharvested hay (principally alfalfa and brome-grass) were not particularly attractive for partridge nesting. By contrast, pheasants at Waupun demonstrated highly selective use of unharvested hay as nesting cover (Gates and Ostrom, 1966).

Preferred nesting cover of partridge seemed to consist of fairly light, open vegetation. Of the 28 nests found in nonhay vegetation, 23 (83 percent) depended on bluegrass *(Poa* spp.) and/or quackgrass *(Agropyron repens)* for actual nest concealment.

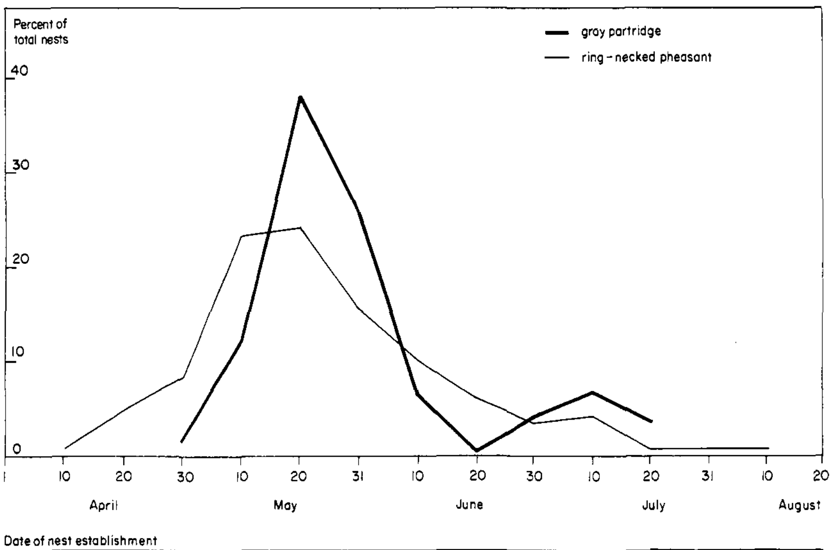

Figure 1
Frequency distribution of nest-starting dates of gray partridge and ring-necked pheasants, Waupun Study Area, 1959-1965. Information on pheasant nesting phenology from Gates (1971).

NEST SUCCESS

Eight percent hatching success was observed in fencelines and 40 percent, in roadsides (Table 1). Virtually all nest mortality in these cover types was attributed to mammalian predators, principally raccoons *(Procyon lotor)* and skunks *(Mephitis mephitis)*. Crows *(Corvus brachyrynchos)* destroyed one nest in roadside cover, and one in fenceline cover was trampled by cattle. The observed difference in hatching success between fencelines and roadsides, although not statistically significant, possibly represented a real difference in predator activity or vulnerability of ground-nesting birds to predation. Pheasants experienced a similar, albeit less-pronounced, difference in nest success between the

TABLE 1
Gray Partridge Nest Density and Hatching Success by Cover Type, Waupun Study Area, 1960–1965.

Cover Type	Nest Density on Study Plots Acres Searched	No. Nests Found	No. Nests Per 100 Acres	No. Nests Found Outside Study Plots	Total No. Nests	No. Successful Nests	Percent Success
Fencelines	49	8	16.3	4	12	1	8
Roadsides	145	9	6.2	6	15	6	40
Ditchbanks	56	1	1.8	0	1	0	0
Hayfields	2,099	28	1.3	11	39	4	10
Small grains	721	1	0.1	1	2	0	0
Wetlands	1,056	0	0.0	0	0	0	–
Peas	414	0	0.0	0	0	0	–
TOTAL		47		22	69	11	16

two sites (31 versus 24 percent, respectively) (Gates, 1971).

In hayfields, only 10 percent of the clutches terminated successfully. Out of 35 unsuccessful nests in hay, incubating hens on 7 nests were killed or seriously injured by mowing machinery.

Overall hatching success for all cover types combined was 16 percent (Table 1). This compares with 32-percent success reported by Yeatter (1934) in Michigan, Yocom (1943) in Washington and McCabe and Hawkins (1946) in Wisconsin.

At least in part, the low rate of hatching success observed at Waupun, compared with McCabe and Hawkins' earlier study, could be attributed to earlier hay-cutting and thus heavier mortality of hayfield clutches. McCabe and Hawkins did not report the success rate for each cover type individually; however, their data show that the first cutting of alfalfa did not begin before 15 June in 1936-1942. In the present study, the first mowing of alfalfa was approximately 50 percent complete by this date in an average year, which suggests that hay harvest probably had considerably greater impact on partridge nesting.

Among pheasants, nest success in mowed hay was 14 percent (Gates, 1971)—not appreciably higher than that of partridge. However, over a 6-year period, only 33 percent of all pheasant nests were found in hayfields. Unlike partridge, pheasants nested extensively in wetlands, and hatching success in this cover type was sufficiently high (43 percent) to mitigate the adverse effects of hay-mowing on reproductive success (Gates, 1971). Because partridge in Wisconsin apparently rely more heavily on hayfields for nesting, mowing mortality undoubtedly acts as a heavier depressant on partridge than pheasant numbers. The advance in hay-cutting dates of the past several decades probably has been even more detrimental to partridges than pheasants.

Heavy nesting use of hayfields by partridge may well have contributed to the low level of renesting activity observed. Because the peak of hay-mowing occurred in mid-June, fully a month after the peak of nest initiation, a high percentage of the hens whose clutches were broken up in hay conceivably were too far advanced in incubation to begin another nesting attempt. In England, Jenkins (1961) reported that renesting rarely followed the destruction of clutches more than 10 days along in incubation.

Of the total number of partridge nests, 35 percent were found in roadsides (left) and fencelines (right).

CLUTCH AND BROOD SIZE

Thirty-one completed clutches contained an average of 14.9 ± 0.7 (SE) eggs per clutch. Eleven successful clutches produced 12.5 ± 1.2 (SE) chicks per brood at hatching and contained an additional 2.2 eggs per clutch that failed to hatch. The overall ability of eggs to hatch was accordingly 85 percent, almost identical to that observed by McCabe and Hawkins (1946), but appreciably higher than the 76-percent figure reported by Yeatter (1934).

The average size of 72 broods for which complete counts were obtained was 8.3 ± 0.5 (SE) chicks. All observations from which this mean was calculated consisted of young at least half grown and presumably beyond the age of maximum vulnerability to juvenile mortality. From these data, the indicated minimum rate of juvenile loss was 34 percent. This compares with 19-percent juvenile mortality in Michigan calculated from Yeatter's (1934) data and 47 percent reported by Yocom (1943) in Washington.

POPULATION DYNAMICS

POPULATION FLUCTUATION

April and August counts of partridge seen remained relatively constant between 1960 and 1962, increased sharply during 1963 and 1964, and stayed comparatively high thereafter (Table 2). Both counts demonstrated a roughly 5-fold increase in population density between 1960 and 1965.

The most notable feature of the available population data was the unusually high rate of spring-to-fall gain for 1963 (Table 2). The index to spring-to-fall gain was 3.69 in 1963, compared with values that ranging from 0.88 to 1.83 during other years of study.

An index to the percentage of pairs producing broods (pair success) was calculated by dividing the number of broods observed per 100 miles in August by the number of adults observed per 100 miles in April. This index was not unusually high in 1963; in fact, it showed little variation throughout the study apart from 1962. The index to pair success was not correlated with the index to spring-to-fall gain ($r = 0.60$; $P > 0.05$), suggesting that annual differences in the latter did not depend on the relative success or failure of breeding pairs in producing broods.

For all years of study combined, average brood size was significantly correlated with the index to spring-to-fall gain ($r = 0.83$; $P < 0.05$). Differences in average brood size could have resulted from yearly changes in juvenile survival, or, alternatively, from annual variation in clutch size. The latter, however, was regarded as the less plausible of the two explanations, and it was concluded

TABLE 2
Summary of Gray Partridge Population Data, Waupun Study Area, 1960-66

Numbers and Indexes	1960	1961	1962	1963	1964	1965	1966
Numbers seen							
Adults (1-30 Apr.)							
No. seen/100 miles	2.6	2.9	4.2	3.9	9.6	12.7	14.1
Miles of roads driven	531	544	567	1,032	1,047	436	331
Broods (1-31 Aug.)							
No. seen/100 miles	0.40	0.47	0.36	0.68	1.22	1.85	–
Miles of roads driven	739	565	670	840	818	880	–
Avg. size of broods	7.1	4.8	5.0	10.6	8.1	9.3	–
(± one standard error)	±1.7	±1.6	±1.6	±1.1	±1.1	±1.0	
Total no. seen	8	6	7	17	20	16	–
Adults plus young (1-31 Aug.)							
No. seen/100 miles	4.5	3.2	3.7	14.4	17.6	21.1	–
Indexes							
Pair success*	0.15	0.16	0.09	0.17	0.13	0.15	–
Spring-to-fall gain**	1.73	1.10	0.88	3.69	1.83	1.66	–
Fall-to-spring survival***	–	0.64	1.31	1.05	0.67	0.72	0.67

*Index obtained by dividing the number of broods seen per 100 miles (1-31 August) by the number of adults seen per 100 miles (1-30 April).

**Index obtained by dividing the number of adults plus young seen per 100 miles (1-31 August) by the number of adults seen per 100 miles (1-30 April).

***Index obtained by dividing the number of adults seen per 100 miles (1-30 April) by the number of adults plus young seen per 100 miles between 1 and 31 August of the previous year.

TABLE 3
Gray Partridge Brood Size Related to Average Daily Temperature and Total Precipitation for the period 1-31 July, Waupun Study Area

Year	Avg. No. of Chicks Per Brood	Precipitation (In.)*		Temperature (F)*	
		Total	Departure from Norm	Average	Departure from Norm
1960	7.1	6.9	+3.7	70.4	-2.6
1961	4.8	5.4	+2.2	71.4	-1.6
1962	5.0	2.6	-0.6	67.5	-5.5
1963	10.6	3.9	+0.7	73.1	+0.1
1964	8.1	6.5	+3.3	73.0	0.0
1965	9.3	3.2	0.0	69.4	-3.6

*Meteorological data from the U. S. Weather Bureau station at Fond du Lac, Wisconsin, located approximately 24 miles northeast of study area.

that rates of spring-to-fall gain more likely depended on rates of juvenile survival.

Both in North America (Dale, 1941 and Westerskov, 1964) and England (Middleton, 1935 and Jenkins, 1961), cool, wet weather has been implicated as a major cause of chick mortality, with the largest proportion of the loss reportedly occurring during the initial month of life (Middleton, 1935; Yocom, 1943; and Jenkins, 1961). At Waupun, the peak of nest establishment occurred in mid-May, and with approximately 6 weeks required for egg-laying and incubation of a successful clutch, the peak of the hatch should have fallen around the end of June. If temperature and precipitation had a significant influence on chick survival, it is reasonable to expect that the month of July would have been especially critical.

The summer of 1963, in which brood size was largest, was the only year in which July weather was not abnormally cool and/or wet (Table 3). Smaller broods in 1960-62 were associated with above-normal rainfall and/or below-normal temperatures. In contrast, larger brood sizes in 1963-65 were associated with essentially normal conditions of July temperature and/or rainfall.

In summary, it appeared that juvenile survival was dependent on July weather, which in turn emerged as the probable influence accounting for short-term population fluctuation observed during the period of study. Jenkins (1961), in England, similarly concluded that reproductive success was chiefly controlled by chick mortality resulting from cool and wet summer weather.

WINTER SURVIVAL

Winter weather during the period 1960-66 was highly variable. The most severe winter of the study occurred in 1961-62, during which between 10 and 24 inches of snow blanketed the study area over a 92-day span. By comparison, the winters of 1960-61 and 1963-64 were virtually snowless. Other winters of study (1962-63, 1964-65 and 1965-66) fell somewhere between these extremes and were considered essentially normal for east-central Wisconsin.

In spite of marked annual differences in snow cover, evidence suggested that winter survival of partridge was constant between years. April population numbers for the years, 1961-66, were significantly correlated with population numbers of the preceding August ($r = 0.86$; $P < 0.05$). If it is assumed that mortality between August and the onset of winter was roughly comparable between years, the strength of this relationship seemed to rule out the possibility of a high degree of variability in winter mortality.

A winter survival index was calculated by dividing the number of adults seen per 100 miles in April by the number of adults plus young seen per 100 miles in August of the previous year (Table 2). Again, the assumption was made that autumn mortality was constant between years. Winter survival indices showed no consistent relationship with winter weather conditions. The index for 1961-62 was the highest during the study, suggesting that unusually heavy snow cover in 1961-62 was not particularly detrimental to partridge survival.

Field evidence of winter mortality was also light. Apart from road kills, only two partridge were found dead during six winters of intensive field work; both of these birds had been preyed upon. The single winter in which a concerted effort was made to determine rates of winter covey shrinkage was 1961-62. Fortunately, this was also the winter in which maximum rates of winter loss might have been expected. Among nine coveys observed between early January and late February, originally totalling 96 birds, only 6 individuals (6 percent) were apparently lost over an average interval of 53 days. Unless coveys disappeared entirely, rates of mortality during the most rigorous of winter conditions appeared quite small.

In summary, I conclude that winter partridge mortality was generally light and nonvariable between years and, therefore, played an unimportant role in population fluctuation. The picture contrasted sharply with pheasants, a species in which winter loss was highly variable between years, and winter weather exerted predominant control over population trends (Gates, 1971). Hammond (1941), in North Dakota, also indicated that partridge were better adapted to deep snow and subzero temperatures than pheasants. In Iowa during the severe winter of 1935-36, Green and Hendrickson (1938) observed 48 percent mortality among pheasants, but reported negligible loss of partridge.

During the winter, partridge remained in upland areas such as this fencerow. In spite of marked annual differences in snow cover, winter partridge survival appeared constant between years.

DISCUSSION

LIMITING FACTORS

Gray partridge at Waupun proved far superior to pheasants in winter hardiness. Although partridge selectively inhabited the most cover-deficient portions of the winter landscape, winter mortality was slight and could not be detected as playing a significant role in population fluctuation. Other workers have also commented on the ability of this bird to withstand severe winter weather (Westerskov, 1966 and Green and Hendrickson, 1938).

Results of this study generally confirm the conclusions of earlier workers that the primary factors governing partridge abundance operate during the period of reproduction. Twomey (1936), Cahn (1938) and McCabe and Hawkins (1946) made use of climographs in comparing climates of the native European range of the partridge with climates of North America into which the species was introduced. McCabe and Hawkins (1946) concluded that winter extremes affecting adult birds are tolerated, but where summer extremes affecting survival of young fall outside European limits, the species either does not become established or fails to thrive. These authors further stated that the north-central states (Ohio, Michigan and Wisconsin) have "an unfavorable nesting season since the months of June, July and August lie well outside the European optimum, indicating that the area is too hot during the nesting season."

If excessive heat adversely affects breeding success, one possible explanation is that high ground temperatures before incubation might lead to poor egg hatchability as described by Yeatter (1950) in ring-necked pheasants. Ability of eggs to hatch in Wisconsin observed in the present study and by McCabe and Hawkins (1946) was 85 percent, not appreciably lower than that recorded in the English portion of the European range by Middleton (1935) (93 percent) and Jenkins (1961) (80-90 percent). Since juvenile survival appears to be higher with warmer summer weather, both in the north-central states (Dale, 1941 and this study) and in the species' European range (Jenkins, 1961 and Sekera, 1966), it would seem that the adverse effects of warm weather, if indeed they do exist, must operate before the eggs are laid and the young have hatched.

High summer temperatures might conceivably interfere with egg production and thereby shorten the period of time that hens remain in breeding condition. A test of this hypothesis would require considerably greater volumes of nesting data over a span of years than were obtainable in the present investigation.

Excessive precipitation may, however, be more important than excessive heat. The Danish portion of the partridge's native European range receives less than 5 inches of precipitation during the months of June and July combined, most of which falls as light drizzle (Westerskov, 1948). By contrast, the north-central states typically receive 7-8 inches of rain during this period, much of which occurs as intense showers. Results of the present study seemed to indicate that above-normal rainfall, coupled with below-normal temperatures, during the early stages of brood-rearing were primarily responsible for year-to-year changes in population density. In Michigan, Dale (1941) concluded that "mortality of young is high in wet seasons" and that the early success of partridge introductions into that state were "made possible by a succession of years with less than average rainfall." If in fact the climate of Wisconsin and other north-central states is basically unfavorable to partridge reproduction, the hypothesis that rainfall is excessive seems better supported by available field evidence than by McCabe and Hawkins' original inference that temperature was the critical factor.

Even though juvenile mortality at Waupun was variable between years, apparently accounting for major changes in population level, the average rate of juvenile loss was not inordinately high. Instead, the primary factor limiting partridge abundance appeared to be the low rate of nest success. Only 16 percent of all clutches were successful, and indirect evidence indicated that renesting was of minor importance. Although the percentage of successful pairs was unknown, my judgment is that even if all pairs nested, no more than 20 percent probably managed to bring off broods in an average year. Available population data are too incomplete to evaluate this level of pair success against what might be required for a population to maintain itself. Apparently, however, it was adequate for maintenance of a low-density population. The Waupun Study Area was far removed from any better partridge habitat, and it seems improbable that study-area populations were being augmented to any appreciable extent by ingress of birds from more densely populated surroundings.

In conclusion, summer weather appeared responsible for short-term changes in partridge density, but the principal long-term depressant on partridge numbers appeared to be low nest success.

MANAGEMENT IMPLICATIONS

Unfortunately, the inherent nesting-cover preferences of partridge offer limited opportunity for improvement of nest success through management. Hayfields are highly preferred as nest sites, and the large acreages of this crop available in Wisconsin apparently attract the majority of the nesting hens. Fifty-eight percent of all nests in the present study were placed in hay, in which cover type the management opportunity was virtually nil. No nests were found in retired cropland, wetlands or other permanent cover aside from fencerows and roadsides.

Of the total number of nests, 35 percent were found in fencelines and roadsides—the only two cover types in which management might be realistically contemplated. A program of strip-cover preservation and management to attract nesting hens out of hayfields might be a feasible approach for experimentation; however, it is conceivable that most of the potential benefits could be lost because of the high vulnerability of strip-cover nests to predation. A joint program of nesting-cover management and predator reduction might be practicable, but only on small units of range under intensive management.

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