MORTALITY OF RADIO-TAGGED PHEASANTS ON THE WATERLOO WILDLIFE AREA

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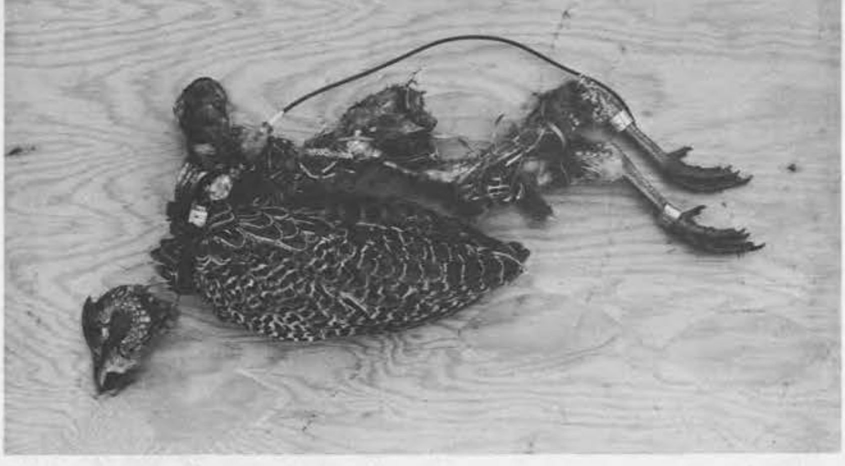

ABSTRACT

The objective of this investigation from 1968-1971 was to identify specific causes of hen pheasant mortality and to assess their relative importance on a seasonal and annual basis. Previous research in Wisconsin has provided a comprehensive evaluation of seasonal and annual mortality rates but only a glimpse of the importance of the individual mortality factors. Radio telemetry allowed the observer to maintain daily contact with individual birds and to get to the scene of death with a minimum of delay.

Field research was conducted at the Waterloo Wildlife Area, a 16,000-acre complex of state-owned and private lands located in Dodge and Jefferson counties. Fall and spring nightlighting and winter trapping were used to capture 244 pheasants for radio-equipping. Sex and age ratio data were obtained on the Waterloo pheasant population to determine annual and seasonal mortality rates for comparison with death rates computed for the radio-tagged sample.

A comparison of mean fall-to-fall mortality rates between the population and the radio-equipped sample revealed favorable agreement. Hen mortality averaged 73.9 percent per year for the population and 79.7 percent per year for the radioed cohort. However, a comparison of mean fall-to-spring and spring-to-fall mortality rates between the hen population and the radio-tagged cohort revealed distinct disagreement. Whereas the population at large realized a relatively low fall-to-spring death rate (35.3%), the radio-tagged sample experienced a comparatively high rate of loss (57.8%). The reverse was true for spring-to-fall loss where the population mortality rate was 57.5 percent compared with 44.8 percent for the transmitter-equipped segment. The seasonal mortality rates for the radio-tagged sample were found to be more consistent with previous research findings in Wisconsin than the comparable population estimates.

An annual pattern of mortality was developed for the radio-tagged sample by computing mortality rates for 6 seasonal periods using 5-day mortality rates (expressed as instantaneous rates). Snow cover and nesting periods ranked first and second, respectively, in importance with 5-day loss rates of 3.7 and 2.7 percent. Combined, they accounted for 50.9 percent of annual mortality, 35.9 percent occurring during snow cover and 15.0 percent during nesting. The 5-day mortality rate during the hunting season ranked third in importance, but applied to the largest annual population level and therefore accounted for 31.6 percent of annual mortality. The periods of brood-rearing and post brood-rearing were of little consequence in terms of annual mortality.

Predation was found to be the most important mortality factor throughout the year and was the only identified cause-of-death during the brood-rearing, post brood-rearing and late winter periods. Predation accounted for 80.8 percent of all classified deaths. Gunshot deaths were restricted to the hunting period and totalled 7.4 percent of all losses. Likewise, hay-mowing mortalities were confined to the nesting period and tallied 5.3 percent. Losses to highway traffic, hunting dogs, and winter weather each accounted for 2.1 percent of annual mortality.

Among losses to predation, 46 (60.5%) were attributed to mammalian predators, 19 (25.0%) to avian predators and 11 (14.5%) were unclassified. Within the category of mammalian predation, the fox was implicated in 16 (80%) of the 20 cases where species designation was possible. Among the 19 losses to avian predation, the red-tailed hawk and the great horned owl were incriminated in 2 and 6 cases, respectively. The species of raptor was undetermined in 11 cases on file.

The number of hens per fox changed from 8 to 14 from the onset of winter to the beginning of spring. The heavy harvest of fox during the winter caused the unusual decrease in the predator-prey ratio from fall to spring. Red-tailed hawks and great horned owls were represented in a proportion of 1:37 and 1:49, respectively, in winter and 1:20 and 1:28 in spring. The exploitation rate of hen pheasants by fox was found to be 1.38 birds per day during the fall-to-spring period.

The period of snow cover accounted for the largest fraction of annual mortality, and the severity of winter weather was found to be the principal determinate of annual fluctuations in fall-to-spring mortality. During all seasons of the year, wind velocity, cloud cover and precipitation averaged higher during nights of recorded mammalian and avian predation than the combined yearly averages. The vulnerability of the hen did not increase during any phase of nesting activity.

The scope of this study did not provide for an evaluation of population regulation; nonetheless it seemed likely that predation was the limiting factor of pheasant abundance at Waterloo. This suspicion was supported by the lack of success of a habitat development program at Waterloo (Frank and Woehler 1969) to produce a *measurable* increase in pheasant density relative to regional population trends. Habitat improvements applied at Waterloo were apparently ineffectual in offsetting the limitations placed on pheasant population density by predation.

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By

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INTRODUCTION

Essential to an understanding of the life history of the ring-necked pheasant (*Phasianus colchicus*) is the development of a detailed life equation showing the seasonal distribution of annual mortality and the relative importance of the various causes of death. Previous research in Wisconsin has provided a comprehensive evaluation of seasonal and annual mortality rates but only a glimpse of the relative importance of the individual mortality factors. The objective of this investigation was to identify specific causes of hen pheasant mortality and to assess their importance on a seasonal and annual basis.

Investigations in the 1940's by Leopold et al. (1943), McCabe (1949) and Buss (1946) furnished a measure of winter-to-winter annual mortality. In a 10-year study (1937-1947) on the University of Wisconsin Arboretum, McCabe (1949:132) found mean annual mortality to be 70 percent for sex and age classes combined. During 5 years when young were distinguished from adults, juvenile mortality averaged 79 percent and adult mortality 54 percent. Buss (1946:111) determined juvenile and adult mortality for sex classes combined to average 81 and 65 percent, respectively, from 3 winters of trapping (1940-43) on the Madison Fish Hatchery Refuge. These survival rates were based on the composition of winter-trapped birds from a banded population and were corrected for survivors in the untrapped segment.

The seasonal distribution of mortality was essentially unknown until Wagner (1957) presented circumstantial evidence for the existence of accelerated late summer mortality of adult hen pheasants. Based on earlier studies in Wisconsin and elsewhere, Wagner demonstrated that the severity of late summer hen loss was a function of nesting phenology. In early nesting years breeding success tended to be high and late summer mortality low; conversely, in late nesting years breeding success tended to be low and late summer mortality high. Kabat et al. (1950, 1956) had previously suggested the possibility of stress-related mortality from the physiological impact of breeding and molting in experiments with hen pheasants. In a later publication, Wagner et al. (1965:68) substantiated his earlier findings by demonstrating a correlation between annually varying reproductive success and survival from statewide population statistics.

In a more recent study (1958-1965), Gates (1971:656) found hen mortality to average 76 percent annually, 52 percent fall-to-spring and 50 percent spring-to-fall on the Waupun Study Area in southwestern Fond du Lac County. Whereas Wagner (1957) identified late summer as the period of accelerated annually varying mortality, Gates (1971:751) found winter mortality to be the most variable. Furthermore, Gates observed a relationship between the magnitude of winter mortality and the severity of winter weather.

McCabe (1949) and Buss (1946) combined sex classes when determining annual mortality rates for their pheasant populations. Gates (1971:589, 656) determined average annual cock mortality to be 93 percent in a population where 83 percent of the cocks are lost during the hunting season in the average year. Wagner et al. (1965:32) estimated 73 percent of the cock population was shot based on statewide winter sex ratio observations collected during 13 years between 1940-1961.

In Wisconsin, Burger (1964) was the first to categorize a large sample of pheasant mortalities for an assessment of relative importance among the various causes-of-death. Of 702 pheasant remains (pen-reared and wild birds) encountered on the Bark River Game Preserve in east central Jefferson County, 226 (33%) were assigned a mortality factor. Predation was the most important decimating factor accounting for 42 percent of the classified mortalities during the fall-to-spring study period. Gates (1971:679) found predation accounted for 49 percent of all losses during the fall-to-spring period at Waupun based on 702 mortality records of marked and unmarked hens. Hay mowing accounted for 34 percent of all spring-to-fall losses based on 265 mortality records and was the leading cause-of-death during that period. Gates (1971:667, 717) indicated the difficulty in interpreting field evidence during seasons other than the period of snow cover. The rapid decomposition of remains and the less frequent incidence of incriminating field sign increases the aspect of speculation in the determination of cause of death.

Gates (1971:659, 811) indicated the need for a refined picture of hen pheasant mortality particularly with regard to the seasonal and annual distribution of the various mortality factors. However, a second impetus for this research came when a program of habitat development at the Waterloo Wildlife Area in southeastern Wisconsin did not produce a *measurable* overall increase in pheasant density relative to regional trends. The program of habitat management was designed to enhance pheasant production and survival through improvement of nesting cover and winter food-cover relationships (Frank and Woehler 1969). The magnitude of pheasant population response after two years of management effort dictated the need for a better understanding of pheasant mortality and habitat relationships.

Hindering a refined study of mortality has been the inability to find birds soon enough after death to identify predisposing and direct factors causing mortality. Radio telemetry provided the means of circumventing this difficulty by allowing the observer to maintain daily contact with individual birds and to get to the scene of death with a minimum of delay. This study was begun in 1968 to collect mortality data for an assessment of seasonal distribution and relative importance of the various causes of death. The text of this paper will deal exclusively with hen mortality; a discussion of cock mortality may be found in Appendix IV. Related life history information including breeding behavior, daily and seasonal movement, activity patterns and the dynamics of habitat use were documented and will be reported under separate cover.

STUDY AREA

LAND USE

Field research was conducted at the Waterloo Wildlife Area, a 16,000-acre complex of state-owned and private lands located in Dodge and Jefferson counties (Fig. 1). Forming the core of this area is a public hunting grounds comprised of roughly 6,600 acres of state-owned and leased lands.

Topography of the study area is characterized by recessional moraines formed by the Cary ice sheet. Average elevation is about 850 feet above sea level with relief of roughly 100 feet between ridge tops and lowlands. Underlying most of the area is Ordovician sandstone (St. Peter Formation) and dolomite (Prairie du Chien Group) (Wisconsin Geological and Natural History Survey 1949). Precambrian quartzite appears as rock outcrops scattered throughout the landscape.

The greyish-brown silt loams found on the study area have an excellent-to-good rating for general agricultural use (Hole and Beatty 1957). Interspersed in glacial pockets are extensive areas of muck (peat) soil.

A summary of land use for the study area reveals 48.9 percent was under cultivation, 18.7 percent in permanent pasture, 14.1 percent in undisturbed wetlands and 18 percent in assorted other cover types (Table 1). Of the acreage under cultivation 41 percent was in corn, 30 percent in alfalfa hay, 17 percent in oats and 12 percent in other crops. Corn-oats-hay rotation has been common procedure.

Dairy farming is the most prevalent agricultural enterprise but cash-crop farming (peas, sweet corn, mint, and blue grass sod) and beef farming are evident. Mint and blue grass sod are cultured on the better

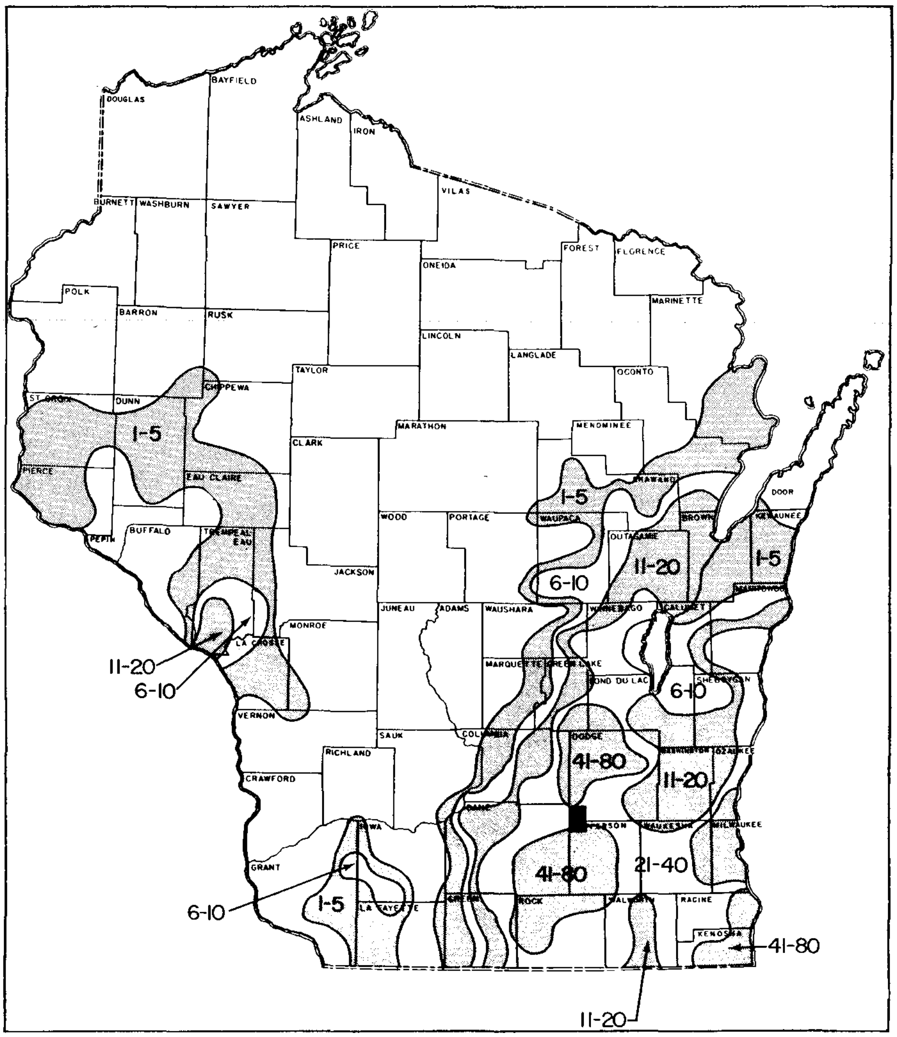


FIGURE 1. *Pheasant hen density, spring, 1971 (hens per square mile).*

drained organic soils. Peas, sweet corn, wheat and soybeans are secondary to forage crops. Average farm size is about 180 acres.

Large tracts of relatively unbroken wetlands occur on the study area (Fig. 2). Historically, these lowland areas were composed of sedge meadows (Curtis 1959:375), although tamarack and fen communities must have been present since they now exist as relics. Drainage or pasturing of the sedge meadows has resulted in meadows dominated by canary grass and shrub carr communities. Spring flooding occurs on about 40 percent of study area wetlands.

The drumlins are mostly cropped but some retain hardwood stands of white oak and shagbark hickory. Woodlands including remnant stands of tamarack and conifer plantations occupy 6 percent of the landscape. Grazing of woodlots and wetlands is common except on state-owned property.

TABLE 1. Land Use Summary, Waterloo Study Area, 1969*

Land Use	Acreage		Percent of Total Area	
Cultivated land	7,785		48.9	
Corn		3,176		19.9
Small grains		1,448		9.1
Hay		2,499		15.7
Misc. crops		662		4.2
Permanent pasture	2,977		18.7	
Semi-disturbed lands**	801		5.0	
Undisturbed wetlands	2,253		14.1	
Woodlands[1]	996		6.3	
Strip cover[2]	405		2.5	
Miscellaneous[3]	713		4.5	
Total	15,930		100.0	

*Gross land use data compiled from 1962 aerial photos (Frank and Woehler, unpubl.) and cropland statistics are from 1970 Wisconsin Agricultural Statistics, Wis. Dep. of Agriculture for the 1969 growing season.

**Marsh hay and idle cropland.

[1]Lowland and upland hardwoods, tamarack and conifer plantations.

[2]Ditchbanks, fencerows, roadsides and R. R. right-of-way.

[3]Farmsteads, road pavement, gravel pits, R. R. track bed and open water.

CLIMATE

Climatological data for the study area were derived from two sources. Temperature and precipitation data were obtained from a secondary weather station located at Watertown, 10 miles east of the wildlife area. Wind, sunshine and humidity information was gathered from the primary weather center at Madison, 20 miles west of the study area. General information on climate was taken from a 30-year summary (1921-1950) of Wisconsin weather compiled by the Wisconsin Crop Reporting Service.

Climate of this area is continental characterized by large annual temperature range and frequent short-period temperature changes. During the period 1968-1970 winter temperatures averaged below normal while summer temperatures were generally typical. Average temperatures for January and February, the coldest months, were 16.3 F and 22.0 F, respectively. July and August are the warmest months and mean temperatures of 72.6 F and 72.4 F, respectively, were recorded for the period 1968-1970.

About 55 percent of the average annual precipitation falls during the months May through September. For the three-year period, summer precipitation was above normal and averaged 19.6 inches. Annual precipitation averaged 31.1 inches for the same period.

Prevailing winds are westerly in the winter, southerly in the summer and variable in the fall and spring. Between 1968-1970, April and December were the windiest months with average velocities of 11.3 and 10.6 mph, respectively. The 30-year summary reveals March, April and November to have the most wind with averages of about 12 mph. July and August were the calmest months with averages of 8.0 and 7.1 mph, respectively. The 30-year average for these months is about 9 mph.

PHEASANT POPULATION

The Waterloo Study Area is located in a region of moderate pheasant density (Fig. 1). Pheasant population trends on the study area were monitored in conjunction with a companion study (Frank and Woehler 1969) which was designed to measure the response of upland game populations to habitat manipulation. Pheasant surveys included an intensive hunter check in the fall, sex ratio counts in the winter, cock triangulation counts in the spring and brood observations in the summer. Spring hen population estimates were obtained from cock triangulation counts corrected for winter sex ratios. Roughly 3 cocks and 25 hens per section comprised the spring breeding population. Fall population estimates were determined using a modified Kelker Index which will be discussed in a later section. The prehunt fall population was composed of roughly 2 adult cocks, 8 adult hens and 52 juvenile birds per section.

METHODS

CAPTURE TECHNIQUES

Nightlighting accounted for 168 of 247 pheasants (68%) leg banded and equipped with radio transmitters (Table 2). Included in this sample were 94 juvenile and 36 adult hens and 16 juvenile and 2 adult cocks. Age determination was not made on 20 hens captured in the spring of 1968. In addition, 189 pheasants (68 females, 121 males) captured by nightlighting were only leg banded. Fifty-seven of the banded females weighed less than 650 grams and were not of sufficient size for radio-tagging. The minimum weight requirement of 650 grams was established arbitrarily, but to some degree based on a desire not to exceed 5 percent of the bird's weight with the 32-gram transmitter package. The remaining 11 hens were of sufficient size for radio-equipping but were captured at a time when the frequencies of the available transmitters would conflict with those already in use in the area of their capture.

The nightlighting technique employed was modified from that described by Labisky (1968). A 4-wheel drive vehicle was equipped with a bank of 8 floodlights and 2 spotlights (Unity Model No. 742). The lighting system was powered by two 12-volt heavy duty automobile batteries and a high amperage alternator. The floodlights were mounted on cartop carriers and provided an arc of light about 15 yards wide. A switch mounted on the rear carrier controlled the floodlights and the vehicle's headlights. The spotlights were on an independent circuit, and each was controlled by a toggle switch on the handle.

Nightlighting vehicle

TABLE 2. Nightlighting Capture Summary for Pheasants Radio-equipped 1968 to 1971*

		Females			Males			
Year	Season	Adults	Juveniles	Subtotal	Adults	Juveniles	Subtotal	Total
1968	Spring	"No age"		20				20
	Fall	13	34	47				47
1969	Spring	2	1	3		1	1	4
	Fall	7	20	27		8	8	35
1970	Spring	4	10	14		2	2	16
	Fall	8	26	34	2	4	6	40
1971	Spring	2	3	5		1	1	6
Total				150			18	168

*Age determination fall of 1968 by bursa measurement (Linduska, 1943) and thereafter by measurement of shaft diameter and total length of the first primary (Wishart, 1969).

Nightlighting was most productive in retired cropland both in terms of total birds captured and in acres searched per bird captured (Table 3). Vegetation on idle cropland most often consisted of quack grass and brome grass with alfalfa and occasionally thistle, goldenrod, and aster depending on the term of its retirement. Nightlighting was conducted in 22 diverted fields ranging in size from 5 to 60 acres ($\bar{x}$ = 14.4). Of the 357 pheasants captured by spotlighting, 203 (57%) were netted in idle cropland and 111 (31%) in lowland. Success might have been better in lowland cover ex-

North Unit

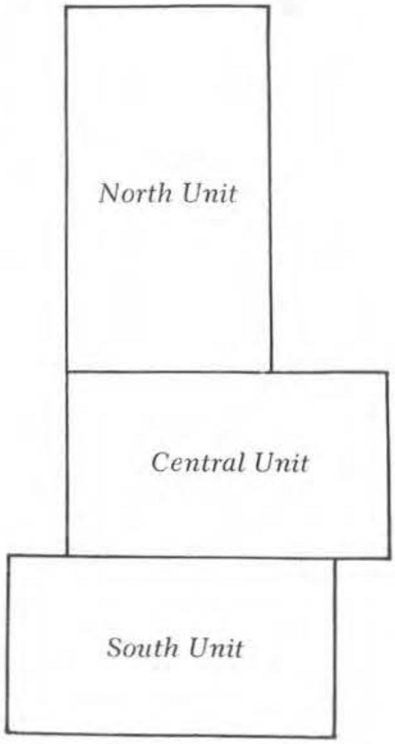
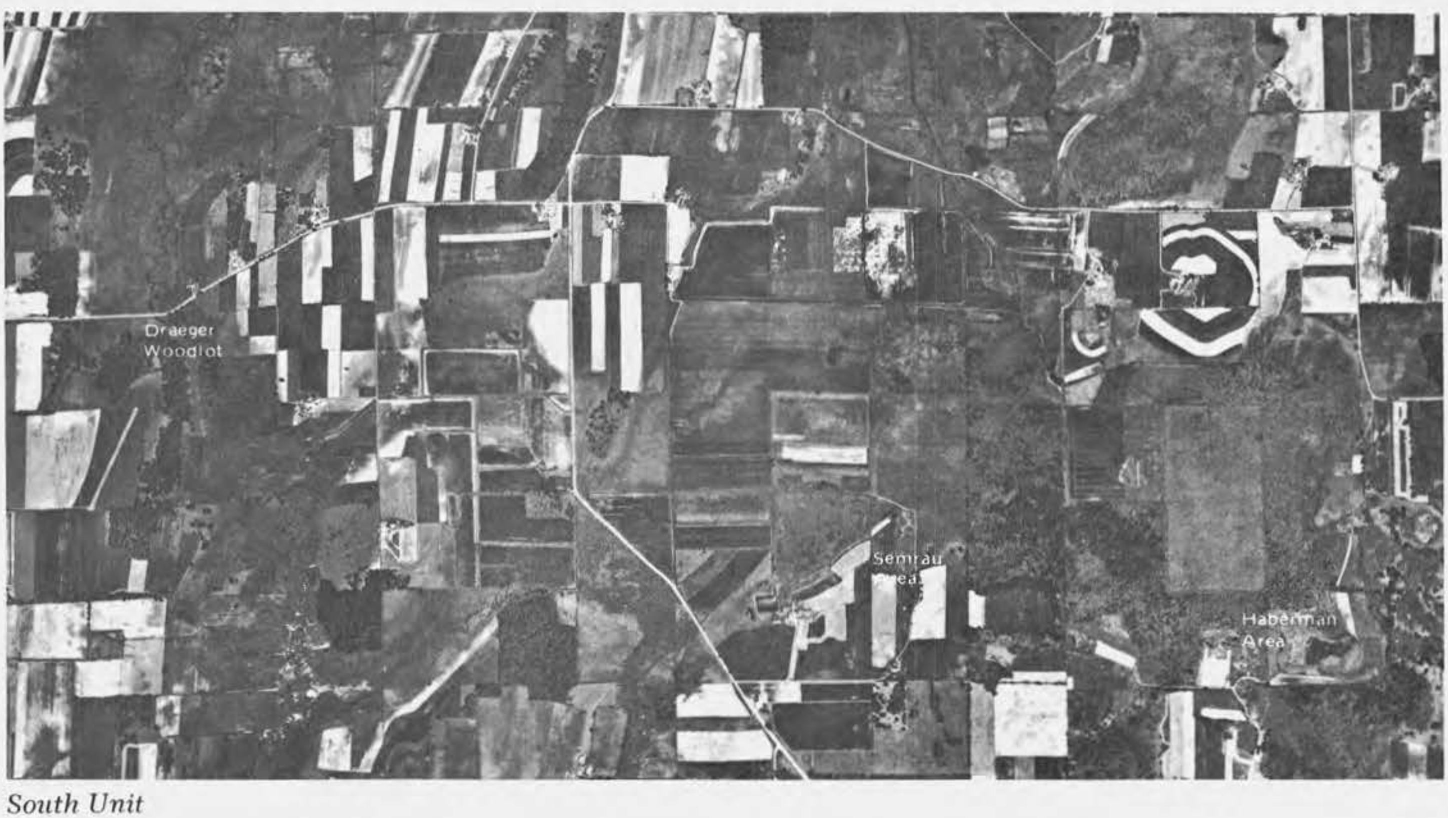


FIGURE 2.

The 16,000-acre Waterloo Study Area encompasses a Public Hunting Grounds composed of about 3,127 acres state-owned and 3,496 acres state-leased lands. The interspersion of wetlands and cropland characteristic of this area is apparent on the accompanying aerial photos. Certain properties referred to in the text are labeled on the photos.

Central Unit



South Unit

cept the vegetation was often composed of aster, goldenrod, canary grass and brush which effectively concealed birds so as to hinder spotlighting or netting. Twenty-one lowland fields ranging in size from 2 to 25 acres ($\bar{x} = 17.2$) were nightlighted.

Annually, nightlighting was begun during the last week in September and continued until 40-50 hens were captured. In 1969, spotlighting was tried following the hunting season (early December) but only 5 birds (3 hens, 2 cocks) were radio-equipped during 4 nights. A total of 18 pheasants (14 hens, 4 cocks) were observed, but "flighty" behavior made capture very difficult. Hunting pressure at Waterloo was very heavy, conceivably forcing most birds into inaccessible cover such as shrub carr and making all birds wary. Spring nightlighting (March-April) was more successful, but most cover was made inaccessible by flooding or undesirable for roosting because of flattening by snow cover. Most birds roosted in drier wetland sites where access was impossible. Of 45 pheasants captured in the spring, 39 were netted in retired cropland, 2 in lowland and 4 in upland cover.

Winter trapping provided 76 of 247 (31%) pheasants tagged with radio transmitters (Table 4). A total of 67 females were radioed of which 49 were juveniles, 9 were adults and 9 were birds of unknown age. Nine cocks including one adult were captured during the 4 winters.

Winter traps and trapping techniques used in this investigation were similar to those described by Gates (1971:27). Traditional winter roosting cover was pre-baited with cob corn shortly after the first snowfall when general appraisal of flock size could be assessed. Use of the bait pile by pheasants determined whether or not trapping was worthwhile at a particular site. Gates (1971:27) reported poor success in habitats where canopy cover was absent so all bait stations were placed in shrub carrs, woodlots, brushy fencelines or brush piles.

TABLE 3. Success Among Various Habitat Types Used for Nightlighting of Pheasants, 1968–1971

		Idle Cropland	Lowland	Upland	Marsh Hay	Total
Acres searched		1,011	1,242	455	58	2,766
Birds captured:	radioed	112	31	18	7	168
	banded	91	80	18		189
	total	203	111	36	7	357
Acres searched/birds captured		5.0	11.2	12.4	8.3	7.7

TABLE 4. Winter Trapping Summary for Pheasants Radio-equipped 1968 to 1971*

	Females			Males			
Year	Adults	Juveniles	Subtotal	Adults	Juveniles	Subtotal	Total
1967–68	"No age"		4				4
1968–69	2	13	15	1	4	5	20
1969–70	3	21	24		3	1	25
1970–71	4	15	24(Incl. 5 no age)		2	3(Incl. 1 no age)	27
Total			67			9	76

*Age determination winter of 1968–69 to 1970–71 by measurement of shaft diameter and total length of the first primary (Wishart 1969).

TABLE 5. Success Among Various Habitat Types Used for Winter-trapping of Pheasants, 1968–1971

	Shrub Carr	Conifer	Tamarack	Woodlot	Brushy Fenceline	Brush Pile	Total
Trap sets*	22	6	5	2	1	1	37
Birds captured	43	23	3	1	6	0	76
Birds/trap set	1.9	3.8	0.6	0.5	6.0	0	2.0

*Trap set represents one trap at a particular site for an indeterminate time period. Some traps remained at a site all winter, others were moved 2-3 times. Traps were set sporadically, dependent on pheasant use, weather, and availability of transmitters. No accurate records were kept of trap dates for all sets so a trap-days comparison was not possible among the various cover types.

Winter trap

Shrub carr sheltered a majority of wintering pheasants and therefore provided the best opportunity for bait trapping (Table 5). Of 76 birds trapped, 43 (57%) were captured in shrub carr. Conifer cover ranked second in birds captured with 23, but trapping success (birds/trap set) was better in this cover type than in shrub carr. Roughly, 4 birds were captured per trap set in conifer groves whereas only about 2 birds were taken per trap set in shrub carr. The brushy fenceline site was located between an extensive wetland unit and a 40-acre unpicked cornfield. Approximately 40 pheasants used this ¼-mile fenceline as a travel lane between food and cover. Often they would roost and loaf in the brushier sections of the fenceline. Seven birds were enticed into the trap despite the abundant food supply. The woodlot and tamarack sites were only partially successful and were used primarily to obtain a good distribution of radioed birds on the study area. Annually about 7 traps were shifted between the various cover types.

Miscellaneous techniques were used to capture 3 additional birds. A pointing dog (Brittany spaniel) was used with a 10x10-foot net to capture one individual. The dog was followed by 2 persons with a large net and allowed to roam in ditchbank or retired cropland cover until a pheasant was encountered. When a bird was pointed, the dog was covered with the net favoring the direction of her point to include the pheasant. This technique was tested in the spring of 1968 to supplement the nightlighting catch. Most birds were very wary and did not hold long enough for the maneuvering required to net the dog and bird.

Mist nets were tried during two winters but only one bird was captured and another recaptured with this technique. In the successful attempt, 2 black nylon mist nets (Model 2100, 3 LP) were set perpendicular to a brushy fenceline used as a travel lane by about 40 birds. The birds were driven along the fenceline by 2 individuals, but deep snow prevented them from applying enough pressure as the birds approached the nets, and most either flew over or ran around the device. Both birds captured on this attempt were well enveloped in the net. Unsuccessful attempts using similar procedures were tried in a large block of shrub carr with 4 nets and a conifer grove with 2 nets.

The third bird was accidentally captured when she was netted on her nest along with a radio-equipped bird that was being recaptured. The radioed hen had been pursued for about an hour with portable tracking gear when she stopped 4 feet from the nesting hen. The 10x10-foot net was set over the suspected hiding spot of the radioed hen and both birds flushed into the bag of the net.

RECAPTURE TECHNIQUES

Twenty-nine percent of all birds (72 of 247 birds) radio-equipped were subsequently recaptured one or more times for transmitter replacement. A technique used in all but 3 of 185 transmitter changes involved the pursuit of an individual with portable receiving equipment (described in the next section) until the bird held long enough at a site to be netted. This proved to be an extremely time-consuming affair. At least 2 men and often 3 were required for 1-3 hours to track down and tire a pheasant before it could be netted.

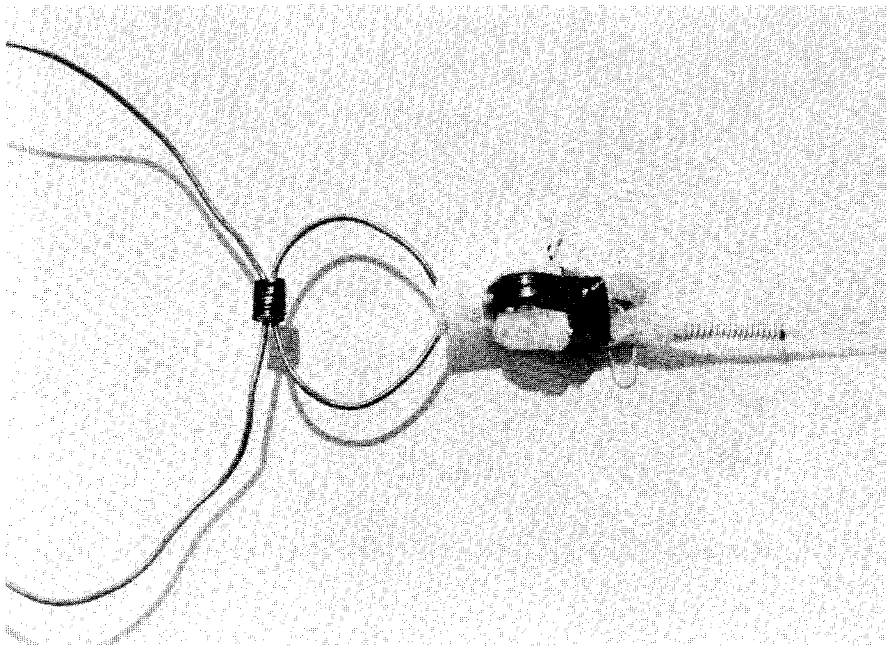
Radio-equipped birds were recaptured using a long-handled hoop net or a 10x10-foot net. The square net was used almost exclusively during the first two years of the study. It required

10x10 foot net

Hoop net

two men but was advantageous because it covered a large area and less precise location of the bird was required before the net could be dropped. Steel hoop nets, 46 inches in diameter, were used occasionally during the early years of this investigation, particularly in shrub carr habitat where the large net could not be manipulated. Two fiber glass-handled, aluminum hoop nets were used in the later years of study. These light weight nets were more maneuverable and, therefore, superior to the heavier all-steel nets used previously.

In general, recapture was most difficult when radio-equipped birds were flocked with others as in late fall and winter. Under such conditions birds seemed to react as a group. If other birds flushed, the tagged bird was less inclined to hold. During spring and summer, hens were generally solitary and comparatively easy to approach and net.



Transmitter

Radio receiver (A.V.M. Instrument Co.)

RADIO TELEMETRY

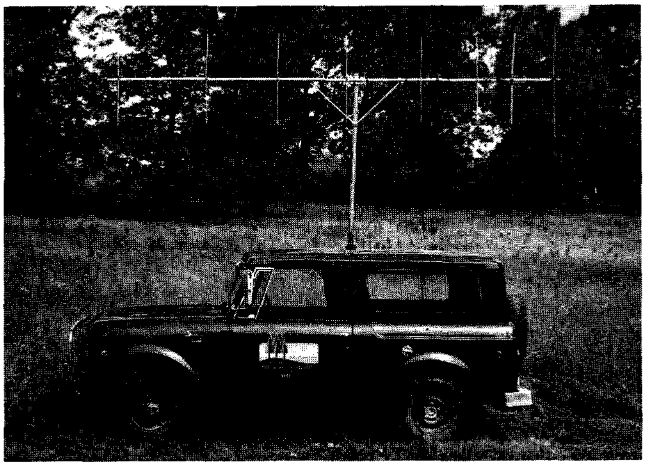
Aluminum leg bands (National Band and Tag Company, Newport, Ky.) were affixed to all pheasants captured during the study. Gold-colored reward bands were placed on both tarsi of radio-tagged birds. Pheasants captured by nightlighting in the fall and not radioed were tagged with one gold reward and one silver band. Game farm birds released on the wildlife area were equipped with one silver band. Therefore, observations of leg-banded birds on the study area could be identified as to their origin. This practice was particularly helpful in identifying transmitter-equipped birds that had shed their radios.

Transmitters used in this investigation employed a circuit described by Cochran (1967) and a design modified from Brander (1968). Development of component configuration and transmitter design was done in cooperation with Harry H. Miller of the University of Wisconsin Instrumentation Systems Center. Most transmitters were powered by Mallory RMI certified cells, with a current drain of approximately 0.35 ma and an operational life of about 100 days under field conditions. The transmitting unit emitted a pulsed signal at the 150 MHz range, easily discernible by mobile receiving equipment up to ¾ mile away.

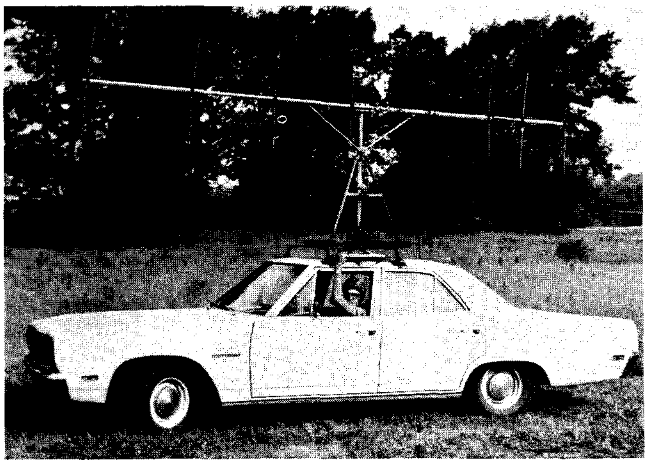
Transmitter components, including the battery, were encapsulated in translucent dental acrylic, which is waterproof, cold-resistant and hard enough to withstand most damage by predators or impact by gunshot or automobile. Weight of the package after encapsulation was about 32 grams.

A 10-inch whip antenna made from guitar string (spring steel, B-flat) with a loading coil emitted a modulating, omnidirectional signal. The antenna wire was protected from breakage by a cover of polyvinylchloride tubing and a ball point pen spring.

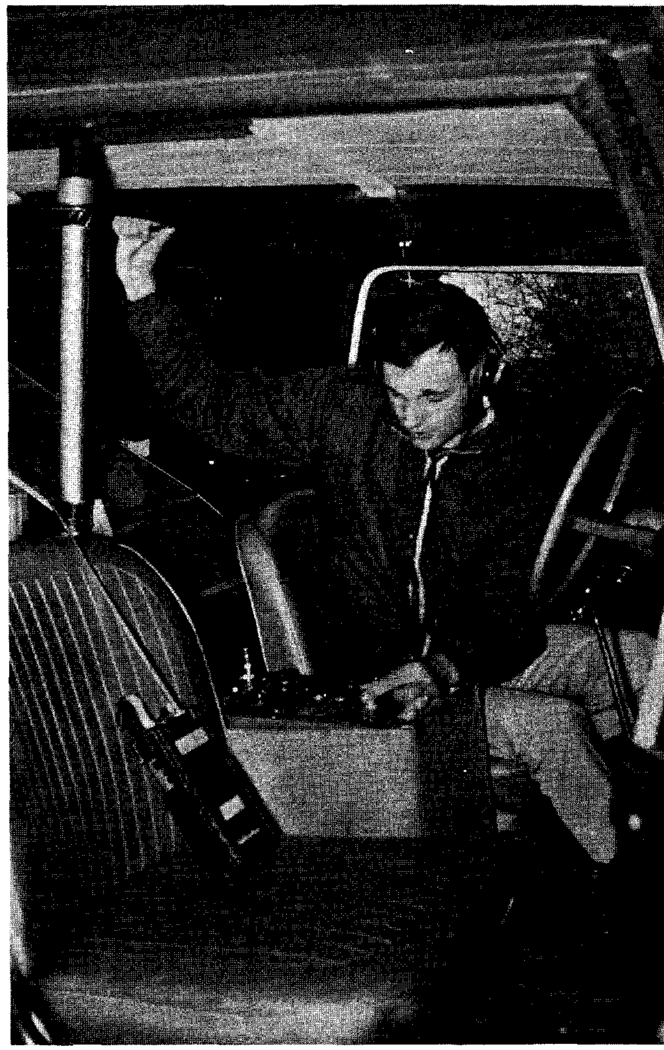
Harness straps were made of



Directional antennas affixed to an internally rotated shaft



Directional antenna externally mounted on cartop carriers



Internally rotated antenna shaft

plastic-coated wire and served a dual purpose in that they also provided capacitance for the electrical circuit. Numerous modifications were made in transmitter design specifically in antenna and harness systems. Specifications and recommendation may be found in Appendix I.

Radio-tracking receivers used in this study were of two types. A crystal controlled, double conversion, super-heterodyne receiver manufactured by Markusen Electronic Specialties, Cloquet, Minnesota was used during the 1968 and 1969 field seasons. A more compact, continuous band, tracking receiver was acquired from A.V.M. Instrument Company, Champaign, Illinois for the 1970 to 1971 study period.

The radio receivers were used with vehicle-mounted antennas to locate the instrumented birds. A single 14-foot, 8-element directional antenna was affixed to an internally rotated shaft and mounted on a 4-wheel drive vehicle. The same antenna externally mounted on cartop carriers constituted the second mobile unit. During the first year of study another antenna system involving two 3-element horizontally stacked yagis was used. The yagis were never properly matched, and gain and directionality were not comparable to the 8-element antenna. Portable 2-element antennas were employed to confirm locations indicated by mobile units, to pinpoint nesting hens and victims of mortality and to recapture birds.

Initial contact with a radioed bird was accomplished with mobile units. The site from which the bird was last located on the previous day was repeated to obtain initial contact. The antenna was rotated until it pointed in the direction of the most intense signal. Signal strength was determined aurally rather than by visual interpretation of the ammeter. A line with respect to an artificial or natural landmark was taken by sighting along the beam of the directional antenna. This could usually be accomplished without getting out of the vehicle. A second line from another vantage point was obtained and the bird located where the two lines intersected. An effort was made to obtain lines that were perpendicular to each other at the point where they intersected to reduce the "error polygon" as described by Heezen and Tester (1967). A third line was occasionally taken to confirm the assigned location of the bird.

Most locations were obtained by approach of the mobile units to within ¼ mile of the bird. Confirmation of mobile unit locations with portable gear revealed most radio-positions fell within ¼-acre of true location; accuracy decreased with distance. Strip-crop farming was commonly practiced on the study area and lines parallel and perpendicular to the long axis of the fields had to be obtained for accurate cover designation. This often necessitated the use of farm trails.

DATA COLLECTION AND TABULATION

Field work began in late September each year when an initial complement of 40-50 pheasants was captured by nightlighting for radio-tagging. Attrition of the radioed cohort due to transmitter failure or mortality necessitated winter trapping to maintain a desirable sample of 30 birds during the fall-to-spring study period. Trapping was usually begun in late December and continued through February.

Fall-tagged birds had to be recaptured for transmitter replacement in December. A conglomerate of fall- and winter-tagged birds was monitored until early spring when nightlighting was used again to capture birds for radio-equipping.

Spring spotlighting was usually begun in late March after winter break-up and terminated mid-April prior to the onset of nesting. Spring rains and flooding of study area wetlands determined how much cover was available for nightlighting. Usually 10-15 birds were needed to attain the desired sample of 25 hens for the spring study period.

Fall- and winter-captured birds required new radios in March and April. No effort was made to capture birds after the breeding season was underway, so the radioed cohort decreased until late September. Recapture after mid-April was limited to hens that reached late incubation, and they were netted at their nest site just prior to hatching. This policy was designated to minimize disturbance of pheasant production on the study area.

Birds were monitored daily with rare exception. An effort was made to locate each bird twice a day, but the burden of capture and recapture activities and searching for missing birds made this impossible. Often, only one check per day was achieved. An exception to this was during the spring study period when the sample of radioed birds was intentionally kept low, so 3-4 checks per day could be employed to adequately document nesting behavior.

After daily contact was made with an individual, time, location, activity, cover selection and pertinent information such as weather, visual observations of the bird and accuracy of the location were recorded. A daily log was used to record all information except the individual's location. The radio-position was recorded on an aerial photo in the field and later transcribed to frosted acetate or mylar for permanent record-keeping.

If a mortality occurred, a special form was used to tabulate the details of field sign, weather and predisposition of the bird. Photographs were taken of most mortality victims when a substantial portion of the carcass remained. All intact carcasses were fluoroscoped (Elder 1950, and Whitlock and Miller 1947) for lead shot.

FINDINGS AND DISCUSSION

Radio-equipping of 245 pheasants (218 hens, 27 cocks) yielded a collection of 137 mortality records (120 hens, 17 cocks). However, the following analysis of mortality will disregard deaths that occurred within 5 days of initial capture due to potential transmitter-related mortality. Appendix II has a discussion of this adjustment period required by pheasants to adapt to the radio package. Computation of mortality rates and a discussion of mortality factors for the hen segment of the pheasant population will be based on 105 mortality records. Cock mortality is discussed in Appendix IV and is based on only 15 deaths.

MORTALITY RATES

The determination of mortality rates for the hen pheasant population at Waterloo was, in general, beyond the scope of this investigation. The intent of this study was simply to ascertain the seasonal and annual importance of the various hen mortality factors. However, the assessment of relative importance among the identified causes-of-death must be formulated from a sample of pheasants whose mortality rates are comparable to the population mortality rates to credibly represent that population. Sex and age ratio data were obtained on the Waterloo pheasant population to determine annual and seasonal mortality rates for comparison with death rates computed for the radio-tagged sample.

Calculation of Mortality Rates for the Population

Two population statistics were required to compute fall-to-fall mortality rates for study area hens. These were an estimate of the prehunt hen population and a fall hen age ratio. Pheasant surveys designed to provide these statistics were conducted in cooperation with the habitat improvement program (Frank and Woehler 1969) and kindly provided by E. E. Woehler from unpublished data. These surveys were intended to measure response of pheasant and rabbit populations to habitat development and have been conducted since 1962. Included in this report are pertinent data from years 1967-1971.

Prehunt Hen Population Estimate

A modified Kelker Index, which is based on the change in sex ratio resulting from the known kill of each sex during the hunting season, was used to obtain prehunt hen population estimates (Table 6). The cock kill was determined from harvest statistics gathered by an intensive hunter survey on the study area. License numbers were recorded for all vehicles parked on roads, in fields and in parking lots. When a hunting party was interviewed, the license number(s) of their vehicle(s) was recorded with other details of their hunting experience. Efficiency of hunter contact was obtained by dividing the number of vehicles whose occupants were interviewed, by the total number of vehicles recorded on the study area. The efficiency of bag check averaged 55 percent during the 5-year period.

Between 214 and 353 cocks were checked yearly during the harvest survey. The total harvest, after compensating for efficiency of hunter contact, ranged between 382 and 619 roosters. Crippling loss was defined as the number of cocks that were reported as hit by gunshot and not recovered and averaged 13 percent during the study period. Total gunshot deaths, after compensating for crippling loss, ranged from 432 to 693 cocks.

Illegal hen kill was found to be about 5 percent based on gunshot loss among the radio-tagged cohort. This rate was low compared with previous Wisconsin findings. Gates (1971:614) estimated the statewide kill of hens to approximate 12 percent of the prehunt population based on the incidence of birds carrying lead shot. On his Waupun Study Area, the recovery of marked birds yielded a minimum mortality rate to gunshot of 10 percent of the preseason hen population. All posthunt sex ratio values in Table 6 were corrected at the 5 percent level to compensate for the illegal hen kill observed at Waterloo.

An assumed prehunt sex ratio of 1.25 was used during all 5 years for which prehunt population estimates were made. Brood observations and nightlighting captures are the usual sources for early fall sex ratios, but Waterloo data from these activities were thought to be inadequate for sex structure determination. Stokes (1954:87) demonstrated that the prehunt fall sex ratio will lie between 1.19 and 1.43 presuming a reproductive success of 4:1 to 2:1 young per adult female and 5:1 to 10:1 fall adult sex ratio. Gates (1971:61) empirically derived an average prehunt fall sex ratio of 1.25 (range 1.19 to 1.32) from August brood observations and prehunt nightlighting for the Waupun pheasant population. At Waterloo, August roadside observations of pheasants revealed roughly a 5:1

TABLE 6. Prehunt Hen Population Estimate Determined From a Modified Kelker Index Computation

Year	Cock Harvest Statistics: Observed Harvest	Efficiency of Bag Check	Total Harvest	Crippling Loss	Total Gunshot Deaths	Sex Ratio: Prehunt	Posthunt	Corrected* Posthunt	Calculated** Percent of Cocks Shot	Prehunt Population Estimates: Cocks	Hens
1967	265	.57	465	.12	521	1.25	7.5	7.9	84.2	619	774
1968	214	.56	382	.13	432	1.25	7.8	8.2	84.7	510	637
1969	353	.57	619	.12	693	1.25	5.3	5.6	77.7	892	1,115
1970	258	.47	549	.12	615	1.25	8.3	8.7	85.6	718	898
1971	294	.59	498	.17	583	1.25	7.3	7.7	83.8	696	870
Averages	277	.55	503	13.2	569	1.25	7.2	7.6	83.2	687	859

*Corrected compensating for an illegal hen kill of 5 percent as determined from the radio-equipped sample.

**Formula: $\text{Percent of cocks shot} = \dfrac{\dfrac{\text{Corrected Posthunt Sex Ratio}}{\text{Prehunt Sex Ratio}} - 1.00}{\text{Corrected Posthunt Sex Ratio}}$

adult sex ratio and nightlighting provided an approximate female age ratio of 4:1. Therefore, a prehunt sex ratio of 1.25 appears realistic for the study area pheasant population.

Posthunt sex ratio observations of pheasants were obtained from roadside observations and flush counts during January and February. Flush counts were gathered from random encounters with birds in winter cover during routine field operations and from drive counts where units of heavy cover were systematically searched by a large crew (8-16 men). Observations from the various activities were treated equally to develop the posthunt sex ratio.

Fall Hen Age Ratio

One additional statistic, the fall hen age ratio, was required before annual hen mortality rates could be computed. These age ratios can be calculated from cock age ratios observed in the bag and prehunt sex ratios. The following formula was derived from Stokes (1954:79):

$$\text{Hen Age Ratio} = \frac{\text{Cock Age Ratio}}{(\text{Cock Age Ratio} + 1)\ \text{Fall Sex Ratio} - \text{Cock Age Ratio}}$$

An average of 3.07 juvenile hens was present per adult hen in the prehunt population for years 1967-1971 (Table 7).

Hen age ratios can also be obtained from the nightlighting sample. Spotlighting was conducted between 1968-1970 with these age ratios observed in the catch: 1968: 3.53 (N=68 hens); 1969: 4.55 (N=50 hens); and 1970: 7.33 (N=50 hens). These observed age ratios displayed poor agreement with calculated values given in Table 7. Gates (1971:78) found close agreement between observed and calculated hen age ratios on the Waupun Study Area. Five years of nightlighting yielded an average hen age ratio of 3.0 as compared with 2.9 juvenile hens per adult hen calculated for 7 years when prehunt sex ratio and cock age ratio data were available. Nightlighting samples at Waterloo were small and likely inadequate to reliably reflect true population structure of sex and age. The observed age ratios were nonetheless consistent with previous abnormally high age ratios observed in the nightlighting catch at Waterloo. The average of 4.6 juveniles per adult hen (N=168) observed in the investigation compares favorably with hen age ratios of 5.2 (N=56) and 5.4 (N=109) observed by Frank and Woehler (unpublished data) for years 1963-64.

Annual Mortality Rates

The fall hen estimates and hen age ratios were used to compute fall-to-fall mortality rates for years 1968-1971 (Table 7). Annual death rates varied between 60.6 percent and 80.2 percent ($\bar{x}$=73.9%) for age classes combined. The mortality rate for 1969 was low (60.6%) when compared with the values for 1968, 1970 and 1971 which averaged 78.3 percent. However, assumed values were used in the determination of fall hen estimates and although their impact should be minimal, little emphasis will be placed on individual annual death rates due to the potential bias. Future discussion of population mortality will center on the mean annual mortality rate of 73.9 percent.

TABLE 7. Annual Mortality Rates (October 1 to September 30) for the Hen Population

Year	Hen Population	Age Ratio*	Adults	Young	Percent Survival	Percent Mortality
1967	774	2.91	198	576		
1968	637	3.16	153	484	19.8	80.2
1969	1,115	3.45	251	864	39.4	60.6
1970	898	2.72	241	657	21.6	78.4
1971	870	3.09	213	657	23.7	76.3
Averages	859	3.07	211	648	26.1	73.9

*Hen age ratio calculated using the cock age ratio observed in the bag.

$$\text{Formula: Hen Age Ratio} = \frac{\text{Cock Age Ratio}}{(\text{Cock Age Ratio} + 1)\ \text{Fall Sex Ratio} - \text{Cock Age Ratio}}$$

Calculation of Mortality Rates for the Radio-Tagged Sample

Mortality rates for the radio-equipped sample were computed for 5-day periods between April, 1968 and August, 1971. The total mortalities falling in each period were divided by the number of radioed birds known to be alive at the onset. To obtain a mortality rate for a series of periods, as for example 73 (one year), the 5-day mortality rates were averaged and the complement of the proportion, the average 5-day survival rate, was obtained and raised to the 73rd power. The resultant survival rate was then converted to a mortality rate for the 73, 5-day periods. To better demonstrate this procedure a series of 5-day periods encompassing the hunting season was excerpted from an annual tabulation of data (Table 8). In this example, a mortality rate is computed for 12, 5-day periods. The upper section of the table shows how 5-day mortality rates were calculated and summed. The lower section demonstrates the stepwise procedure used to procure a seasonal mortality rate.

Rates thus calculated although imperfect, are used as estimates of "instantaneous" mortality rates, since the 5-day period is a relatively small proportion of the average longevity of radio-equipped birds. This period length seems especially allowable in view of the magnitude of the coefficient of variation that is associated with these rate estimates (C.V. = 75% for Table 8 data). Also an artificial calculation of the approximate data in Table 8 yields a relative difference of less than 0.5 percent when calculated on a 5-day vs. a 1-day basis. In a subsequent discussion of mortality, seasonal periods of unequal length will be compared. Average 5-day mortality rates as well as cumulative rates will be provided for direct comparison in these examples. Otherwise, when periods of equal length are involved only the cumulative rates of mortality will be given.

Comparison of Population and Sample Mortality Rates

To strengthen confidence in the credibility of the radioed sample as representative of the population, a comparison of annual and seasonal mortality rates was undertaken. Fall-to-fall, fall-to-spring and spring-to-fall death rates were collated among the population and sample. Fall-to-spring was defined as October 1 to March 31, and spring-to-fall as April 1 to September 30 for the radio-equipped cohort. Hen estimates and age ratios used to compute the population mortality rates were pre-hunt (early October) and pre-breeding (early April). In addition, 6 seasonal periods of specific importance for the hen pheasant were defined and mortality among the radio-tagged sample computed for each. In this manner the annual pattern of mortality was conveniently portrayed.

Gates (1971) provided a comprehensive picture of annual and seasonal losses for a pheasant population at Waupun. Mortality rates were based on a synthesis of computed losses from a back-tagged sample and for the population as a whole. Annual and seasonal mortality rates from the hen segment at Waterloo will be compared with parallel rates at Waupun.

Annual Mortality

A comparison of mean fall-to-fall mortality rates between the population and the radio-equipped sample reveals favorable agreement (Table 9). Hen mortality averaged 73.9 percent per year for the population and 79.7 percent per year for the radioed

TABLE 8. Excerpt from Tabular Data Used to Compute Mortality Rates from the Radio-tagged Sample
Example: Juvenile Hens for Hunting Season with All Years Combined

Period		Total Hens Alive Onset of Period*	Total Mortalities During Period	Mortality Rate During Period (Percent)
October	16–20	77	1	1.29
	21–25	71	2	2.81
	26–30	65	2	3.07
November	30–4	59	4	6.77
	5–9	53	1	1.88
	10–14	50	3	6.00
	15–19	46	2	4.34
	20–24	44	0	0
	25–29	43	1	2.32
December	30–4	42	1	2.38
	5–9	40	0	0
	10–14	38	1	2.63
Cumulative sum				33.49
Average mortality rate (12 periods)				2.79
Standard error				0.60
Confidence limits (95%)				±1.32

	1.00−Average Mort. Rate	$(1.00-\text{Average Mort. Rate})^{12}$	$1.00-(1.00-\text{Average Mort. Rate})^{12}$	Mortality Rate Hunting Season
Average rate	.9721	.7120	.2880	28.8
Confidence limits (95 percent)	.959 – .985	.604 – .837	.163 – .396	16.3 – 39.6

*Total number hens alive at onset of period calculated by subtracting the number of hens lost from the sample in the previous period through mortality and/or radio failure.

TABLE 9. Comparison of the Annual Mortality Rates Between the Radio-equipped Sample and the Population as a Whole (Adult and Juvenile Hens Combined, 1968–1971)

Year (Oct. 1–Sept. 30)	Mortality Rate: Population	Mortality Rate: Radio-equipped Cohort (N = 201)
1967–1968	80.2	
1968–1969	60.6	80.3
1969–1970	78.4	76.1
1970–1971	76.3	82.8
Mean Annual Mortality Rate	73.9	79.7

cohort. Gates (1971:629) found fall-to-fall hen mortality to range between 65 and 89 percent with a mean annual rate of 75 percent for the period 1959-1964 on the Waupun Study Area. Earlier calculations of annual mortality for Wisconsin pheasant populations were based on winter-to-winter trapping data. These investigations by McCabe (1949) and Buss (1946) found yearly mortality to be roughly 70 percent for sex and age classes combined.

A comparison of annual mortality rates between juvenile and adult hens was possible with the radioed sample of birds (Table 10). Adult hens exhibited an average fall-to-fall death rate of 67.3 percent in contrast with 82.4 percent for juvenile females. Sample size was insufficient for a serious consideration of yearly trends; however, annual variation in mortality did not overlap between the age classes. Juvenile mortality was consistently high (80.3-85.4%), and adult death accordingly low (61.2-78.7%). Mean annual mortality was only slightly less among adults at 69 percent than juveniles at 74 percent for the Waupun hen population studied by Gates (1971:648).

The preceding annual mortality rates computed for 4 Wisconsin pheasant populations are among the highest reported in the literature. Leedy and Hicks ture(1945:83) developed an annual survival series for a hypothetical population of pheasants based on the results of all previous Ohio studies. Hen mortality showed no age class differential and totalled 63 percent per year. Mallette and Harper (1964) found mean annual mortality to be 60 percent from 6 years of study at Sutter Basin, a 68,000-acre area in the Sacramento Valley of California. Mortality rates were based on the returns of banded wild birds. Age differential mortality was identified with mean annual loss for juveniles of 65 percent and adults 58 percent. Hen hunting was permitted during 3 years (1955-57) of the 6 years (1952-58) of this investigation. Loss rates were compared under both hunting conditions and found to be similar. No survival advantage was awarded to adults by Stokes (1954:96), who determined mean annual mortality to be 47 percent for the Pelee Island hen pheasant population.

Seasonal Mortality

The determination of fall-to-spring and spring-to-fall mortality rates required annual estimates of the spring hen population in addition to the fall estimates already obtained. Spring hen estimates were based on a spring cock population estimate corrected for the winter sex ratio (Table 11). Winter sex ratio observations were obtained from roadside and flush counts during January and February. A spring census of cocks on the study area was accomplished by systematically triangulating each "crowing" cock during April and May. An average of 73 cocks and 548 hens were present on the 25-section study area each spring. A direct comparison was made between fall and spring hen estimates to determine fall-to-spring and spring-to-fall population mortality rates.

FALL-TO-SPRING MORTALITY. A comparison of mean fall-to-spring mortality rates between the hen population and the radio-equipped cohort reveals distinct disagreement (Table 12). Whereas the population at large realized a relatively low fall-to-spring death rate (35.3%), the radio-tagged sample experienced a comparatively high rate of loss (57.8%). Gates

TABLE 10. Comparison of Mortality Rates for Adult and Juvenile Hens, Radio-equipped 1968 to 1971*

Year (Oct. 1 to Sept. 30)	Mortality Rate Adults (N = 43)	Juveniles (N = 132)
1968–1969	78.7	81.5
1969–1970	61.2	80.3
1970–1971	61.9	85.4
Average Annual Mortality Rate	67.3	82.4

*Of 201 hens, 132 were classified juveniles, 43 were adults and 26 were not aged.

TABLE 11. Spring Hen Estimate from Spring Cock Population Corrected for Winter Sex Ratio

Year	Spring Cock Triangulation Count	Winter Sex Ratio	Spring Hen Estimate
1967	74	8.9	659
1968	69	7.5	517
1969	76	7.8	593
1970	74	5.3	392
1971	70	8.3	581
Averages	73	7.6	548

TABLE 12. Comparison of Fall-to-Spring Mortality Rates Between the Radio-equipped Sample and the Population as a Whole (Adult and Juvenile Hens Combined, 1968–1971)

Year (Oct. 1 to March 31)	Mortality Rate	
	Population	Radio-equipped Cohort
1968–1969	6.9	44.7
1969–1970	64.8	49.3
1970–1971	35.3	79.3
Mean Seasonal Mortality Rate	35.3	57.8

TABLE 13. Comparison of Spring-to-Fall Mortality Rates Between the Radio-equipped Sample and the Population as a Whole (Adult and Juvenile Hens Combined, 1968–1971)

Year (April 1 to Sept. 30)	Mortality Rate	
	Population	Radio-equipped Cohort
1968	70.4	43.9
1969	57.7	64.5
1970	38.5	52.8
1971	63.3	18.2
Mean Seasonal Mortality Rate	57.5	44.8

(1971:656) found fall-to-spring mortality to range between 36 and 73 percent and average 48 percent at Waupun. The mean seasonal mortality rate for the sample appears more consistent with Gates' findings than the companion population statistic.

Gates (1971:662) also demonstrated a correlation between trends in fall-to-spring (October 1-May 1) mortality and mortality during the winter segment. Winter mortality, in turn, was associated with the severity of winter weather with respect to snow accumulation and temperature. Gates used a winter hardness index to describe weather severity. A similar relationship was observed at Waterloo but discussion of this subject will be deferred to a later section. It is, however, important at this point to indicate that winter weather conditions were least severe in 1968-69 and became progressively worse through 1970-71. Looking again at Table 12, the parallel relationship of fall-to-spring mortality and winter weather was not demonstrated by the trend in population mortality rates, but was exhibited by the radio-tagged cohort.

Leedy and Hicks (1945:82) developed a schedule of seasonal losses by combining results from a series of Ohio studies and determined October 1 to April 1 hen mortality to total 38 percent. On the 9,000-acre Prairie Farm in Saginaw County, Michigan, Shick (1952:33, 88) provided prehunt and prenesting hen population estimates for the years 1939-1942. Calculated from the author's original data, fall-to-spring mortality for the 3-year period averaged 57 percent and ranged between 43 and 68 percent. These mortality values were comparable to those reported for the Waupun hen population and the radio-tagged sample at Waterloo. Anderson (1964) reported the highest fall-to-spring mortality rate in the literature, but it applied to a marginal pheasant population that was not self-sustaining. At the Neoga Study Area in Cumberland County, Illinois, Anderson determined hen mortality to be 72 percent for the years 1960-62.

Spring-to-Fall Mortality. A comparison of spring-to-fall mortality rates between the hen population and the radioed sample shows poor agreement. The mean spring-to-fall mortality rate for the population was 57.5 percent in contrast with 44.8 percent for the transmitter-equipped segment (Table 13). Gates (1971:656) found spring-to-fall (May 1 to October 1) mortality to fluctuate between 42 and 66 percent with a mean rate of 50 percent. Both the population and the radioed sample displayed a wider variance than exhibited by the hen population studied by Gates. However, average values compared favorably. Leedy and Hicks (1945:83) determined spring-to-fall (April 1 to September 30) hen mortality to total 42 percent based on previous investigations in Ohio.

Annual mortality rates agreed very well between the radio-equipped cohort and the population as a whole. However, the hen population experienced a lower fall-to-spring mortality rate and a higher spring-to-fall mortality rate. This could be the result of an inflated spring hen population estimate which would yield an apparent lower rate of fall-to-spring mortality and a higher rate of spring-to-fall loss. Three factors would result in an overestimate of the spring hen population: (1) a biased winter sex ratio too high to hens, (2) an exaggerated spring cock population estimate, and (3) a differential mortality of hens to cocks between the times that sex ratios were determined and the time of the spring census. Of these, the first and third are likely most strongly influencing the spring hen estimate at Waterloo. Gates (1971: 43,47) has summarized the biases associated with winter sex ratio counts and has also presented evidence for sex differential winter mortality. The biases associated with the spring hen population estimate discussed by Gates may also be acting to produce the wide ranging fall-to-spring (6.9 to 64.8%) and spring-to-fall (38.5 to 70.4%) population mortality rates.

It is not our desire to pursue the many aspects of associated biases of spring hen estimates but only to indicate their possible existence. The lack of agreement between fall-to-spring mortality rates does not necessarily prove that the radio-equipped hens survived less well over winter than the hens in the population at large. Likewise, it does not prove that the radioed cohort experienced higher survival from spring-to-fall than the hen population as a whole.

Sequence of Seasonal Mortality Rates for the Radio-tagged Sample

The seasonal importance of mortality can be further examined for the transmitter-equipped hens by combining juvenile and adult records for three seasons, reproductive, autumn and winter. The reproductive segment is defined as April 15 to August 27 and includes nesting and most of the brood-rearing activity. The autumn unit, August 28 to December 14, encompasses the period of fall dispersal and the hunting season. The periods of snow cover and early spring are bracketed by the winter segment which is December 15 to April 14. The segments are of roughly equal length; reproductive 134 days, autumn 108 days, and winter 120 days.

Mortality rates during the reproductive and winter segments were similar in importance and of greater magnitude than the autumn period (Table 14). However, in terms of total birds lost from the hen population, autumn is very significant in that the mortality rate applies to the period of highest population density. From a hypothetical population of 1,000 hens, 248 would be lost in autumn, 375 in the winter and 158 in the reproductive period.

An interesting relationship borne out by Table 14 is the compensating mortality rates between consecutive winter and reproductive periods. For example, winter mortality was least severe (32.1%) in 1968-69 while the rate of loss the following reproductive period was the most severe (62.9%) reported for all years. Conversely, when winter mortality was high (68.8%) in 1970-71, reproductive loss was low (18.2%). Winter and subsequent reproductive mortality were highly negatively correlated ($r = -0.99$) but this does not imply a casual relationship. Rather, the relationship may be coincidental and a function of independent environmental variables which influence pheasant mortality. These will be discussed under the Mortality Factors section. Gates (1971: 736) found poorer survival during a reproductive period following a severe winter. He hypothesized that winters with severe weather conditions (snow accumulation and temperature) not only took an immediate toll of birds, but weakened the physical condition of hens entering the reproductive period thereby reducing survival in this season also. Mechanisms of accelerated spring loss following more arduous winters were not identified by Gates but were believed to be stress related from weight loss during the period of snow cover.

Annual Pattern of Mortality Rates for the Radio-tagged Sample

To develop an annual pattern of mortality, 6 periods were designated: (1) hunting, (2) snow cover, (3) late winter, (4) nesting, (5) brood-rearing, and (6) post brood-rearing. Mortality rates were calculated for each for all years combined (Table 15). The period of hunting was defined as October 16 to December 14 and encompassed the actual season, which fluctuated between an opening date of October 18-30 and a closing date of November 23 to December 12. The period of snow cover was established as December 15 to February 18. During 1968, 1969, and 1970 the first significant accumulation of snow occurred on December 22 (3 inches), December 7 (5 inches) and December 11 (14 inches), respectively. Therefore December 15 seemed a reasonable compromise for the onset of snow cover.

TABLE 14. Seasonal Mortality Rates for All Hens Radio-equipped April, 1968 to September, 1971

Year	Seasons: Reproductive (April 15–August 27)	Autumn (August 28–December 14)	Winter (December 15–April 14)
1968	44.0	22.3	32.1
1969	62.9	18.9	48.8
1970	42.6	33.3	68.8
1971	18.2		
Mean Seasonal Mortality Rate	41.9	24.8	49.9

TABLE 15. Mortality Rates for Six Important Periods for 175 Hen Pheasants (All Ages and Years Combined)

Season	Avg. 5-day Mortality Rate	Seasonal Mortality Rate	Hypothetical Hen Population: Individuals Alive Onset	Individuals Alive Terminus	Individuals Lost During Season	Percent of Annual Loss
Hunting (Oct. 16–Dec. 14)	2.4	25.4	1,000	746	254	31.6
Snow cover (Dec. 15–Feb. 18)	3.7	38.7	746	457	289	35.9
Late winter (Feb. 19–Apr. 14)	2.2	21.4	457	359	98	12.2
Nesting (Apr. 15–June 28)	2.7	33.8	359	238	121	15.0
Brood-rearing (June 29–Aug. 27)	1.5	16.8	238	198	40	5.0
Post brood-rearing (Aug. 28–Oct. 15)	0.1	1.0	198	196	2	.2

Snow accumulation dropped to zero on February 18, February 28, and March 18 of years 1969, 1970 and 1971. The selection of February 18 as the terminal date for snow cover was reasonable for years 1969 and 1970 but early for 1971. The period of late winter, February 19 to April 14 is characterized by fluctuating snow depths (0-14 inches) and temperature. It is usually a distinct period between the critical phase of winter and the onset of breeding. Also, it is a time of dispersal from winter cover and of weight gain prior to the burden of the reproductive season. The period of nesting was fixed as April 15 to June 28. Dumke and Pils (unpubl.) have demonstrated by following the reproductive histories of 68 radio-tagged birds that April 15 would precede the onset of egg-laying at a nest for most hens. August brood observations have revealed that 80 percent of all successful clutches are hatched by June 28 (Woehler, unpubl.). The brood-rearing period, June 29 to August 27, encompasses the time of chick-rearing. In addition the physical impact of egg-laying has brought the hen to a low ebb in her annual weight cycle which is further compounded by the immediate demands of feather molt. The post brood-rearing period, August 28 to October 15, is characterized by gradual weight gain and the onset of fall dispersal.

The periods were necessarily of unequal length so 5-day mortality rates were provided for direct comparison in Table 15. The periods of snow cover and nesting rank first and second, respectively, when comparing the 5-day mortality rates (3.7 and 2.7%) and cumulative seasonal death rates (38.7 and 33.8%). Combined, they account for 50.9 percent of annual mortality, 35.9 percent occurring during snow cover and 15.0 percent during nesting. The 5-day mortality rate during the hunting season ranked third in importance, but applied to the largest annual population level and therefore accounted for 31.6 percent of annual mortality. The periods of brood-rearing and post brood-rearing are apparently of little consequence in terms of annual mortality.

Wagner (1957) presented circumstantial evidence for the existence of accelerated, annually varying, late summer mortality of adult hen pheasants. Furthermore, it was suggested that late summer mortality was linked to the physiological stresses of breeding and molt. The severity of stress during the breeding season appeared to be a function of the number of eggs laid. Kabat et al. (1956) demonstrated that the amount of weight lost during the laying period was dependent on the number of eggs produced. Annual variations in egg production resulted from fluctuations in the interval between egg-laying and the onset of actual nesting and the degree of nest destruction. Wagner found that mortality was high in years of late nesting and suggested it was due to the increased stress of larger numbers of eggs laid in those years. Therefore, yearly variations in nesting phenology ultimately determined annual variations in hen mortality through stress-related mortality during the late summer period. The actual factors causing death were not proposed by Wagner.

Dahlgren (1963:291) found late summer to be a period of high mortality for both sex classes in South Dakota based on rural mail carrier surveys and harvest statistics. The mechanisms of loss were not identified but stress-related mortality associated with the molt was suggested. Furthermore, spring-to-fall loss was found to constitute a majority of annual mortality. Although late summer was determined to be a period of high loss, a major share of the spring-to-fall mortality occurred in the spring-to-summer segment. With the exception of a few extreme variations in fall-to-spring mortality, this period was of little consequence in terms of annual mortality.

The existence of accelerated late summer mortality was not confirmed by this investigation nor by the research of Gates (1971) at Waupun. The sex and age data presented by Wagner et al. (1965:71,73) implied that fall-to-spring mortality was rather constant between years and that annual fluctuations in mortality were linked to the degree of variation in spring-to-fall loss. Gates (1971:747) found fall-to-spring mortality to be highly variable with winter isolated as the most significant period of accelerated, annually varying mortality. The principal determinant of annual fluctuations in survival was the severity of winter weather which indirectly influenced hen pheasant mortality. Variations in spring-to-fall mortality were detected but found to be a function of nesting season losses rather than mortality during the late summer months.

The findings at Waterloo concur with those of Gates in that winter was identified as the most important component of annual mortality. The summer periods of brood-rearing and post brood-rearing were least important in terms of annual mortality. However, it is reasonable to question whether an adequate sample of radio-tagged hens was present during these periods for survival determination since it was previously mentioned that the number of tagged birds decreases throughout the summer. To ascertain if a sufficient sample of birds was present during the summer months, the mean number of hens radio-equipped in each period was computed for all years combined (Table 16). The brood-rearing and post brood-rearing periods together average only slightly fewer birds than the period of snow cover. If mortality was considerably accelerated during the summer, an adequate sample of radio-tagged hens should have been available to demonstrate this phenomenon.

Table 10 demonstrated a disparity in annual mortality rates between juvenile and adult hen pheasants. Juvenile mortality averaged 82.4 percent per year while adult mortality averaged 67.3 percent. The cause of this survival variability was apparently not a function of accelerated juvenile mortality during a specific seasonal period (Table 17). Again, the 5-day mortality rates provide the best basis for comparison. Adult survival was consistently better during each period with the exception of late winter. Accelerated adult mortality during this period was significant enough to rank it second to the period of snow cover in terms of annual loss. No explanation for the apparent im-

TABLE 16. Number of Bird-days and Mean Number of Birds Radio-tagged by Season for 201 Hen Pheasants (All Years Combined)

Season	Season Length (days)	Bird-days*	Mean Number of Birds**
Hunting (Oct. 16–Dec. 14)	60	4,504	75.1
Snow cover (Dec. 15–Feb. 18)	65	2,980	46.6
Late winter (Feb. 19–Apr. 14)	55	3,333	60.6
Nesting (Apr. 15–June 28)	75	5,083	68.7
Brood-rearing (June 29–Aug. 27)	60	2,082	35.3
Post brood-rearing (Aug. 28–Oct. 15)	50	2,315	48.2
Totals	365	20,297	

*Computed daily and totalled by season.

**Formula: $\text{Mean Number of Birds} = \dfrac{\text{Bird days}}{\text{Season Length (days)}}$

TABLE 17. Mortality Rates for Radio-equipped Juvenile and Adult Hens During Six Periods (All Years Combined)

Season	Juvenile (N = 132) Avg. 5-day Mortality Rate	Seasonal Mortality Rate	Individuals Alive Onset	Individuals Alive Terminus	Individuals Lost During Season	Percent Annual Loss	Adults (N = 43) Avg. 5-day Mortality Rate	Seasonal Mortality Rate	Individuals Alive Onset	Individuals Alive Terminus	Individuals Lost During Season	Percent Annual Loss
Hunting (Oct. 16–Dec. 14)	2.8	28.8	1,000	712	288	34.6	1.2	13.7	1,000	863	137	20.5
Snow Cover (Dec. 15–Feb. 18)	4.1	42.1	712	412	300	36.0	2.1	24.3	863	653	210	31.5
Late Winter (Feb. 19–Apr. 14)	1.9	19.4	412	332	80	9.6	3.0	28.8	653	465	188	28.2
Nesting (Apr. 15–June 28)	3.0	37.2	332	208	124	14.9	1.5	20.8	465	368	97	14.5
Brood-rearing (June 29–Aug. 27)	1.8	19.3	208	169	39	4.7	0.8	9.5	368	333	35	5.2
Post Brood-rearing (Aug. 28–Oct. 15)	0.1	1.2	169	167	2	0.2	0.0	0.0	333	333	0	0.0

portance of late winter mortality of adult hens was available. It may simply be a function of the relatively small sample size (N=43).

The importance of the snow cover period for juvenile mortality is aptly demonstrated in Table 17. An average 5-day mortality rate of 4.1 percent for the juvenile cohort provided for a seasonal loss rate of 42.1 percent. On an annual basis, 36.0 percent of all losses occurred during the period of snow cover. Juvenile mortality accelerated again during the period of nesting with a seasonal loss of 37.2 percent. The loss rate applied to a relatively low population level and therefore accounted for only 14.9 percent of annual loss.

Age- and Weight-related Mortality

Juvenile hens equipped with radio transmitters during late September were 11 to 20 weeks of age. To determine if the older juveniles were experiencing a lower mortality rate, 77 fall-tagged young were segregated into two groups, 11-15 weeks (39 birds) and 16-20 weeks (38 birds). A comparison of mortality rates for the two groups between October 1 and February 8 (a date arbitrarily selected when 80 percent of the sample was lost to radio failure or mortality) reveals comparable mortality; 63.2 percent for the 11-15 week class and 66.1 percent for the 16-20 week group.

These same juvenile hens weighed between 695 and 1134 grams. To determine if the smaller birds were suffering a higher rate of mortality, the 77 individuals were divided above or below the mean weight of 850 grams. Roughly comparable mortality rates of 69.2 percent and 61.8 percent were computed for under and over 850 grams, respectively, for the period of October 1 to February 8.

Johnson (1971) placed 393 mock radios on pen-reared cock pheasants to test the effects of a 28-gram transmitter on pheasant survival. The radioed cocks were released with 392 leg-banded roosters in Watonwan County, Minnesota prior to the 1968 and 1970 hunting seasons. Roughly, 25 percent of both the radioed and non-radioed cocks were recovered, primarily through weekend bag checks. One of the conclusions of this report was that radio-tagged pheasants over 850 grams survived better than birds under 850 grams. Among the leg-banded cohort, cocks over 793 grams survived better than roosters under 793 grams.

Stokes (1954:112) examined survival of cocks and hens captured during the summer and recovered at the hunting season. Median weights for both sexes were determined daily during the trapping period. Birds were segregated above or below this weight and termed heavy or light. Recovery of heavy cocks was 13 percent greater than light cocks. Likewise, heavy hens were recovered at a level 10 percent greater than light hens. Stokes speculated that food shortage, disease or congenital weakness may have contributed to poorer survival among the smaller birds.

The conclusions of Hessler (1968) on survival advantage for heavier birds did not concur with those of Johnson (1971) and Stokes (1954). Based on the release of 74 sub-adult radio-tagged pheasants (39 cocks, 35 hens) that were monitored up to 28 days, survival of hens below the median weight at release was significantly better than females above the median value. No survival advantage was awarded to either heavier or lighter cocks. Hessler could offer no explanation for the better survival of smaller hens; however, it could be a function of the small sample size. The findings of Johnson (1971) and Hessler (1968) are based on the release and subsequent recovery of game farm birds and are not as directly comparable with ours as Stokes (1954) who evaluated survival of wild-trapped birds.

Summary

Annual and seasonal mortality rates were calculated for the population of hen pheasants at Waterloo from sex and age data and for the radio-tagged sample from exponential expansion of 5-day mortality rates. Fatality rates for the radio-equipped cohort were based on the histories of 201 hen pheasants which provided a collection of 105 mortality records.

Mean annual mortality for the population was 73.9 percent as compared with 79.7 percent for the radioed sample. General agreement of annual mortality rates between the population and the radio-tagged sample adds credibility to the subsequent analysis of mortality factors that is based exclusively on the sample. Among the radio-tagged cohort, age differential mortality existed with adults experiencing a 67.3 percent annual mortality rate and juveniles an 82.4 percent yearly loss.

Fall-to-spring (October 1-March 31) mortality for the hen population averaged 35.3 percent in contrast to 57.8 percent for the radio-tagged sample. Mean spring-to-fall (April 1-September 30) loss for the hen population was 57.5 percent and 44.8 percent for the radio-equipped hens. A comparison of fall-to-spring with spring-to-fall mortality rates for the hen population reveals the spring-to-fall segment to be the most important component of annual mortality. The opposite pattern was demonstrated by the radio-tagged cohort and was in agreement with the findings of Gates (1971).

MORTALITY FACTORS

The main thrust of this investigation was to identify specific causes of pheasant mortality and to assess their relative importance on a seasonal and annual basis. The previous discussion of mortality rates was presented to provide a qualitative basis for analysis of data on mortality factors presented in this section. With the necessary background information now provided, we can proceed to a discussion of the principal findings of this investigation.

Evaluation of Mortality Data

The interpretation of field evidence at a mortality site is very complex. The elapsed time between death and recovery of the mortality victim is of critical importance. The influences of weather and scavenging on the remains are uncertain when the elapsed time is unknown.

Radio telemetry permitted shortening of the time lapse between death and discovery of the mortality victim by daily monitoring of the transmitter-equipped birds.

Mortality was initially suggested by a combination of factors including inactivity, a departure from the bird's usual behavior pattern, and the radio-location of the individual. Early in the investigation the incorporation of a thermistor in the radio circuit was considered. The thermistor would have altered the pulse rate of the signal proportionate to body temperature of the bird, thus facilitating rapid determination of whether a bird was dead or alive. However, this feature turned out to be unnecessary, since it became apparent that pheasants were active during the daytime hours throughout the year and modulations of the signal due to movement of the radio-tagged individuals would adequately serve the same purpose.

There were exceptions to daylight, year around activity and in these examples a knowledge of the bird's behavior became important. Experience demonstrated that 2-3 checks daily rarely detected activity among incubating hens. However, knowledge that the hen was nesting at a particular site was always discovered during the egg-laying stage, so inactivity at that location was anticipated. If death occurred during incubation with the carcass remaining at the nest site, mortality was not suspected until the calculated date of hatch was reached and no corresponding activity was detected.

Inactivity was also noted during extremely cold temperatures or blizzard conditions when the birds sought dense shrub carr or conifer cover for shelter. Radio-tagged birds were rarely disturbed under these weather conditions, and occasionally mortalities were not investigated within 24 hours of death.

The location of an inactive bird was also very important. If the radio-location fell within the previous pattern of the individual's movements, suspicion of mortality was not as great as when locations fell outside the bird's established home range. Proximity of the inactive locations to fox dens or raptor nests was usually cause for prompt investigation.

In summary, the key factor in identifying potential mortality victims was inactivity as detected by the absence of modulations of the radio signal. However, not all motionless birds were dead and the decision to approach the bird was resolved by the individual's prior activity patterns.

Roughly 65 percent of the 105 hen mortalities were discovered on the day or day after death occurred. Furthermore, most mortality occurred during the nocturnal or crepuscular hours, and the elapsed time between death and discovery was less than 18 hours in a majority of cases.

The influence of weather on field sign was generally negative, that is, it obliterated field evidence but occasionally it was beneficial in evaluating the mortality. Snow and rain served to help determine the time of death in conjunction with the telemetry data. The mortality histories of Hens 107 and 201 demonstrate how weather and telemetry data can be integrated to determine the time and cause-of-death.

Hen 107 had just begun to incubate her clutch of 19 eggs on June 6, 1969, when her transmitter expired. On June 9, the hayfield nest was examined. Numerous feathers were found at the nest bowl and 10 feet away along a brushy fenceline. A thorough search of the area failed to disclose the transmitter or carcass. The condition of the feathers indicated that they had not been rain soaked. Since the last rain shower occurred on the evening of June 7, it was theorized that the transmitter failed on June 5 but the hen was not preyed upon until after the rain of June 7. The sign appeared relatively "fresh". A small portion of skin clinging to one of the feather clusters was still rather moist. The mortality was dated June 8 with the cause-of-death listed as undetermined predator.

Hen 201 had moved 2 miles off the study area prior to her death on December 24, 1970. On December 21 she was located and monitored as being active. Access to the area of her activities was very poor and she could not be found on December 22. She was relocated on December 23 but her signal was so weak that activity could not be accurately determined. Early on December 24 she was approached with portable receiving gear. Numerous breast and wing feathers and the transmitter were found under ½ inch of light snow. The feathers and transmitter showed extensive chewing with tooth marks evident on feather shafts and the radio harness. Numerous fox tracks, urine and a fox scat were found with the remains and likewise covered with a dusting of snow. The urine was 18 inches from the transmitter and the scat was at one of the feather piles. The remains were found in a shallow ditch above 9 inches of snow. Scattered canary grass clumps and willow brush typified this depression, which was bordered by unpicked corn and a small shrub carr unit. The dusting of snow, which occurred on December 23, covered the evidence and aged the kill before that date.

Since signal range drops significantly when the transmitter is lying on the ground, this was the probable reason radio contact could not be made with the hen on December 22. Death by fox predation likely occurred on the evening of December 21.

Hen 107 was killed at her nest; therefore, evidence used to determine cause-of-death came from the "kill-site". If the field sign suggested the location of the remains to be the actual site at which the kill was made, predation was implicated with a fair degree of confidence. If however, as in the case of Hen 201, the evidence indicated the location to be a "feeding site" (site of feeding on the carcass apart from the kill site) the question of whether the remains represented predation or scavenging had to be answered. For example, Hen 201 may have been killed by highway traffic and carried to the site where the transmitter and remains were found. This was not likely since her remains were found within a 20-acre area encompassed by her movements since mid-November and ¾-1 mile from the nearest highway. Death caused by weather, disease, gunshot or a flight accident were also unlikely but not above suspicion. An element of doubt always existed whenever cause-of-death determination was based on "feeding site" evidence.

To gain an appreciation for the mechanics of scavenging, 49 pheasant carcasses were placed throughout the study area in various cover types. The most important objectives of this test were to identify field sign characteristic of scavenging and to document the time lapse between disposal and the onset of scavenging activity. This endeavor was undertaken during the fall of 1970 after scavenging activity had not been specifically identified among 50 mortalities of radioed birds involving mammalian or avian feeding on the remains. All 50 mortalities were believed to represent true predation and not scavenging. A majority of these cases involved an evaluation of evidence at a feeding site rather than kill site.

Virtually every carcass was placed in a different situation with respect to cover type and location within cover types. The frozen carcasses were thawed and handled with gloves prior to use in this experiment. The birds were deposited by approaching to within 15 feet of the desired location and tossing the carcass to the drop site. Some birds remained atop the vegetation while others fell through and were concealed by the plant material. An examination of the carcasses followed at random intervals commencing 2 days after deposit and continuing for 19 days. On these subsequent examinations the birds were approached to about 5 feet. Only if the carcass was not intact was a further examination undertaken. Twenty-two carcasses were deposited in November, 1970 and 27 in May and June, 1971. The fall and spring samples were grouped for analysis.

Of the 49 pheasant carcasses deposited on the study area, 29 (59.2%) were still intact after 3 days (Table 18). Ten additional carcasses were disturbed by rodents, insects, crows and medium-sized mammals (skunk-opossum size). Therefore, only about 20 percent of the 49 carcasses were located by large scavengers after 3 days in the field. Roughly 85 percent of all mortalities to radio-tagged birds were discovered before three days had lapsed since death.

Grondahl (1958) placed 71 dead pheasants on a 5-section study area in Bowman County, North Dakota. The birds were placed in 11 groups of 3-10 individuals between April and June. Drop sites were revisited 1-11 days after depositing the carcass. Twenty-one of the 71 carcasses were checked within 3 days, and 13 were found to be missing, 8 were intact. Apparently, the large scavengers (those capable of carrying the carcass away) on the Bowman Study Area were encountering the carcasses considerably sooner than their counterparts at Waterloo.

Grondahl (1958) reported 4 cases of scavenging by beetles and a few other examples of partially eaten carcasses where no attempt was made to identify the species of scavenger. Scavenging by mice, shrews, carrion beetles, crows, weasels and unidentified medium-sized mammals (opossum, skunk) was documented in this investigation. The field sign left by these scavengers is very distinctive from that observed at the remains of radio-tagged pheasants whose deaths were attributed to fox, hawks and owls. Scavenging by hawks and owls was not reported among the carcasses that remained at the drop sites and were partially consumed. However, scavenging by raptors may have been represented among the sample of birds that disappeared from the deposit site.

Carcasses deposited along ditchbanks, roadsides, and fencelines were the first to be

TABLE 18. Fates of 49 Pheasant Carcasses Placed Throughout the Study Area to Document the Mechanics of Scavenging

Day Carcass Checked After Disposal	Sample Size*	Condition of Carcass: Missing**	Partially Consumed: Rodent/Insect	Med. Mammal[1]	Lg. Mammal	Crow	Intact	Percent of Carcasses From Original Sample Remaining Intact
Third	49	8	3	6	2	1	29	59.2
Sixth	33	6	10	5	1	2	9	18.4
Ninth	11	1	2	2	0	2	4	8.2

*Sample size is number of intact and nearly intact carcasses remaining from previous period.
**Likely in most cases the carcass was carried off by a large scavenger (fox-dog). Human interference may be involved but was not detected in any of the cases.
[1]Category includes skunk-opossum sized species.

discovered by the large scavengers. Whereas about 12 percent of the carcasses were placed in strip cover in this investigation, roughly 56 percent of the dead pheasants were deposited in this cover type by Grondahl (1958). This may partially explain the higher rate of encounter of carcasses by large scavengers on the Bowman Study Area.

Probably the most complex cause-of-death analysis which involved a distinction between predation and scavenging evidence concerned the death of Hen 1. Her transmitter was accidentally found along a town road on September 11, 1969 after it had ceased functioning on August 29. The radio was badly damaged with portions of the dental acrylic broken off and indentations evident on the crystal case. Tooth marks were found on tape on the transmitter package and on the harness wires. The antenna wire was kinked in two places 1¾ inches apart. Harness wires were intact, and the knot used to join them was still tied. Two small back feathers were found stuck to the transmitter package. The condition of the transmitter was characteristic of that observed in examples of mammalian predation. However, the transmitter was located on the road and initial suspicion pointed to highway traffic as the mortality factor followed by scavenging. The harness wires were intact and the transmitter could only have been removed from the bird by severing one or both of its wings. If the transmitter was removed from the bird at the roadside, wing feathers should have been present. A search of the roadside ditch in the immediate vicinity of the transmitter revealed no other remains. If the hen were killed by highway traffic, the scavenger would had to have carried the carcass elsewhere to remove the transmitter and then return it to the road. It seemed equally logical that a predator could have killed the hen anywhere in the vicinity of the road and subsequently dropped the radio on the road. It was common practice for mammalian predators to remove the transmitter from the bird and drop the unit most anywhere. The extensive damage to the transmitter could have been caused by the impact of a vehicle or by a large predator or scavenger; in either case it was an unusual happening. The dental acrylic resisted damage by the agents of mortality in a vast majority of cases. Indentation of the crystal case appeared to have been caused by chewing and was the cause for radio failure. Therefore on August 29, when radio contact was lost with the hen, the predator or scavenger had already damaged the radio. The bird was monitored as active on the afternoon of August 28. If a factor other than predation caused death, the scavenger that fed on the carcass and damaged the radio would had to have encountered the dead hen almost immediately. The investigator believed predation was the more probable mortality factor and August 29, the date on which it occurred.

Sources of Mortality Data

Mortality data on 105 radio-tagged hen pheasants came from 3 sources — project personnel (93), hunters (8) and study area residents (4). Four project personnel had occasion to evaluate field evidence and determine cause-of-death. Observer bias inherent in the interpretation of field sign could only be minimized. Evidence available at the site of a mortality victim was collected and examined in the laboratory. Photographs were often taken of the mortality site but occasionally only of the remains. Most mortalities were discussed among the authors' colleagues, and a consensus of opinion on the mortality factor usually resulted. However, the ultimate determination of the mortality factor fell on the person who discovered the dead bird and had first-hand account of the available evidence.

Rewards were paid to non-project personnel for the return of leg bands ($2.00) and the transmitter ($3.00). Most landowners on the study area were aware of the reward system and were encouraged to examine pheasant carcasses encountered during routine farming activities. Despite this awareness, only 4 residents provided information on pheasant mortalities. These cases involved death by highway traffic, hay mower, gunshot, and predation.

Hunters recovered 8 radio-equipped hens of which 4 were victims of gunshot, 2 were killed by hunters' dogs and 2 were lost to predation. Two of the hens that were killed by gunshot were returned by the hunters who shot them, but in one of these cases the hen had developed partial cock plumage.

Relative Importance of the Mortality Factors

Of the 105 hen mortalities investigated between April, 1968 and September, 1971, 11 lacked sufficient field sign for the determination of cause-of-death. Predation accounted for 80.8 percent of the remaining 94 mortalities that were classified (Table 19). Relegated to lesser importance were deaths by gunshot (7.4%), hay mower (5.3%), highway traffic (2.1%), hunters' dog (2.1%) and winter weather (2.1%).

Gates (1971:679,726) has identified and assessed relative importance to mortality factors operating on a pheasant population near Waupun. A comparison of the seasonal importance of the various causes of death between the Waupun and Waterloo investigations can be found in Table 20. Predation was identified by both studies to be the most important mortality factor during the fall-to-spring period. However, predation was much more significant at Waterloo where it accounted for 78.6 percent of all losses than at Waupun where it totalled only 49.1 percent of fall-to-spring mortality. Deaths by illegal shooting at Waterloo and Waupun were 12.5 percent and 23.2

percent, respectively, ranking this factor second in importance on both areas during the fall-to-spring period.

During the spring-to-fall period, predation remained the most important mortality factor at Waterloo, while hay mowing was the leading cause of death at Waupun. However, Gates (1971:726) reported "unexplained losses" in the spring totalling 35 percent of all mortality and indicated predation may have comprised a large share of these losses since deaths due to agricultural operations, highway traffic and miscellaneous factors were not grossly underestimated. Nonetheless, only 18.2 percent of spring-to-fall loss at Waupun was attributed to predation as compared with 84.2 percent at Waterloo. Hay mowing accounted for 13.2 percent and 52.2 percent of spring-to-fall loss at Waterloo and Waupun, respectively.

Annual Pattern of Mortality Factors

The annual pattern of mortality factors shows predation to be important throughout the year (Fig. 3). It was the only identified cause-of-death for the brood-rearing, post brood-rearing and late winter periods. Certainly, highway traffic takes birds during these seasons, but death by this factor for the radio-tagged sample was only reported for the periods of snow cover and nesting. Likewise, hay mowing mortality must occur during the brood-rearing period, yet it was not documented among the radioed cohort in this study.

One might question whether all of the mortality factors were identified. Gates (1971), Randall (1940), Wagner et al. (1965) and others have reported losses to farm machinery other than hay mowers, to railroad trains and to miscellaneous types of flight accidents. Flight accidents among untagged birds were observed at Waterloo. Also hen mortality due to pea-picking machinery was reported by a study area resident. These miscellaneous accidents likely account for a small but as yet undetermined fraction of annual mortality.

Disease was not identified as a mortality factor although gape worm was noted among radio-tagged birds. A few hens were found dead with no apparent cause-of-death. A necropsy of each of these intact carcasses

TABLE 19. Mortality Factors of Radio-equipped Pheasant Hens, April 1968 to September 1971

Cause of Death	Number of Individuals		Percent of "Known" Causes of Death	
Predation	76		80.8	
Mammalian		46		48.9
Avian		19		20.2
Undetermined		11		11.7
Other Causes	18		19.2	
Gunshot		7		7.4
Hay mower		5		5.3
Highway traffic		2		2.1
Hunter's dog*		2		2.1
Winter weather		2		2.1
Unknown	11			
Total	105		100.0	

*The category "hunter's dog" has been designated to represent mortalities of hen pheasants by dogs accompanying hunters in contrast to dogs hunting independently or in packs. This category includes hunters and dogs not residing on the study area. Examples of predation by local farm dogs or feral dogs have been categorized as mammalian predation.

TABLE 20. Percentage Comparison of the Relative Importance of the Various Mortality Factors of Hen Pheasants Between the Waupun and Waterloo Study Areas During the Fall-to-Spring and Spring-to-Fall Periods*

	Fall-to-Spring Period		Spring-to-Fall Period	
Cause of Death	Waupun**	Waterloo	Waupun[1]	Waterloo
Predation	49.1	78.6	18.2	84.2
Illegal shooting	23.2	12.5		
Legal shooting[2]	4.4			
Highway traffic	16.9	1.8	15.1	2.6
Hay mower			52.2	13.2
Other farm machinery	0.2		9.9	
Winter weather	2.0	3.6		
Miscellaneous[3]	4.1	3.6	4.6	
Seasonal Mortality Rate	51.6	57.8	50.0	44.8

*Fall-to-spring refers to October 1 to May 1 for Waupun data and October 1 to March 31 for Waterloo statistics. Spring-to-fall refers to May 1 to October 1 for Waupun data and April 1 to September 30 for Waterloo statistics.

**Gates (1971:679).

[1]Gates (1971:726).

Figures for Waupun Study Area recalculated from author's table (Gates 1971:726) to exclude "unexplained" category. Gates indicated only predation could have comprised an appreciable fraction of the unexplained total since hens lost to agricultural operations, highway traffic and miscellaneous factors were not believed to be grossly under-estimated. The unexplained losses constituted 35.2 percent of all mortalities during this period and could conceivably have altered significantly the relative importance of predation.

[2]Gates (1971) reported legal harvest of hens at licensed shooting preserves at Waupun.

[3]Miscellaneous category includes hens killed by farm dogs and in flight accidents.

failed to identify a serious disease among any of them. Shick (1952:71) reported no evidence of any disease including coccidiosis or gape worm among pheasants in a 3-year study on the Prairie Farm in Michigan. Stokes (1954:102) found no sickly birds in 3 years of trapping on Pelee Island where prehunt pheasant density exceeded 2,300 birds per section.

Predation

In public discussions of wildlife, no topic is more controversial than predator-prey relationships. The subject is often discussed with more emotion than biological facts. Numerous special-interest groups surround the controversy. One faction argues for complete protection of the predators on the premise of their esthetic and "balance of nature" values. Another segment, near the opposite end of the spectrum, argues that predators must be eliminated so the more "favored" wildlife can be fostered for man's enjoyment. Obviously neither view is totally acceptable, but where between these divergent opinions is the compromise to be made? Future research should clarify this enigma. The intent of this section is not to proclaim predator control or protection but to simply add a small increment to our knowledge of predator-prey relationships. The influence of weather on predation, particularly during the winter and spring, will be explored as will the relationship of pheasant nesting on levels of predation. Predator-prey ratios and the impact of various predators on pheasant abundance will also be discussed.

Predation was determined as the cause-of-death in 76 mortalities of radio-equipped hens, including 46 (60.5%) attributable to mammalian predators, 19 (25.0%) to avian predators and 11 (14.5%) unclassified (Table 19). A publication by Einarsen (1956) formed a partial basis for interpretation of field sign among losses to predation. Einarsen described the manner of attack and feeding habits of the major avian and mammalian predators in the Pacific Northwest including the great horned owl, the red-tailed hawk, the red fox, and the house cat which are commonly found at Waterloo. Integrated with the interpretations of Einarsen were the experiences in evaluating field sign by J. M. Gates, F. N. Hamerstrom, Jr. and Frances Hamerstrom, all formerly of the Wisconsin Department of Natural Resources, and T. H. Nicholls, North Central Forest Experiment Station, St. Paul, Minnesota.

The distinction between mammalian and avian predation was moderately easy, but within these categories species designation was considerably more difficult. Chewed transmitter packages or feathers regularly provided for the distinction between mammalian and avian predation in cases where little other evidence was found. Mammals generally consumed flesh and bones, whereas raptors stripped meat from the bones leaving most of the skeleton. Numerous descriptions of pheasant remains will be integrated into the subsequent discussion of predation to illustrate the various feeding patterns observed in this investigation.

Gates (1971:683) classified 194 cases of winter predation from 7 years of study at Waupun. Avian predators accounted for 49 percent of winter losses while mammalian counterparts took 34 percent. However, Gates suspected that the proportion allotted to raptors was overestimated since kill remains were less often cached or carried off, and therefore were more likely encountered in the field. At Waterloo, avian predation accelerated during the period of snow cover but did not surpass mammalian predation in importance. Avian and mammalian predators accounted for 36 and 48 percent, respectively, of winter losses to predation. In both investigations 16 percent of winter predation was classified "undetermined predator".

Shick (1952:72) classified 214 pheasant kills found between January, 1940 and January, 1942 on the Prairie Farm in Saginaw County, Michigan. This sample was composed of both partially and fully grown birds of both sexes. Statistics cited previously from the Waupun and Waterloo studies refer exclusively to fully grown hens. On the Prairie Farm, raptors accounted for 38 percent of annual predation as compared with 36 percent for mammals. The importance of avian predation was due primarily to the impact of marsh hawks on young pheasants. Shick found that crows often located dead birds before the investigators and disguised the true mortality factor. Therefore, 25 percent of suspected predation at the Prairie Farm went unclassified as to a category of predation.

Mammalian Predation

Mammalian predation accounted for 48.9 percent of annual mortality and represented the single most important decimating factor. Within the category of mammalian predation, species designation was only possible in 20 of the 46 cases on file. The field sign present at the site of mammalian predation varied from a few feathers to a portion of the carcass with tracks or other incriminating evidence (Table 21). In 16 of the 46 cases (34.8%) only a few feathers were found with the transmitter. The site at which meager remains such as this were found usually represented neither a kill nor a feeding location. Instead, it represented an intermediate point where the predator stopped to intentionally remove the transmitter. The remains of Hen 49 are typical of mortalities in this classification.

Hen 49 was associated with the canary grass-brush marsh complex on Stoney Island prior to her death on November 14, 1968. Numerous feathers and the right wing were the only remains found with the transmitter in nettle cover under a canopy of mixed hardwoods. The harness system was intact, the carcass apparently removed by severing the right wing

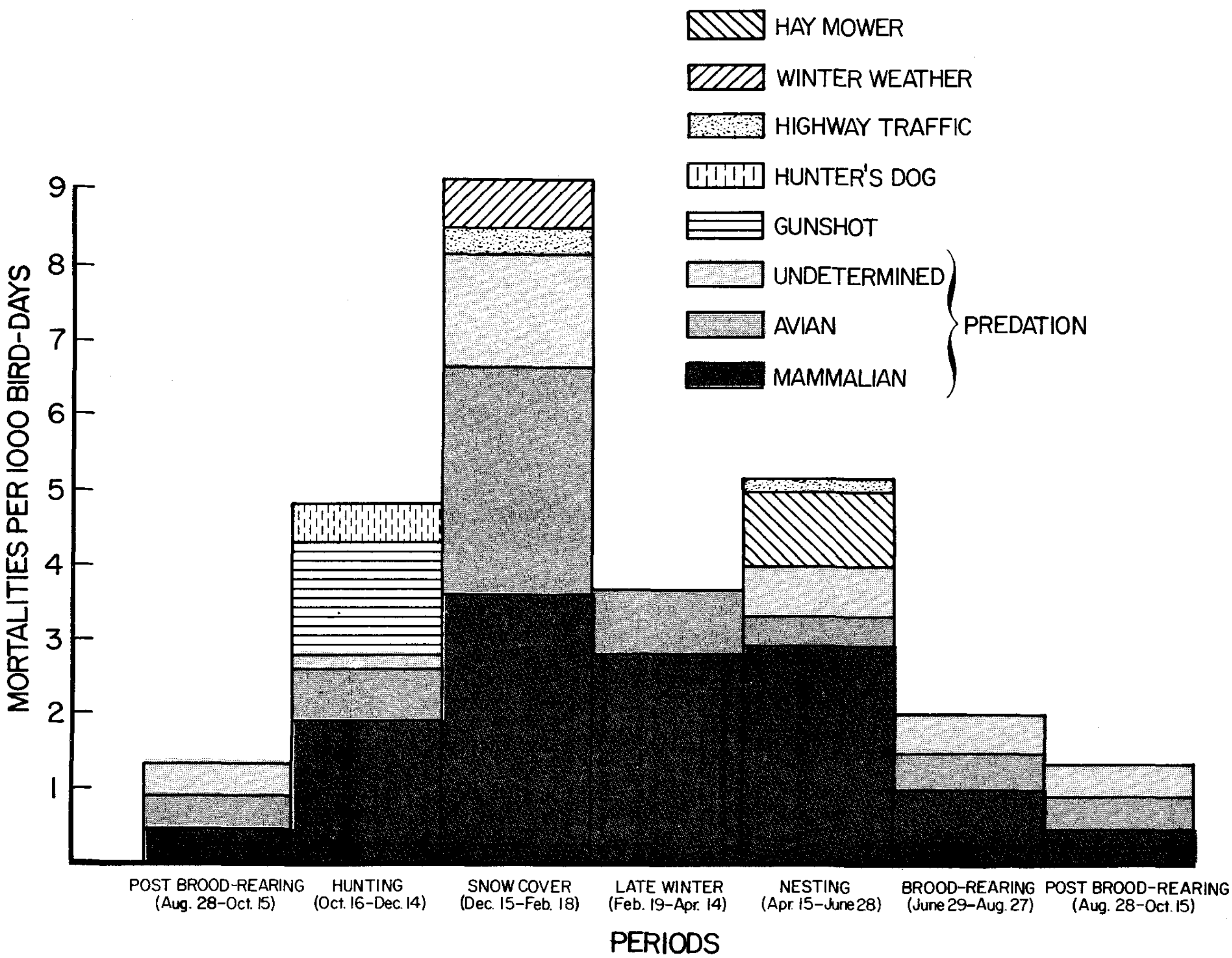


FIGURE 3. *Annual pattern of mortality factors at Waterloo.*

TABLE 21. Some Evidence Present at the Site of Mammalian Predation

	Category of Mammalian Predation						
Evidence with Transmitter	Fox	Large Mammal	Unknown Mammal	Dog	Raccoon	Mink	TOTAL
Feathers (usually breast and/or wing)		1	15				16
Feathers, bones and some flesh		2	1				3
Feathers and tracks	3	2					5
Fair portion of carcass			2				2
Portion of carcass and tracks	3	1		1			5
Portion of carcass cached	4	1	1				6
Portion of carcass cached and tracks	5						5
Portion of carcass at den	1				1	1	3
Carcass observed in possession of predator				1			1
TOTAL	16	7	19	2	1	1	46

and slipping the transmitter over the head and left wing.

In the case of Hen 49, the entire wing was found with the transmitter. More often the fleshy portion of the wing was consumed leaving only the primary and occasionally secondary flight feathers with the transmitter. No tooth marks were evident on the harness or transmitter tape in the case of Hen 49. This was typical, but chewing of the harness did occur as in the case of Hen 213.

Hen 213 was associated with the Abendroth Marsh prior to her death on March 29, 1971. A few breast feathers and wing coverts were found with the extensively chewed transmitter in a 35-acre cornfield. The corn remained unpicked from last year and provided a food source for about 80 pheasants during the winter. Numerous tooth marks were evident on the harness, and it was severed in 3 places. The antenna wire was stripped of its protective cover and kinked at 4 sites.

It remains unknown if Hen 213's transmitter was removed elsewhere and carried to this site with a mouthful of feathers or if the transmitter was actually removed at this site and all fleshy portions carried off. In the case of Hen 1, discussed earlier, the transmitter was thought to have been dropped by the predator along the road where it was eventually found. Other examples similar to Hen 213 and Hen 1 will be analyzed in the section covering unclassified predation.

Relative Importance of Various Categories of Mammalian Predation. Species determination was only possible when a portion of the carcass or incriminating evidence such as tracks or scats were present. The fox was implicated in 16 of the 46 cases (34.8%) of mammalian predation (Table 21). In 9 of these examples the carcass was cached. Sargeant (pers. comm.) has demonstrated that fox will rarely waste a kill, and if flesh remains on the carcass after hunger is satisfied the kill will be cached. Carcasses were stored in earthen and snow graves as typified by the mortality histories of Hens 146 and 253.

Hen 146 was associated with the moderately farmed Draeger area prior to her death on December 16, 1969. The carcass was found buried under 4 inches of snow in the center of a plowed field. Most of the flesh was consumed from the breast; the head and right leg were missing. Tooth marks were evident on the harness and antenna cover. Fox tracks were present at the cache site. Apparently the fox proceeded directly to the burial site from the field border and returned by the same route. He did not meander in search of the site to cache the remains.

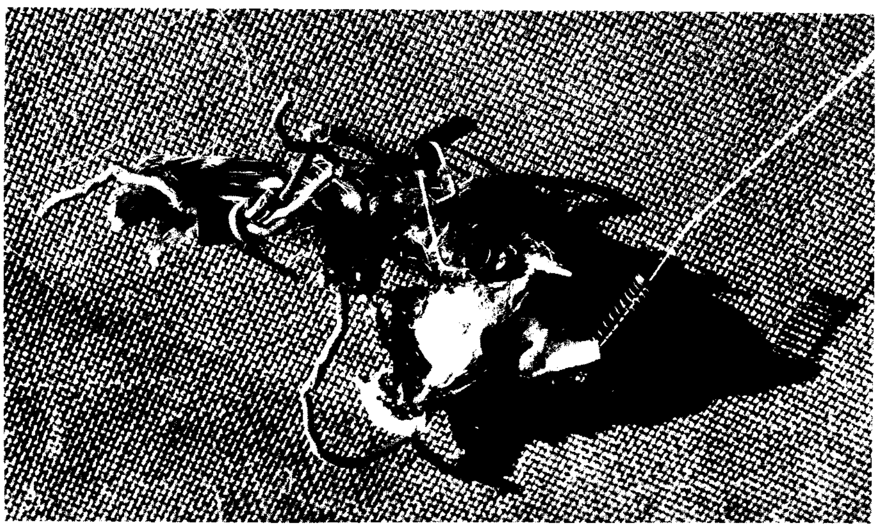
Hen 253 was thought to be egg-laying on the edge of the Draeger Woodlot in the southwest unit prior to her death on May 8, 1971. She had been visiting a site along the east edge of the woodlot for about 3 days, but a nest bowl was not found. The carcass, about 50 percent consumed, was found freshly cached in a grain field ⅜ mile south of the suspected nest site. The left leg, head, viscera and most of the back and right wing were missing. Flesh was removed from the right leg, left wing and a portion of the breast. Fox tracks were evident in the newly planted oats field. Adjacent to the new seeding was a hayfield and bordering both was a brushy cattle lane. The fox carried the carcass along the oats-hay edge until he was 15 feet from the cattle lane at which time he proceeded 10 feet into the new seeding and cached the remains under 3 inches of dirt.

Most of the flesh was missing in the examples of fox predation where the carcass was cached. Feeding patterns and methods of caching the remains described in the two cases above were typical of other examples in this category.

The category "large mammals" was designated to include cases where either dog or fox predation was involved (Table 21). Tracks were present at 3 of 7 examples in this category, but the characteristic pad impressions of the two species were not distinguishable. This often happened in snow as exemplified by the mortality history of Hen 201 (described page 22). In that case, a scat was present in addition to the tracks and a fox was implicated as the mortality factor. Similar incriminating evidence was not present in the case of Hen 153.

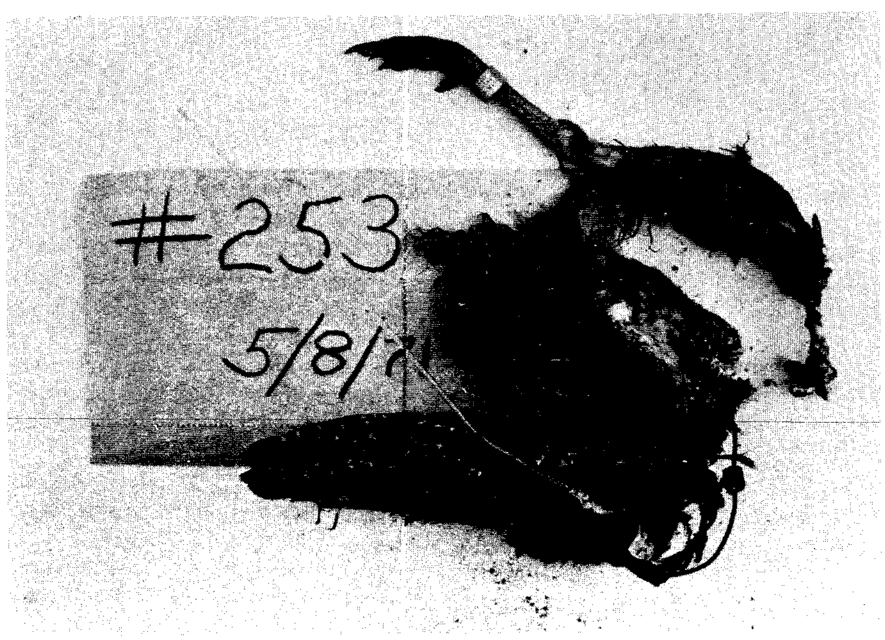
Hen 153 was associated with the Klecker Shrub Carr prior to her death on January 18, 1970. She was lost during a period of severe weather when temperatures dropped to −15 F and snow depths averaged 16 inches. The carcass was cached in a snow-covered cornfield adjacent to shrub carr. Tracks at the burial site were fox-size but dusted with a fresh layer of snow. The characteristic pad impression of the fox could not be detected. Nearby fresh fox tracks and urine were found.

The category "unknown mammal" accounted for 41.3 percent of loss attributed to mammalian predation and included a large share of the examples where little evidence was available (Table 21). The mortality his-



Extensively chewed transmitter similar to that described for Hen 213


Hen 146 found cached in snow: fox predation



Hen 253 found cached in oats field: fox predation

tories of Hens 49 and 213 were cited previously (page 28) to illustrate the limited evidence characteristic of mortalities in this classification. However, this category also included some unusual patterns of feeding that were observed only once and could not be assigned to a species of mammalian predator. For example, Hen 121 is suspected to have been preyed upon by a medium-sized mammal (cat, mink) incapable of crushing heavy bones thus leaving evidence superficially identical to that ascribed to raptors. No distinctive incriminating evidence could be found so the predation was classified as "unknown mammal".

Hen 121 was associated with the Dunneisen Marsh prior to her death on October 22, 1969. The partially consumed carcass was found amidst flattened sedge and canary grass. Femoral and humeral bones were broken but loosely attached to the body. Most flesh from the appendages and body were consumed; the viscera, head and neck were missing. The unusual evidence in this case was the chewing of the toes of both feet. Small indentations on the harness and transmitter tape were also believed to be tooth marks.

Despite the similarity with raptor evidence, the case of Hen 121 was thought to represent predation by a medium-sized mammal. This broad category included the cat, mink, small dog, raccoon and badger all of which were common at Waterloo but apparently took so few birds that their feeding patterns could not be assessed. Two mortalities were attributed to dogs and one case each to mink and raccoon. One of the hens lost to dog predation was incubating a clutch of eggs when she was killed on June 13. The dog carried the freshly killed hen home and the resident turned in the carcass for a reward. The second hen killed by a dog was lost during the severe winter period of 1970 when evening temperatures dropped to —10 F and snow depths averaged 14 inches. Numerous dog tracks were evident at the cache site where only one leg and a wing were found with the transmitter.

The raccoon and mink predations are very distinctive and deserve to be cited as mortality histories. Hen 136 was lost to a raccoon and 217 to a mink.

Hen 136 had been moving extensively during April, but her day-to-day movements had stabilized just prior to her death on May 2, 1970. Nesting behavior had not been detected, however. Her remains were found scattered in and around a decaying willow tree. The right wing remained attached to a portion of the sternum and the humerus of the left wing. All bones were stripped of flesh, and chewing was evident on the keel of the sternum, the scapula and the humerus of the left wing. This portion of the carcass, with a fresh raccoon scat, was found in the crotch of a willow tree 7 feet above the ground. The left leg, stripped of flesh, was located near the transmitter on the ground below the tree. The transmitter harness and antenna were intact with no tooth marks evident anywhere on the package. Nearby, at another feeding site, was a portion of the left wing and numerous breast feathers. Yet at another site was part of the pelvic girdle. Juvenile and adult raccoon feces were scattered on the tree limbs and on the ground. The willow tree was located on the edge of a 10-acre woodlot at the intersec-

Portion of the carcass of Hen 136 found in the crotch of a willow tree 7 feet above the ground: raccoon predation.

tion of 2 drainage ditches. Dens were found under the tree and along the ditchbank.

Hen 217 was associated with the Kerl-Killian Shrub Carr prior to her death on December 12, 1970. The hen was alive prior to the blizzard of December 11 which dropped 16 inches of snow on the study area. Numerous feathers, intestinal waste, one leg band and the transmitter were found in a ditchbank den on December 16. The den was located in a spoil bank adjacent to a large block of shrub carr. The entrance measured 3-4 inches and the tunnel to the cavity containing the remains was 24 inches long and dropped 18 inches below ground level. Two tunnels extended further down from the cavity. Likely, portions of the carcass were carried further into the den complex, but excavation did not extend beyond the first cavity. The mink was implicated based on the size of the den, since no tracks or other remains could be found.

Other investigations in Wisconsin and Michigan have found the same distribution of relative importance among the various mammalian predators as was observed at Waterloo. At Waupun, Gates (1971:683) implicated fox in 43 of 66 losses (65.1%) attributed to mammalian predation. Similarly Shick (1952:72) determined fox to be responsible for 65 of 78 mortalities (83.3%) ascribed to mammalian predators at the Prairie Farm. However, 12 of the 65 mortalities were categorized as "possibly fox". Shick did not establish an "unknown mammal" category but instead he classified all predations and distinguished them as "red fox" and "possibly red fox" or "dog" and "possibly dog", etc. In this report, the two classifications for each identified mammalian predator will be grouped when citing Shick's data. Gates (1971:683) was unable to classify 18 of 66 losses (27.3%) as to the type of mammalian predation at Waupun as compared with 19 of 46 mortalities (41.3%) at Waterloo.

Shick (1952:72) and Gates (1971:683) incriminated dogs in 2 of 78 and 3 of 66 losses, respectively, to mammalian predators. At the Prairie Farm, roaming dogs were considered more important as agents causing nest abandonment than actual predators of adult birds, although one adult cock was killed by a dog, and reports of several young lost to dogs were registered. At Waupun and Waterloo the importance of free-roaming dogs was similar, except both of these investigations reported losses of nesting hens to dogs. At Waterloo, the dog ranked behind the fox and great horned owl in importance as a predator of fully grown birds.

The cat was not specifically identified as a predator of mature pheasants at the Prairie Farm, Waupun or Waterloo. However, Shick (1952:80) noted some loss of juvenile pheasants to cats. Like dogs, cats were implicated in cases of nest abandonment at Waterloo (Dumke and Pils unpub.). Certainly there were individual cats capable of killing mature pheasants at Waterloo, and other investigators have labeled the species an important predator of fully grown birds. Hubbs (1951) found 33 pheasants in 31 of 184 cat stomachs (16.8%) collected in the Sacramento Valley of California. Twenty-nine of the 33 pheasants were mature birds, and a majority of these were adult hens. Einarsen (1942) identified 10 mature birds and one immature bird in a sample of 21 pheasants found in cat stomachs during an investigation in Washington. Hubbs (1951) noted that of the 33 pheasants, 28 birds were lost between April and September. Most of these losses occurred during the peak period of nesting. Pearce (1945) labeled the cat an important predator of nesting hens in the northeastern states and Leedy and Hicks (1945) concurred, indicating that "all evidence indicates that these domestic predators" . . . cats and dogs . . . "are responsible for losses far more important than those due to natural predators."

Shick (1952:72) and Gates (1971:683) both identified losses due to mink and weasel but considered them insignificant. At the Prairie Farm, 3 mink and 1 weasel were represented among the 78 losses to mammalian predators. No mention was made, however, if the pheasants lost to these mustelids were partially or fully grown. At Waupun, 2 mature hens were lost, one each to mink and weasel. The mink is a formidable predator and certainly capable of killing mature pheasants, but apparently are not common enough at Waterloo or elsewhere to be of much significance to pheasants.

Raccoon predation of fully grown pheasants was not reported by Gates or Shick, although at the Prairie Farm they were common and suspected capable of taking at least juvenile birds.

ANNUAL PATTERN OF MAMMALIAN PREDATION. Mammalian predation was most important during the period of snow cover and the fox was implicated in about 64 percent of these losses during that period (Fig. 4). Except for the post brood-rearing period, the category of "unknown mammal" was smallest during the period of snow cover, when incriminating evidence, particularly tracks, were more often available. The level of mammalian predation was comparable during the late winter and nesting periods and 75 percent of that occurring during the snow cover period. Likewise, the rate of loss during the hunting period was roughly 75 percent of that occurring during the late winter and nesting periods. The classification "unknown mammal" was required for 40-70 percent of the losses during the hunting, late winter and nesting periods. The brood-rearing and post brood-rearing periods were of least significance in the annual pattern of mammalian predation.

At the Prairie Farm, Shick (1952:75) concluded the impact of fox on the pheasant population was greatest during the spring season. During the summer, both juvenile and adult birds were lost to fox, and juvenile birds to dogs and cats. Little mention was made of the importance of these species during the winter months. Gates (1972: 682, 729) stressed the importance of mammalian predation during the periods of snow cover and nesting at Waupun. These findings were substantiated by the Waterloo investigation.

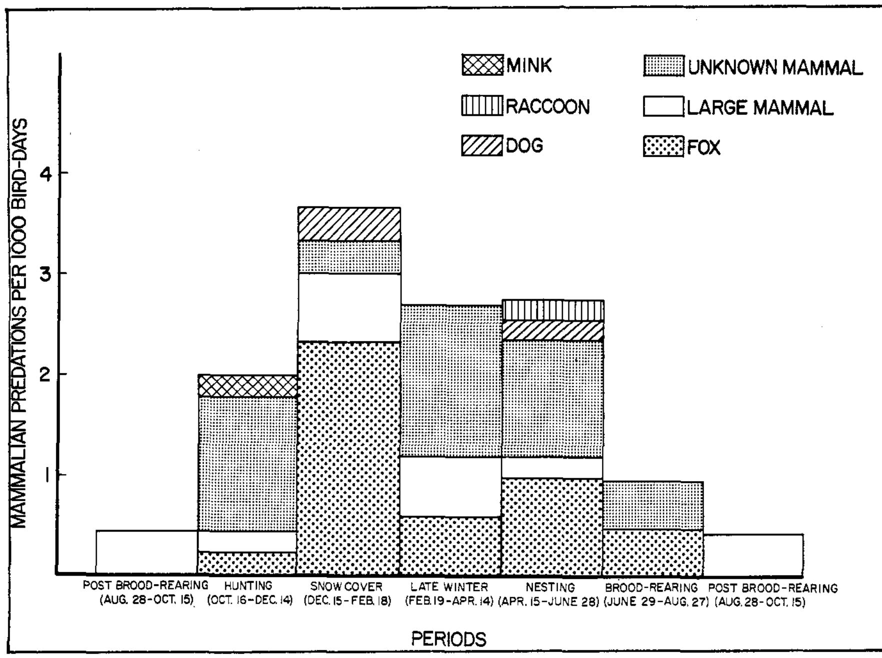


FIGURE 4. *Annual pattern of mammalian predation.*

POPULATIONS OF MAMMALIAN PREDATORS. Nearly all of the mammalian predators found in Wisconsin were represented to some degree on the Waterloo Study Area. Representing the Canidae were the red fox and domestic dog which were abundant, and the gray fox and coyote which were rare. Feral and domestic cats were common. Of lesser importance to fully grown birds were the mink, raccoon and badger. With this representation of mammals on the study area, species determination was often difficult. Since the fox and dog were implicated either specifically or as a group ("large mammal") in 92.6 percent of classified losses to mammalian predation, further discussion will concentrate on these two species.

To obtain estimates of spring and fall fox populations, a spring inventory of active dens, a winter fox harvest survey and a winter track count survey were initiated in 1969. Frank and Woehler (unpubl.) estimated a spring density of 1.1 fox per section from a partial count of active dens on the Waterloo Study Area in 1966. An inventory of active dens in 1969 provided a density figure of 1.0 fox per section with 12 dens discovered on 24 sections. This estimate presumes 2 adult fox per den. The active dens were discovered by a survey of traditional denning sites and a cursory examination of potential denning locations. In addition to the 12 active dens, 11 dormant or little-used dens were located on the 24-section area. Sargeant (1972) has demonstrated that a fox family will use a number of dens in their territory during the pup-rearing period. Therefore, all traditional and potential den sites on a particular unit of the study area were surveyed on a single day to minimize counting the same fox family twice. Although the distribution of active dens was widely spaced (closest active dens ½ mile apart) duplication of family units was possible. Nonetheless, considering the superficial nature of the inventory the number of active dens must be considered minimal. Also, the fox estimate, calculated by doubling the den count, does not account for unmated animals and likewise must be considered a minimum figure. A spring den survey in 1970 was even less comprehensive but revealed some of the dens occupied in 1969 to be vacant in 1970. Gates (1971:687) obtained a density of 1.0 fox per section in the spring for the Waupun Area by expanding den survey results from nesting study areas within the larger unit.

The winter track counts provided a relative index to the fox population from year to year. Six transects were laid out in the manner described by Gates (1971:688) and run during the winters 1969-70 and 1970-71. Fox tracks were encountered at a rate of 4.2 and 4.6 track interceptions per mile in 1969-70 and 1970-71, respectively. These values averaged higher ($\bar{x}$=4.4 track interceptions per mile) than the mean 2.4 track encounters per mile calculated for Waupun by Gates (1971:689).

Most of the fox hunting at Waterloo occurred from December through March, although a few animals were taken in the fall incidental to pheasant hunting. Furthermore, a vast majority of fox were shot by 2 groups of resident hunters, each comprised of about 7 members. During the winters of 1968-69, 1969-70 and 1970-71, 88, 70 and 60 fox were removed by these hunters from 35 sections encompassing the study area. It was estimated that an average of 52 of these fox were removed from the study area proper (25 sections). Gates (1971:689) determined that an average of 17 fox were removed from the Waupun Study Area (42 sections). Thus, a heavier harvest is indicated for Waterloo with 2.1 fox shot per section as compared with 0.33 for Waupun.

Gates (1971:689) calculated a fall fox population for Waupun by adding to the spring population that increment lost during the winter to hunting. Using this same procedure, a fall population of 77 fox (25 fox + 52 fox) or 3.1 fox per section was calculated for Waterloo. This compares with a fall density of 1.2 fox per section for Waupun. The apparent greater abundance of fox at Waterloo during the early winter is reflected in the higher track counts there than at Waupun. This method of computing fall density does not account for the percentage of fox shot on the study area that moved in from adjacent areas over the winter to occupy the vacated territories of harvested animals. Inflated fall estimates would result were it not for the fact that the kill figures and spring estimates used to compute the fall density were, as previously mentioned, minimum values. Gates demonstrated good agreement between the annual fox population calculated by the above procedure and the respective winter track survey. He concluded the procedure provided a conservative estimate of the early winter fox population.

In summary, spring and fall fox population estimates were 1.0 and 3.1 red fox per section, respectively or 25 and 77 fox, age and sex classes combined for the study area. A mid-winter fox population of 51 animals can be presumed based on the mean of the spring and fall estimates.

The number of dogs regularly or intermittently residing at each farmstead on the study area was tallied. A density of 7 dogs per section was computed, and it was estimated that at least half of these dogs were free-roaming. In addition, there was an indeterminate number of feral dogs on the study area. The annual peak in the fox population was estimated at only 3.1 animals per section so by numbers alone the dog cannot be disregarded as a detriment to pheasants. The chance killing of a mature bird may not, however, be as important an impact as the disruption of nesting activities. Roaming dogs were also observed scattering birds during the critical winter period and may indirectly have accelerated mortality at this time.

Impact of Fox on the Pheasant Population. To measure the impact of fox on the Waterloo pheasant population, mortality rates and pheasant population estimates, previously reported, were used to calculate the number of birds lost to fox predation from October 1 to April 1 (Table 22). Fox accounted for 251 hens lost from a fall population of 859 birds. To obtain a crude estimate of incidence of pheasant remains in fox stomachs the number of hens lost daily (1.38) was divided by the average winter fox population on the study area (51 animals). The resultant figure of 2.7 percent should, however, be at least doubled to compensate for (1) the occurrence of 2 or more meals from one kill and (2) the persistence of undigestible pheasant remains in the stomach before a comparison is made with fox food habits findings (Pils 1965). Hypothetically, if the 51 fox on the study area were removed on a particular winter day, roughly 5 percent of their stomachs would contain pheasant remains. Besadny (1966) reported an average of 9 percent of fox stomachs with pheasant remains for southeastern Wisconsin. His sample of 1180 stomachs were collected during winter periods between 1955 and 1965. Although our figure of 5 percent applies only to the hen segment of the population, our reported levels of fox exploitation of the pheasant population seems consistent with previous food habits investigations in Wisconsin.

Avian Predation

Avian predation accounted for 20.2 percent of all losses and represented the second most important mortality factor on an annual basis. Field sign at a raptor kill varied from a feather pile and whitewash to 3 cases where the predator was flushed from a freshly killed pheasant (Table 23). Whereas nearly all mammalian kills were moved from the kill site to a feeding site, the reverse was true for raptor kills. In 15 of the 19 cases of avian predation the pheasant carcass was believed to be at the kill site. Two pheasant remains were found in trees, one 16 feet high in an oak tree used as a great horned owl feeding site and another 25 feet high in a vine-covered cherry tree used as a red-tailed hawk feeding site. It was common for mammalian predators to pause at an intermediate point between the kill site and feeding site to intentionally remove the transmitter. Among the cases of avian predation, only one carcass appeared to be at neither a feeding nor a kill site. In this example, the partially consumed carcass was found in a flooded sedge meadow with no characteristic plucked feathers or bits of flesh usually associated with raptor

TABLE 22. An Estimate of the Incidence of Pheasant Hen Remains in Fox Stomachs Based on Rates of Loss of Radio-tagged Birds to Fox Predation During the Fall-to-Spring Study Period

Mortality rate for hen pheasants Oct. 1 to April 1 (Table 12)	57.8
Oct. 1 hen population estimate (Table 7)	859
Calculated April 1 hen population	362
Total hens lost from Oct. 1 to April 1	497
Percent of total losses due to mammalian predation Oct. 1 to April 1*	63.1
Percent of losses to mammalian predation due to fox predation (Table 21)**	80.0
Percent of total losses due to fox predation	50.5
Total hens lost to fox predation Oct. 1 to April 1	251
Number of days Oct. 1 to April 1	182
Number of hens lost each day to fox predation	1.38
Number of fox on Waterloo Study Area (25 sections) Oct. 1 to April 1[1]	51
Percent of fox stomachs with hen pheasant remains, single meal evident in stomach 1 day	2.7

*Includes fall-to-spring mortality classified as mammalian predation as well as proportional share of "undetermined predation". This presumes that mammalian and avian predators are represented in the same ratio among the unclassified losses to predation as they are in the identified cases.
**Represents percentage of fox predation among cases of mammalian predation classified to species (16 of 20).
[1] Represents an average of the fall (77) and spring (25) fox population estimates.

TABLE 23. Some Evidence Present at the Site of Avian Predation

Evidence with Transmitter and Partially Consumed Carcass	Hawk		Owl	Undetermined
	Red-tailed	Unidentified Buteo	(Great-horned)	Raptor
Small amount of flesh removed from head and neck				1
Moderate amount of flesh removed				3
Majority of flesh removed: whitewash not present				2
whitewash present				4
pellets present			2	
femoral bone broken			4	
Raptor flushed from carcass	2	1		
	2	1	6	10

kills. It was suspected the kill and feeding occurred elsewhere and the carcass was dropped at this site. The head and neck were missing, and 30 percent of the flesh was stripped from the sternum. The legs and wings were intact, except that some feathers had been plucked from them.

Relative Importance of Various Categories of Avian Predation. The species of raptor was only identified in 8 of the 19 cases on file (Table 23). Two red-tailed hawks and an unidentified Buteo were flushed from freshly made kills. One of these cases involved the previously described situation where the carcass was found in a tree.

Hen 165 had recently lost her second nest in a hayfield near the Weber Shrub Carr unit prior to her death on July 3, 1970. The legs and pelvic girdle were mostly stripped of flesh and attached by skin to a portion of the pectoral girdle and the wings. The sternum, viscera, head and neck were missing. The carcass was located atop a 25-foot vine-covered cherry tree. An adult red-tailed hawk was flushed from the carcass when the mortality was investigated. Very few feathers and no whitewash were found on or below the tree. The cherry tree was thought to represent a secondary feeding site. Feathers and the sternum were probably left at the initial feeding site which was likely also the kill site. The transmitter remained attached to the pectoral girdle by a thread of flesh.

In only one case involving predation was a natural injury to a bird detected prior to the individual's death. It has long been established that predators cull sick and injured prey from a population. Predators are opportunists; in this investigation and others they have been observed testing prey in an effort to detect an easy kill. However, considering the total number of pheasant deaths attributed to predation and the apparent low incidence of diseased and injured birds in the population the predator must work hard for most kills. The example of predation on an injured bird also involved a situation where the raptor was flushed from the kill.

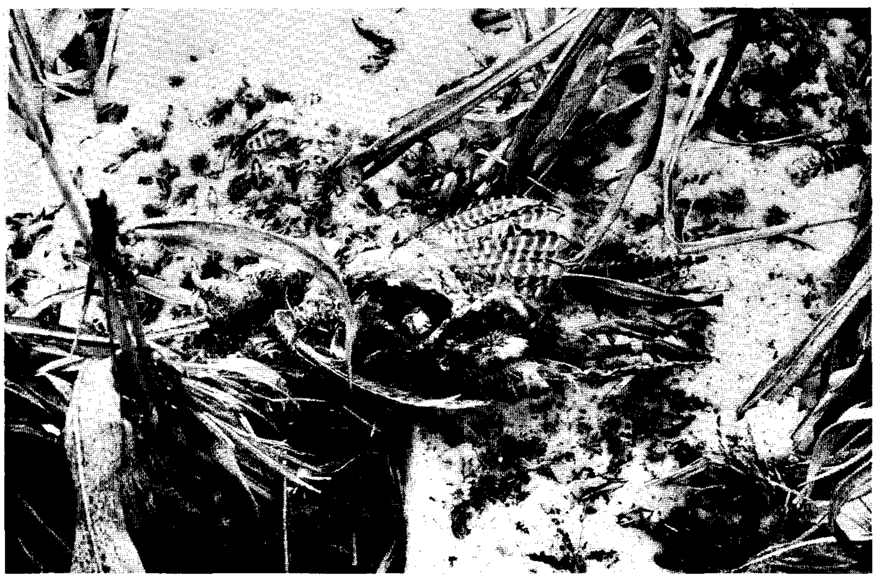
Hen 56 was associated with the Klecker Shrub Carr unit prior to her death on February 7, 1969. On February 5 this hen was routinely flushed to determine her status. Her flight was excellent but her left leg was hanging slightly. On February 7 at 1340 an unidentified Buteo flushed from her remains as she was being approached to confirm the injury. The kill had just been made and the hawk had removed feathers and consumed some flesh from the neck and breast. The skin on the upper portion of the left thigh was green and the muscle a yellowish-brown. The injury was not a result of an improperly fitted transmitter, and the bird had not been handled for 51 days, so the injury must have resulted from a natural accident. The hen had apparently been loafing in a sorghum-corn food patch when she was killed. Two other hen pheasants were flushed 15-20 feet from the mortality victim. The hawk flew about 100 yards and perched in a dead elm. The carcass was briefly examined and left for the hawk to return and commence feeding. The hawk was observed at 1420 perched in another dead elm about 150 yards from the carcass. At 1530, when the hawk was flushed from the carcass again; a major portion of the breast, neck and right leg flesh was consumed. The viscera was removed from the body cavity but not consumed. Feathers and skin had been removed from the injured left leg but no meat consumed. Streaks of whitewash were noted radiating from the carcass after both visits by the hawk. A major portion of this pheasant had been devoured by the hawk in about an hour.

Of the large raptors on the study area, only the great horned owl was thought to be capable of breaking pheasant femoral bones. This factor, combined with others including proximity to an active nest or feeding perch, implicated the horned owl in 4 cases. The mortality history of Hen 85 is representative of owl kills where heavy bones have been severed.

Hen 85 was associated with the Landsee retired cropland fields and adjacent marsh prior to her death on January 17, 1969. The legs, pelvic girdle and most of the thoracic vertebrae were found completely stripped of flesh, with the transmitter, above 8 inches of snow in willow brush. The tibio-tarsus of the left leg was broken. Feathers were scattered in a 3-foot circle. The transmitter harness and antenna were intact except the antenna wire was kinked in 2 places 5/16 inch apart. The bent antenna could have been caused by the raptor's beak. During this same period a great horned owl pair established a nest less than 1/4 mile from the kill site.

Great horned owl pellets were found at 2 raptor kills. Both situations involved aboreal feeding sites used by this species. Only a few feathers were found with the transmitter in both cases.

Ten of the 19 examples of avian predation remained unclassified. In cases where the raptor was flushed from the kill or incriminating evidence such as pellets were present to implicate either the great horned owl or red-tailed hawk, it was apparent the owl consumed more feathers with flesh than the hawk and left fewer feathers scattered around the carcass. Based on a meager amount of feathers associated with a feeding site, at least 2 kills in the



Hen 56 found in a corn-sorghum food patch: hawk predation

Hen 85 found in willow brush above 8 inches of snow: owl predation "undetermined" category are suggestive of horned owl predation. In one case a portion of the carcass and a few feathers were found scattered over an area of 15 feet in diameter in a woodlot with a dense understory of thornapple and gooseberry. In the second case the carcass was intact, except the head and neck were missing. A few feathers were plucked and scattered in a 2-foot circle. A large amount of blood was present in the snow adjacent to the carcass. Einarsen (1956) reported that great horned owls flushed from fresh bird kills had invariably begun to feed on the carcass at the neck. In this example an owl may have abandoned the kill after consuming only the neck meat.

Other cases in the "undetermined" category were suggestive of hawk predation based on an abundance of feathers at the feeding site.

Hen 92 was associated with the Klecker Shrub Carr unit prior to her death on February 16, 1969. (Hen 56 was killed by an unidentified Buteo in this same area 9 days before this hen — page 34). The almost completely consumed carcass was found above 3 inches of snow in red osier and gooseberry cover. Flesh was removed from the entire skeleton with all large bones intact except the left wing which was severed at the wrist. Two large piles of feathers were present at the kill site. Streaks of whitewash radiated from the feather pile where the carcass was located. A puncture wound was evident on the head at the occiput. The transmitter harness and antenna were intact.

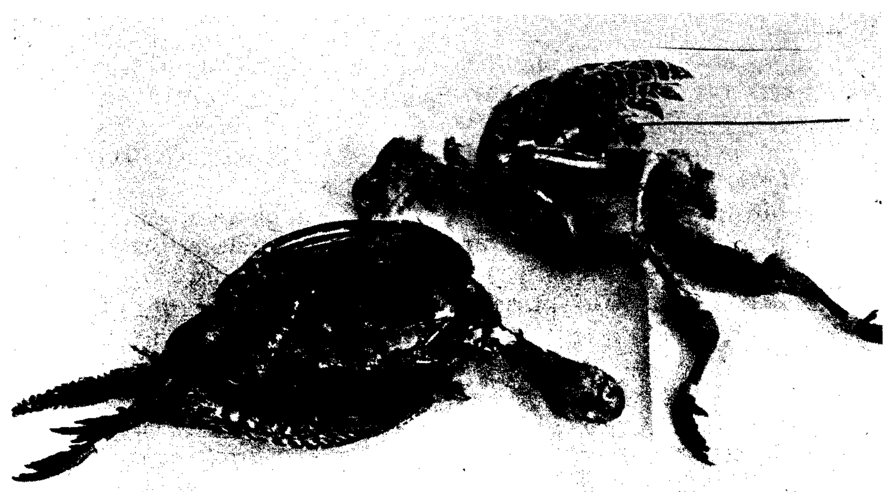
Hen 101 hatched a clutch of eggs from a nest adjacent to the Kerl shrub carr unit and was believed to be with her 2-week old brood on June 17 when she was preyed upon. The carcass, almost completely stripped of meat, was found along a railroad embankment in grass-forb cover. Flesh was removed from all skeletal parts except portions of the left leg, back and wings. The viscera, except the large intestine, and the head were missing. The transmitter harness was intact, but hooked only to the left wing. The final disposition of her brood was not determined.

Gates (1972:683) found the red-tailed hawk accounted for the largest share of losses to raptors at Waupun. Of 99 examples of avian predation during the winter months, 28 (28.3%) were attributed to the red-tailed hawk, 11 (11.1%) to the horned owl, 9 (9.1%) to the Cooper's hawk, 2 (2.0%) to the rough-legged hawk and 49 (49.5%) were unclassified as to species. Fewer horned owls were present at Waupun than at Waterloo, likely accounting for the lesser importance of this species with respect to the red-tailed hawk. Cooper's and rough-legged hawks were present at Waterloo in winter but not specifically identified with any mortalities among the radio-tagged birds.

Shick (1952:72) found the Cooper's hawk to be the most important predator of mature pheasants among the hawk species at the Prairie Farm. However, in terms of total pheasants lost to raptors, the marsh hawk was most significant since it took numerous immature birds. Shick considered the red-shouldered, red-tailed and rough-legged hawks which frequented the Prairie Farm to be of little consequence to pheasants. The great horned owl was implicated in most of the losses due to owls.

Annual Pattern of Avian Predation. Avian predation was distinctly most important during the period of snow cover (Fig. 5). This was logical considering that small mammals, the principal items in the raptors' diet, are concealed under a blanket of snow. In addition, the observability of pheasants for the aerial predator is increased on snow cover, resulting in an alternative food source. The level of raptor predation was roughly comparable during the other periods and about 20 percent of that occurred during the period of snow cover. Apparently there was not a detectable acceleration of

Hen 92 found in shrub carr: raptor predation, hawk suspected



Hens 56 and 92 showing patterns of raptor feeding

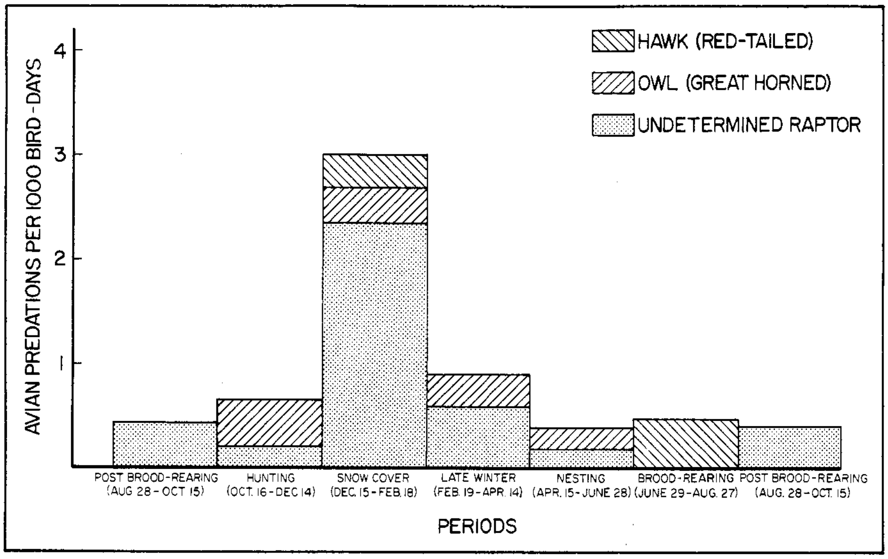


FIGURE 5. *Annual pattern of avian predation.*

hawk predation during the periods of fall and spring migration.

POPULATIONS OF AVIAN PREDATORS. To determine which avian predators were represented on the study area all observations of hawks and owls made incidental to other activities were recorded on daily logs or raptor observation forms. Patterns developed showing the seasonal occurrence of a variety of species. The most common resident hawk on the study area was the redtail. Transient Buteo hawks included the rough-legged hawk, the broad-winged hawk and the red-shouldered hawk; of the Accipiter hawks, the Cooper's hawk and the sharp-shinned hawk were occasionally observed and the goshawk rarely sighted. The harrier was a summer resident.

A common resident owl although seldom seen was the great horned owl. The short-eared owl was the most commonly observed owl and was a summer resident. Also present and observed, occasionally, were the screech owl and the barred owl. One observation was made of a long-eared owl. Likely only the red-tailed hawk and great horned owl were of any consequence to mature pheasants, and further emphasis will center on these two species. The Accipiter hawks, particularly the goshawk and Cooper's hawk, are capable pheasant predators, but were represented at such a low density at Waterloo that they were of little concern.

To obtain estimates of raptor abundance historic red-tailed hawk and horned owl nests were inventoried in the spring of 1970. Of 20 raptor nests investigated, 9 were occupied by red-tailed hawks, 2 by great horned owls and 9 were either destroyed or not in use. An exhaustive nest inventory at Waterloo in 1972 by Petersen (pers. comm.) revealed breeding populations of 8-9 pairs of red-tailed hawks and 6-7 pairs of great horned owls. In addition, two non-breeding individuals of each species were observed. Craighead and Craighead (1956:225) found that breeding densities of the redtail were stable from year to year; therefore, our spring estimate (9 pairs, 1970) was reasonable based on Petersen's findings (8-9 pairs, 1972).

To supplement the nest inventory, a winter triangulation count of "hooting" owls was established in 1969. Results of the survey were sporadic and time did not permit refinement of techniques. A minimum of 13 horned owls were triangulated in 1971, the only year with good survey results. The estimate (13 owls), however, was more compatible with Petersen's results (14-16 owls) than an expansion of the nest inventory data (4 owls).

In summary, breeding population estimates of 18 red-tailed hawks (0.7 birds/section) and 13 great horned owls (0.5 birds/section) were established for the study area. An inventory of raptor nests provided a reasonable count for the redtail, and a triangulation count of "hooting" owls was used to measure the horned owl population.

Undetermined Predation

Undetermined predation was a category used when classification of the predator, *viz* mammalian or avian, could not be designated due to inadequate field sign. This category ranked third among all decimating factors and accounted for 11.7 percent of annual mortality.

Often examples of predation were relegated to this category when field sign was very limited or obliterated by rain or snow. Occasionally evidence implicating both avian and mammalian predators was present at the feeding site. The mortality history of Hen 83 illustrates a combination of complicating factors.

Hen 83 occupied an area centered around Bauman's Marsh prior to her death on December 31, 1968. The partially consumed carcass was found covered with 3-5 inches of fresh snow on a 2-foot snow drift along a ditchbank. The head, neck and left wing beyond the elbow were missing and flesh was consumed from the left side exposing the ribs. The left humerus was mostly stripped of flesh but intact. Only a few feathers were found under the snow blanket. The transmitter was intact, except the knot was partially untied.

Superficially the remains were indicative of avian predation except few feathers were found with the carcass. The snowfall and strong wind which preceded investigation of the kill may have eliminated many feathers if they were present at the feeding site. If a medium-sized mammalian predator, such as a cat, had made the kill, likely few feathers would be present at the feeding site, and the amount of flesh removed might represent a good meal. In most cases of raptor predation, more flesh was removed than indicated with this

TABLE 24. Predator-Hen Pheasant Ratios on the Waterloo Study Area (25 Sections) 1968 to 1971

Predator	Onset of Winter (December 15)			Onset of Spring (April 1)		
	Hen Estimate	Predator Estimate	Ratio	Hen Estimate	Predator Estimate	Ratio
Red-tailed hawk	641	18*	1:36	362	18	1:20
Great-horned owl	641	13	1:49	362	13	1:28
Red fox	641	77	1:8	362	25	1:14
Combined			1:6			1:6

*Mean 1968–71 Winter Transect Count.

kill. It was unlikely the kill was made at the site described above, unless the hen was forced into this area. No concealing vegetation was present for about 60 yards. However, it seemed equally illogical that a predator would carry the hen to this open site to feed on it. The hen may have been killed by a hawk while in flight and hit the ground at this point. Numerous alternative hypotheses are available; therefore, this mortality and 10 other similar cases were classified in the category "undetermined predation".

Predator-Pheasant Ratios

Predator-hen pheasant ratios were computed for the winter and spring seasons (Table 24). Hen estimates were based on the fall population level corrected for fall and fall-to-spring mortality rates for radio-equipped birds (Tables 12 and 15). The determination of predator densities for the onset of winter and of spring were discussed previously in this section.

The number of hens per fox changed from 8 to 14 from the onset of winter to the beginning of spring. The heavy harvest of fox during the winter caused the unusual decrease in the predator-prey ratio from fall to spring. While the pheasant population was being reduced by 43.5 percent over the winter, the fox population declined by 69.5 percent.

Red-tailed hawks and great horned owls were represented in a proportion of 1:37 and 1:49, respectively, in winter and 1:20 and 1:28 in spring. The winter red-tailed hawk estimate used in this proportion represented the mean number of individuals observed on a winter roadside transect. Counts varied from 26 in 1968 to 15 in 1971 ($\bar{x} = 18$) on the 44-mile route along which all hawks observed were tallied. The survey was designed to gather trend information and the resultant red-tailed hawk count can only be considered a very conservative estimate. The late winter triangulation count of great horned owls was used for calculating both the winter and spring predator-prey ratios.

The combined predator-prey ratio for the fox, red-tailed hawk and great horned owl was 1:7 in winter and 1:6 in spring. Gates (1971:690, calculated from the author's data) found a ratio of 1:23 in winter for these 3 predatory species at Waupun. Higher predator-hen pheasant ratio at Waterloo may partially explain the higher mortality rate (38.7% vs. 26.7%) and the greater relative importance of predation (78.6% vs. 49.1%) reported there as opposed to Waupun.

Predator-Pheasant Relationships

There are many factors which cause annual variation in the magnitude of predation, and most of these relate to the availability of prey species. Latham (1952:14) pointed out that predators are opportunists, and such factors as (1) abundance of prey, (2) weather conditions, (3) physical condition of prey, (4) amount of protective cover, and (5) introduced species can influence prey availability. The importance of weather conditions on prey availability is the first topic of this section.

The second aspect explored in this section is the relationship between pheasant nesting and predation; namely if the hen pheasant is particularly vulnerable to predation at any stage in the nesting cycle. Ease in recapturing hen pheasant for transmitter replacement during late incubation aroused speculation that the hen might be especially vulnerable to predation at that time.

INFLUENCE OF WEATHER ON PREDATION. The period of snow cover (December 15-February 18) accounted for the largest fraction of annual mortality and winter (December 15-April 14) exhibited variation in mortality rates of 32.1 percent in 1968-69 to 68.8 percent in 1970-71 (Tables 14 and 15). To explore the possible influence of winter weather on annual variation in mortality rates, a weather hardness index was computed following the procedure outlined by Gates (1971:24). Basically, the computation accounted for a combination of temperature and snow depth between December 1 and March 31 of each year. Lower mean temperatures and higher snow depths resulted in larger hardness values. These values for each winter were plotted against corresponding fall-to-spring mortality rates from Table 12. A comparison of the relationship between winter hardness and fall-to-spring mortality was made between the Waupun Study Area for the years 1958-65 (Gates, 1971) and the Waterloo Study Area for the years 1968-71 (Fig. 6). In addition, the incidence of pheasant remains in fox stomachs was plotted against winter hardness. These data applied to southeastern Wisconsin and years 1958-1965 (Besadny, 1966).

Figure 6 demonstrates that annual fluctuations in fall-to-spring mortality are due largely to the severity of winter weather. Fall-to-spring mortality was high during years when winter weather was severe. Likewise, the frequency of occurrence of pheasant in fox stomachs increased in years when winter hardness values were high. It appears the accelerated rate of mortality during the period of snow cover was largely a function of increased predation. Gates (1971:747) had previously come to the same conclusion based on the Waupun data. The addition of the Waterloo data and fox stomach analysis information further substantiated his findings.

During the nesting period, accelerated loss is shown by the annual pattern of mortality portrayed in Figure 4. In addition, yearly variation in mortality rates during the reproductive period (April 15-August 27) ranged between 18.2 percent in 1971 and 62.9 percent in 1969. Nesting period loss was the principal determinant of reproductive period mortality since loss during the brood-rearing period was of little consequence (Fig. 4, Table 15). To determine how weather might influence annual variation in mortality rates, precipitation during May and June was plotted against mortality during the reproductive period (Fig. 7). Annual variability in loss during the reproductive period appears to be a function of precipitation during the nesting period and likely due to accelerated rates of predation. That is, reproductive period mortality was low in years of little precipitation and high in years of heavy rainfall.

The importance of precipitation on predation was supported by an analysis of 37 examples of mammalian predation occurring in all seasons except winter. Among this sample, 26 mortalities (70.3%) occurred during a 24-hour period of precipitation. That is, precipitation occurred at night or during the previous day or during both periods. (All cases of mammalian predation in this sample occurred at night.) In addition, the incidence of precipitation was subjectively appraised for a period of 5-7 days prior to the mortality. The period was classified "wet" or "dry". Of the 37 cases of mammalian predation, 20

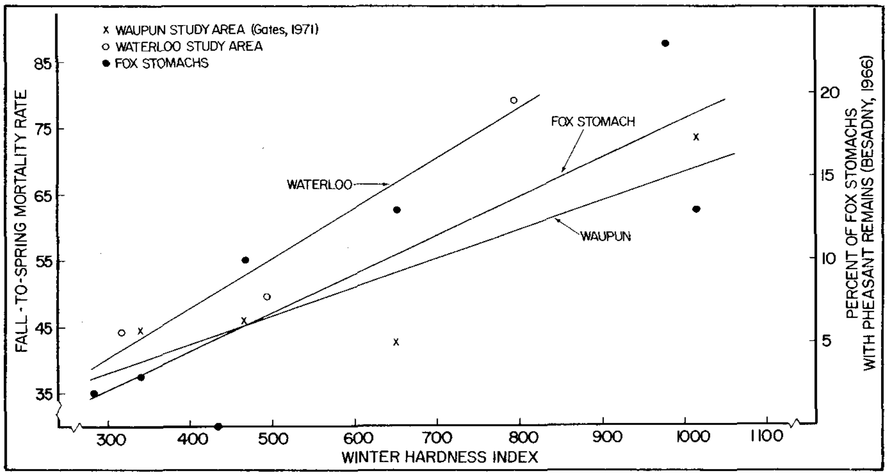


FIGURE 6. *Comparison of fall-to-spring mortality rates and the incidences of pheasant remains in fox stomachs with the severity of winter weather. (Snow depth from Madison; temperature from Watertown)*

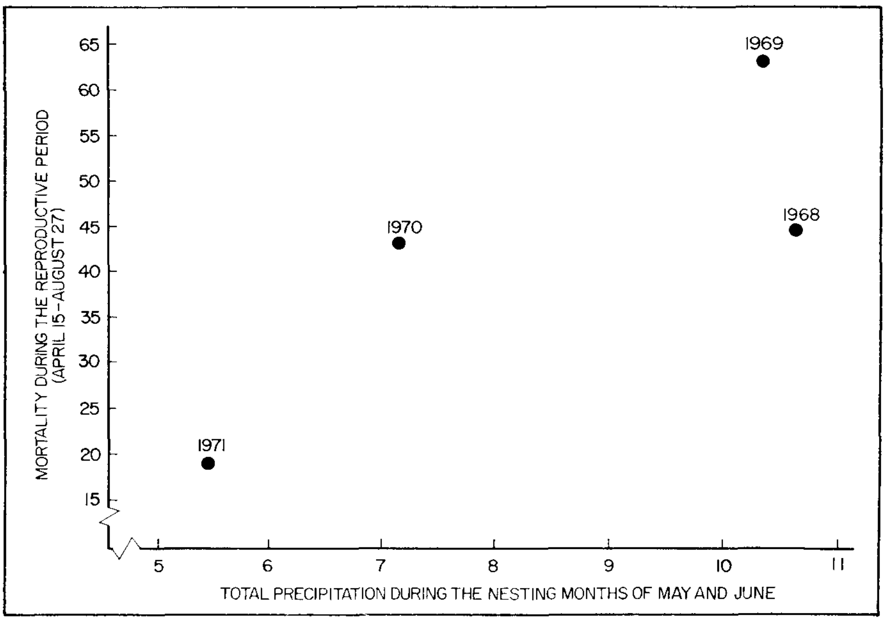


FIGURE 7. *Mortality during the reproductive period vs. precipitation during May and June.*

mortalities (54.0%) occurred during a dry period and 17 (45.9%) during a wet period. However, it is important to note that 10 mortalities occurred on wet days during the 20 dry periods, while only 2 losses occurred on dry days during the 17 wet periods.

Wagner (1965:80) summarized the findings of midwest studies with regard to spring-summer precipitation and nesting. With the exception of a few investigations demonstrating a direct effect of excessive precipitation on nesting (flooding of nests or abandonment of nest due to heavy rainfall) none of the studies indicated a serious effect of rain during the reproductive season. Furthermore, Wagner found no correlation between average June rainfall in southeastern Wisconsin and population trend between 1938-1956. The findings at Waterloo suggest that precipitation may play an important role in the variability of reproductive period mortality principally through its influence on levels of predation. More research is needed to clarify the importance of weather factors on predation particularly during the periods other than snow cover.

To determine if wind velocity and cloud cover as well as precipitation might be influencing rates of predation, all 3 factors were averaged for the 37 nights when mammalian predation occurred and compared with yearly averages (Table 25). All 3 weather factors averaged higher during nights of recorded mammalian predation than the combined yearly averages. In a chi square analysis wind (3.03) and precipitation (3.28) were not significant at the .05 percent level (3.84), whereas cloud cover (7.99) was significant at .01 (6.63) (Yates Correction applied).

In a similar comparison of weather and the incidence of avian predation, wind velocity, cloud cover and precipitation also averaged higher but not significantly during days with recorded loss to raptors than yearly averages (Table 26).

Relationship of Pheasant Nesting and Predation. To explore how accelerated mortality during the breeding season might relate to nesting, 22 radio-tagged hens lost to predation during May, June and July were classified according to 10 categories of nesting activity (Table 27).

Except for 9 individuals that were lost in May prior to their first nest, predation was rather evenly distributed over the entire spectrum of nesting activities. Apparently the vulnerability of hens is not greatly increased during incubation as previously suspected based on the ease of recapture at that time. Concerning the 9 individuals lost prior to the establishment of their first nest, it is important to note that in 6 of these cases "nesting behavior" was indicated by radio monitoring, but subsequent nest searching did not locate the clutches. Dumke and Pils (unpubl.) describe incidents where a portion of the eggs from a clutch were removed with no shell fragments left at the nest bowl. Conceivably entire clutches could be removed, and in certain cover types the remaining nest bowl would be indistinguishable and easily overlooked in a nest search. Sargeant (pers. comm.) has indicated that a fox will often remove duck eggs from a clutch leaving no shell remains at the nest bowl. If these 6 cases actually represented egg-laying at the first nest, it would increase the importance of this nesting activity with respect to predation.

Gunshot

Seven radio-equipped hens were victims of gunshot ranking this factor first among non-pre-

TABLE 25. Comparison of Weather Conditions on Nights When Radio-equipped Hens Were Lost to Mammalian Predation with Average Annual Weather Conditions for All Nights*

Weather Factor**	1968 April–Dec.	1969 Jan.–Dec.	1970 Jan.–Dec.	1971 Jan.–Sept.	All Years Combined	Nights with Losses to Mammalian Predation (N=37)
Wind (knots)	7.65	6.56	7.02	8.06	7.18	8.40
Cloud cover	55.4	56.8	57.7	53.5	56.2	67.0
Precipitation	40.4	39.2	37.3	33.5	37.9	54.0

*Night arbitrarily defined as 1800 hours to 0600 hours.
**Wind expressed as "mean velocity", cloud cover as "average percent" and precipitation as "percent of nights with trace or better".

TABLE 26. **Comparison of Weather Conditions During 24-Hour Period When Radio-equipped Hens Were Lost to Avian Predation with Average Annual Weather Conditions***

Weather Factor**	April–Dec.	Jan.–Dec.	Jan.–Dec.	Jan.–Sept.	All Years Combined	24-Hour Periods with Losses to Avian Predation (N=19)
Wind (Knots)	10.0	8.7	9.5	10.6	9.6	10.8
Cloud cover	59.5	60.8	58.7	57.2	59.3	68.0
Precipitation	52.0	53.4	52.3	42.0	50.8	56.7

*24-hour period defined as 1200 hours to 1200 hours.
**Wind expressed as "mean velocity", cloud cover as "average percent" and precipitation as "percent of nights with trace or better".

TABLE 27. **Incidence of Predation and Corresponding Nesting Activity For 22 Radio-equipped Hens Lost During May, June and July, 1968–1971**

Nesting Activity	Mammalian	Avian	Undetermined	Combined
Prior to first nest	8		1	9
Egg-laying first nest	1			1
Incubating first nest	1	1	1	3
Lost first nest, second nest not confirmed			1	1
Egg-laying second nest	1			1
Incubating second nest	1			1
Lost second nest, third nest not confirmed	2	1		3
Egg-laying third nest				
Incubating third nest	1			1
After hatching of clutch		1	1	2
TOTAL	15	3	4	22

dation losses. Three birds were discovered by project personnel, 2 were found by hunters and 2 were turned in by the hunters that shot them. The carcasses of all gunshot victims were intact and registered positive on fluoroscopy tests.

Of the 7 hens, 2 were shot on the first day of the hunting season, 2 were killed during the first week and one each were harvested on the second weekend, second week and third weekend. This distribution of the illegal hen kill agrees with the findings of Gates (1971:616) and Wagner et al. (1965-116) who have demonstrated that hen kill does not increase with declining cock numbers as the hunting season progresses. One of the 2 hens shot during the first week of the season had developed plumage characteristics of a cock, and the hunter was unaware he had shot a hen. The female was identified as a juvenile when she was initially captured the previous fall.

An illegal hen harvest of 5 percent was calculated for Waterloo. This estimate was determined by dividing the number of radioed hens shot during the hunting seasons of 1968, 1969 and 1970 by the number of radioed hens alive at the onset of each season. The 5 percent hen kill is below the statewide illegal hen harvest of 12 percent as determined by Gates (1971:613). One possible explanation for this discrepancy may be the intensive hunter checks which were conducted on the study area. The hunters, certainly aware of this, may have responded by less intentional and accidental shooting of hens.

Hay Mowing

Hay mowing accounted for 5 deaths of radio-equipped hens. Four hens were nesting, and one was with a 2-day old brood. Of the nesting hens, 2 were egg-laying (one at her first nest, the other at her second), and 2 were incubating (one on her third nest, the other on at least her second). The egg-laying hens were killed on June 3 and June 16 and the incubating females on July 4 and July 6.

The incubating hen that was thought to be on her second nest was not under radio surveillance at the time she was killed. However, the incident was reported by the farmer immediately, and evidence at the nest site could be pieced together very accurately. The hen had reached 15 days of incubation on July 4 when the clutch was destroyed, and back-dating revealed the nest to have been established on or about June 7. It seems probable that she had at least one clutch before this, since most hens at Waterloo come into production during late April. All hens, with the exception of this individual, were killed in hay fields. She was killed in a retired cropland field that was being cut to facilitate its conversion back into production.

The brood-rearing hen was killed on June 9 in a hayfield 2 days after she had hatched 12 of 13 eggs at her woodlot nest site. The hayfield was about 30 yards from the nest.

Highway Traffic

Two radio-tagged hens were killed by highway traffic. One was reported by a study area resident who hit the bird on an ice-covered town road. The hen was apparently flying across the road with a flock of 6-7 birds when she was hit. The second victim of highway traffic was found by project personnel along a heavily traveled state highway. The site where she was killed was a frequent crossing for pheasants.

Hunter's Dog

Two transmitter-equipped hens were victims of hunters' dogs. Both mortalities were reported to project personnel by the hunters whose dogs were responsible for the death. Neither bird carried lead shot (fluoroscope technique, Elder 1950) nor evidence of a previous injury.

Winter Weather

Two radio-tagged hens were lost to winter weather. One individual was found under 16 inches of new snow and matted canary grass. The storm that trapped this juvenile female occurred on December 11, 1970. The second hen died during a mid-January ice storm. She was found with her beak forced open by packed ice. The occurrence of death by ice storms is rare in Wisconsin (Gates 1971:705).

Unknown Cause

Evidence was inadequate in 11 of the 105 mortality records to identify the cause-of-death. Seven of the 11 hens in this category were suspected cases of predation, but crows or mammalian scavengers obliterated evidence at the site prior to arrival of the investigator. Some of these remains were 3-5 days old and decomposition of the carcass was underway.

One case in this category involved a hen that was apparently killed in a flight accident. The hen was found venter down in a slight depression in the snow. The female's head was cocked over her back, and her beak was filled with blood. She was found in a tree and shrubbery plantation.

Another interesting case in this category concerned a radio-equipped hen that was found intact in 2 feet of water. Thin ice skirted the edge of the flooded shrub carr where the female was found. Three sets of pheasant tracks in the snow led to the water's edge. Drowning was the suspected cause of death, but a necropsy revealed no water in the lungs. Shortly after this death a cock pheasant was found 1¼ miles away, carcass intact, in 2 feet of water. A necropsy of this individual also revealed no water in the lungs.

CONCLUDING STATEMENTS

The objective of this investigation was to identify specific causes of hen pheasant mortality and to assess their relative importance on a seasonal and annual basis. It was a necessary adjunct to Gates' (1971) intensive study of pheasant ecology at Waupun and was designed to refine the mortality picture he developed. Furthermore, this study was needed to obtain a better understanding of pheasant mortality on a wildlife area where a program of habitat management was being conducted (Frank and Woehler 1969). Essentially this aspect required an extrapolation of the mortality findings of Gates (1971) at Waupun, a study area of limited wetland and idle acreage, to Waterloo a study area formed around a core of large units of wetland and retired cropland.

Gates (1971) was the first investigator in Wisconsin to piece together a cogent picture of seasonal and annual mortality for a pheasant population. His investigation at Waupun implicated predation as the most important mortality factor limiting pheasant abundance. Previously Errington (1946:166) and Wagner et al. (1965:112) had alluded to the possible significance of predation on pheasants, particularly in marginal habitat. However, in good habitat Wagner (1965:113) speculated that hay mowing was the chief mortality factor.

The findings of this investigation supported the conclusions of Gates (1971) that predation was the most important direct cause of death. The scope of this study did not provide for an evaluation of population regulation; nonetheless predation is likely also the limiting factor of pheasant abundance at Waterloo. This suspicion is supported by the inability of the habitat development program to produce a *measurable* increase in pheasant density relative to regional population trends. Habitat improvements employed at Waterloo were apparently ineffectual in offsetting the limitations placed on population density by predation.

The relative importance of predation, with respect to the other causes-of-death, was much greater at Waterloo than Waupun. This was primarily due to the lack of importance of hay mowing mortality at Waterloo. Only 20.0 percent of all nests on the wildlife area were established in hay and, therefore, vulnerable to the hay mower. This was not the case at Waupun (Gates 1971:417) where, in an area of limited idle acreage, 33 percent of all nest production was in hay. In addition, roughly 42 percent of the hayfield nests at Waterloo were disrupted by predators well before the crop was harvested. This compares with 3 percent at Waupun. One of the important facets of the Waterloo habitat improvement program was to provide alternative nesting cover to "bait" hens away from the less secure cover such as hay. In all likelihood fewer hens nested in alfalfa but the overriding effect of predation on birds and nests negated the benefits of this endeavor.

A comparison of late winter predator densities between Waupun and Waterloo revealed fox, great horned owl and red-tailed hawk abundance to be significantly higher at Waterloo. Fox densities of 1.0 and 1.6 animals per section were computed for Waupun and Waterloo, respectively. The great horned owl and red-tailed hawk were found at densities of 0.1 and 0.5 birds per section, respectively, at Waupun as compared with 0.5 and 0.7 birds per section at Waterloo. These densities combined with a 30 percent lower pre-winter hen pheasant population at Waterloo provided for significantly higher predator-pheasant ratios at the Wildlife Area than at Waupun. This certainly accounts in part for the higher percentage of hens lost to predation at Waterloo. Likewise, if the other state-operated Wildlife Areas characteristically support higher predator populations, the importance of predation as a limiting factor of pheasants might be greater on these areas than on private lands.

The importance of predation as a limiting factor of pheasant abundance in Wisconsin cannot be easily discounted considering the conclusions of the Waterloo and Waupun investigations. However, these results should not be construed to imply a need for predator control. Neither study was designed to evaluate predator control as a management tool, the value of predators in maintaining biological balance and the factors that make pheasants susceptible to predators; rather both studies included procedures which provided information on the direct mortality factors affecting individual pheasants.

The Waterloo investigation indicted the red fox, the great-horned owl, and the red-tailed hawk as chief predators of fully grown hen pheasants. All 3 species are aesthetically appealing members of our native fauna, and large-scale control of their numbers should not be considered without substantive data on factors involved in natural control of predator populations, and cost-benefit ratio's involved in a control program. Immediate consideration should also be given to improving the public understanding of the values of predators based on ecological consideration in maintaining a quality environment. Meanwhile, the pursuit of information on the population dynamics and elementary ecology of the major pheasant predators as well as the influences of habitat changes on predator and pheasant interactions are being continued in earnest.

APPENDIX I: Improvements in Transmitter Design

INTRODUCTION

Recent innovations in component systems and power supply have increased operational life of radio transmitters considerably. A 20- to 30-gram radio suitable for studying game birds now can have a calculated life of 300 to 400 days (W.W. Cochran, pers. comm.). Brander (1968) described a transmitter harness and depicted a whip antenna system conventionally used on game birds (Bernhoft, 1968, Kuck, 1966, McEwen and Brown, 1966, and Robel et al., 1970). This radio package worked well in investigations when expected radio life ranged between 30 and 70 days. However, with transmitter life extended to 400 days, harness or antenna failure became limiting factors that had to be modified to realize the benefits of improved circuitry.

This paper presents the harness and antenna modifications that were developed during a 4-year investigation of mortality among wild hen pheasants at the Waterloo Wildlife Area in southeastern Wisconsin.

METHODS

Two hundred and forty-five pheasants were equipped with transmitters employing a circuit described by Cochran (1967). Most of the radios were constructed by the Instrumentation System Center of the University of Wisconsin. Calculated field life for the units varied between 90 and 175 days, weight averaged 32 grams, and frequencies were in the 150 MHz range. Twenty-five transmitters were purchased from the A.V.M. Instrument Company, Champaign, Illinois in the last year of study. The outstanding feature of these units was their expected operational life of between 150 and 300 days. Receivers from Markusen Electronic Specialties, Cloquet, Minnesota and A.V.M. were used with vehicle-mounted antennas to obtain daily locations on the radio-equipped pheasants.

Figure 8 depicts the transmitter described by Brander (1968) and the model used in this study. We encapsulated the battery with the other radio components since the transmitter described by Brander would cease to operate if the harness wires (lead wires) were severed by a predator. After a bird's initial adjustment to the radio, no problem with balance was detected as a result of the battery on the dorsum rather than breast. Otherwise, the two transmitters appeared superficially very similar.

HARNESS MODIFICATIONS

Two subtle modifications were required to improve the harness for year-long operation. At the neck loop (Point A, Fig. 8) the harness wires were crossed and secured with tape to hold the joint. Despite using cold-weather electrical tape, the joint often loosened, particularly during the winter-to-spring study period. The extremes in temperature followed by precipitation in the spring resulted in the tape losing its adhesive quality. The harness wires were then free to slip at this point. To alleviate the problem harness wires were tied in a square knot at this point and wrapped with tape.

A second modification was necessary to abate a problem that developed at the junction of the harness wires and the component package (Point B, Fig. 8). Flexing at this point resulted in breakage of the harness and the transmitter was then easily shed by the bird. In the first year of this investigation, 19 examples of this harness problem were tabulated with transmitters shed between 5 and 86 days ($\bar{X}$=32.4). This situation was rectified the following year by taping the harness to component package junction in the manner demonstrated in Figure 9. The harness wires were held in a fixed position with respect to the component package. No transmitters were cast off after this procedure was adopted.

ANTENNA MODIFICATIONS

B-flat steel guitar string, 8-12 inches in length and coated with a spray plastic, was used throughout most of the study for antenna wire. Whereas whip antennas give more range than loops at 150 MHz, they are far more vulnerable to breakage, a significant problem in this study and in other investigations (W.W. Cochran, pers. comm., Marshall, 1964). Observations of radio-equipped pheasants under penned conditions revealed that bending and breakage were caused by preening. Preening bent and kinked the wire, reducing its efficiency as an antenna, and also stripped the plastic coating allowing corrosion to weaken the wire until it broke.

A telescoping system of P.V.C. (polyvinyl chloride) tubing was originally developed to protect the antenna system from such damage (Dumke and Pils, 1967). The system functioned moderately well to distribute stress evenly along the antenna, but was rather bulky.

An alternative was found which involved imbedding the base of a ball-point pen spring in the encapsulating material and passing the antenna wire with one P.V.C. cover through the spring (Fig. 8 Insert). The spring assists the P.V.C. tubing in distributing the stress on the antenna wire at the point where it leaves the transmitter package. This is the site where most of the kinking and ultimate breakage of the antenna had occurred. The single P.V.C. cover protects the antenna from manipulation and prevents wearing off of the spray coating.

Prior to use of this system during the second year of study, radio contact was lost with at least 6 birds and 7 additional birds had to be recaptured due to breakage of the antenna wire. The range over which the signal could be heard decreased from ¾ mile to about 100 yards when antenna breakage occurred. Very likely, many of the 25 unexplained examples of radio failure tabulated during the entire study were due to antenna breakage, since 21 disappearances occurred prior to implementation of the spring-P.V.C. antenna protective system.

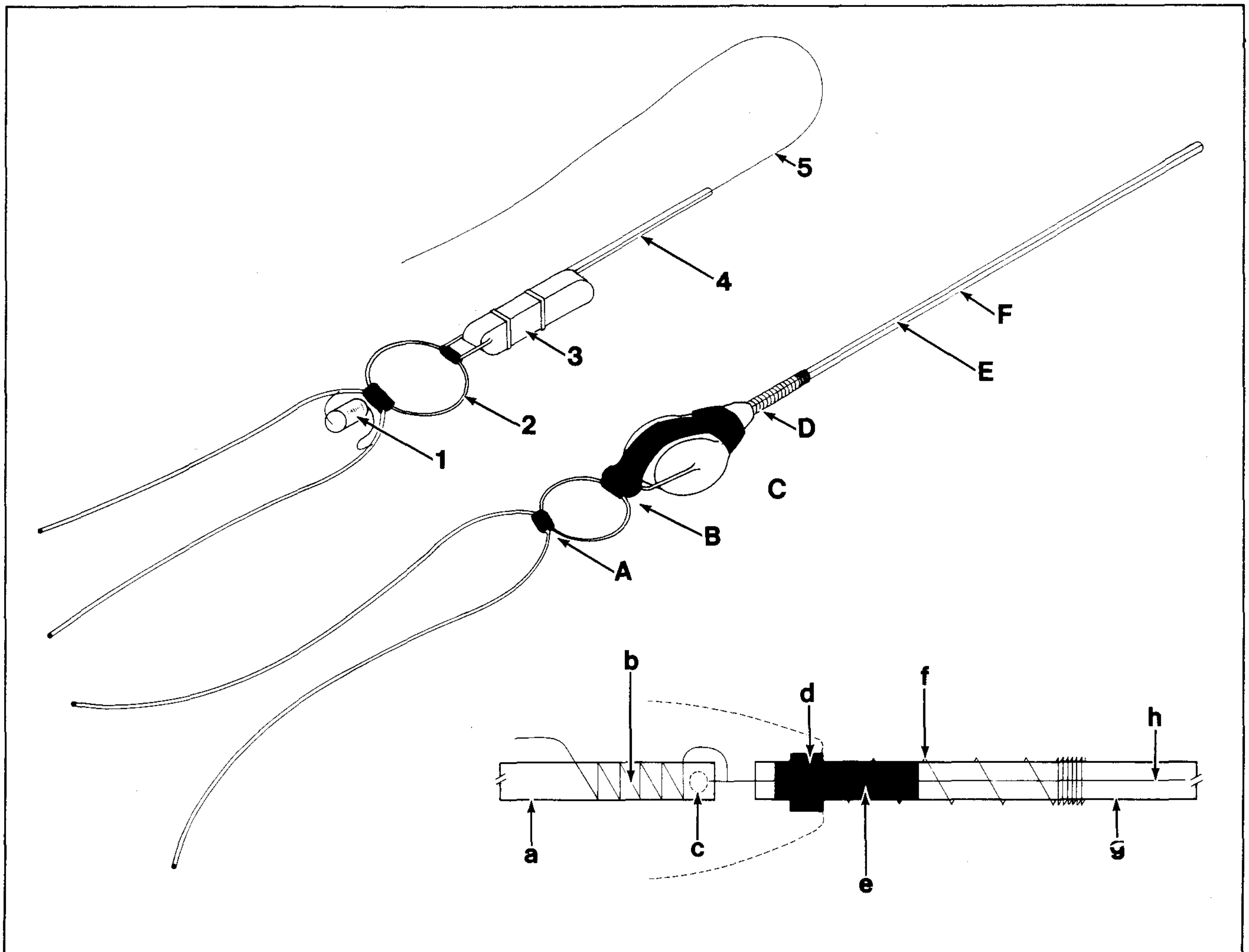


FIGURE 8. The transmitter described by Brander (1968) and the model used in this study are depicted for comparison. Brander transmitter: 1. battery; 2. harness incorporating battery leads; 3. component package; 4. plastic tubing; 5. whip antenna. Our transmitter: A. harness junction formed by square knot with cover of electrical tape; B. harness junction formed as described in Figure 2; C. transmitter package including battery encapsulated with dental acrylic; D. antenna protective system pictured in detail in Insert; E. gold-plated whip antenna; F. polyvinyl chloride tubing encasing entire antenna. Insert: a. polystyrene rod, dia. 1/8-inch; b. loading coil; c. whip antenna imbedded in base of polystyrene rod; d. copper ring, width 1/8-inch, i.d. 1/8-inch, o.d. 3/16-inch; e. single turn of electrical tape; f. ball-point pen spring; g. vinyl tubing, gauge 14 or 16; h. whip antenna, gold-plated steel guitar string (B-flat). The copper ring is cinched over the vinyl tubing and anchored with the pen spring in the dental acrylic. The single turn of electrical tape protects the P.V.C. from the chemical reaction during curing of the acrylic and prevents severing of the P.V.C. by the copper ring.

All antenna breakage recorded after the incorporation of the spring-P.V.C. system was due to corrosion of the guitar wire. Plastic spray reduced corrosion but did not eliminate it. Gold-plated guitar wire was tested with the 25 transmitters purchased from the A.V.M. Instrument Company in the final year of study, and to date appears to be the best alternative tested. Only one example of antenna breakage occurred in this sample. It occurred after 5 months of field life on the transmitter. Fortunately we were able to monitor the bird daily in spite of the broken antenna, until the battery expired 4 months later. Field life for 14 additional transmitters exceeded 5 months, with 7 of these units functioning for 8 months or more. In 4 of these cases, 2 birds carried the transmitter before its battery life was exhausted. Of the remaining 10 transmitters, 2 were suspected premature failures and 8 were destroyed by predators and not suitable for continued field use. An examination of the transmitters that were on pheasants for more than 5 months revealed that the pen spring should also have been gold-plated.

Certainly, improvements can be made on the harness and antenna systems reported here, but these modifications have improved our transmitter package for pheasants and should give other investigators a starting point for further refinements.

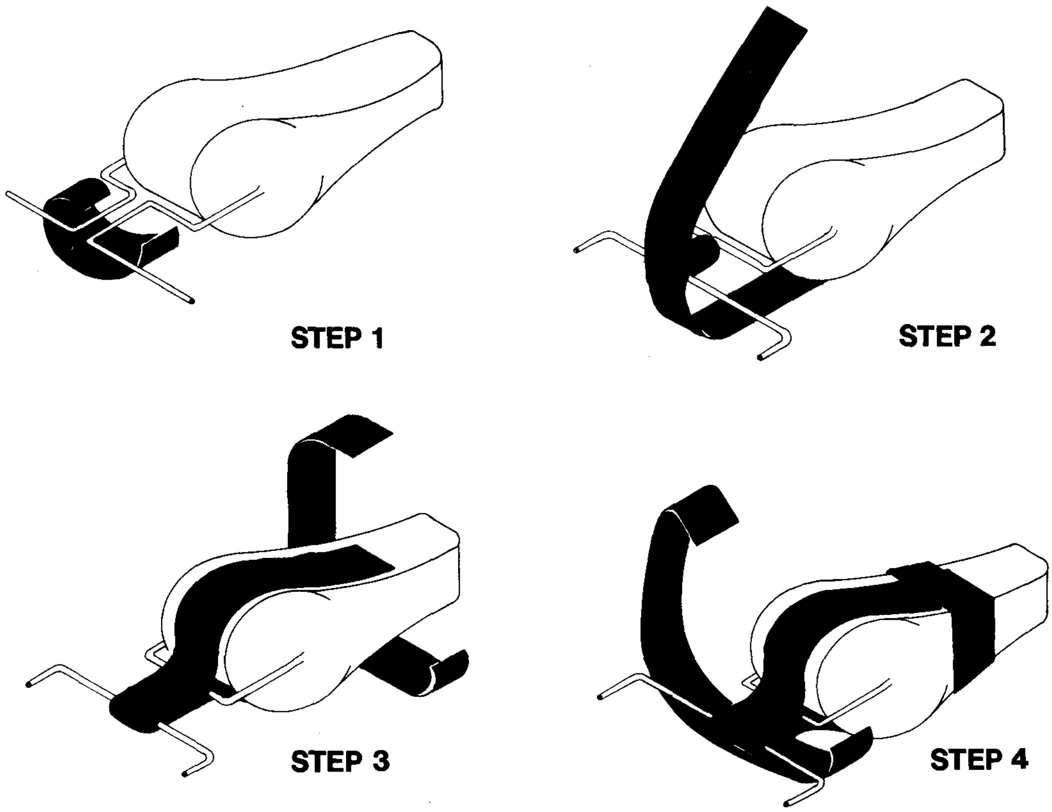


FIGURE 9. Procedure used to anchor harness to transmitter package with cold-weather electrical tape.

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APPENDIX II: Adjustment to the Radio Transmitter

In most reports of investigations involving the use of radio telemetry on free-roaming individuals, statements such as "the radio did not impair the bird's natural behavior" or "the transmitter did not make the bird more vulnerable to predation" were inevitably present. The objective of this appendix is to examine these statements relative to the findings of this investigation.

We believe an animal's behavior is unconditionally altered from the moment it is initially captured and handled. Equipping of an individual with leg bands and a backtag or transmitter further changes its behavior. The important element to determine is the degree to which the individual's behavior is modified. Most often a change in behavior is tolerated if it is not drastic. This is especially true when the tagging device does not permit free contact with the individual to regularly determine its status. Most radio telemetry studies give the investigator the option to observe the individual at any given moment. Thus, adjustment of the animal to the tagging device can be followed rather closely. Adaptation problems associated with other devices such as collars, streamers, backtags and wing clips are not as easily identified as with radio tags.

In this investigation, many techniques were used to evaluate the impact of radio-equipping on pheasant behavior. The history of the evaluation dates back to pen studies in the fall of 1967. Numerous transmitter designs were tested on fully grown hen and cock pheasants at the Poynette Game Farm. Behavior during initial adjustment to the various radio packages was carefully documented. Certain types of aberrant behavior such as rolling over backwards and excessive preening were noticed with some transmitter designs. Most birds displayed initial flight problems with all harness systems tested but adjusted quickly to the change in weight distribution. More subtle modifications in behavior were reflected in abnormal weight loss and in interactions with other birds. The optimum transmitter weight and most acceptable harness system were developed based on behavioral response of the birds to the various experimental designs.

In the latter stages of the pen study, birds were equipped with operating transmitters and monitored while under visual observation. This permitted matching of characteristic radio signal modulations with corresponding aberrant behavior. Thereafter, the adjustment of a bird to the transmitter in the field could be crudely measured from interpretation of radio signals. Initially, game farm birds were released at Waterloo to develop the logistics of radio-tracking. Hourly checks were made on the liberated birds to monitor their response to the transmitter and their new environment. Most pen-reared birds adjusted to both within 2-3 days based on an interpretation of radio data.

Similar intensive monitoring of radio-equipped wild birds revealed most individuals adjusted to the radio within 1-2 days. Evaluation of adaptation to the transmitter was measured directly by (1) the incidence of radio signals indicative of aberrant behavior, (2) the performance of an individual in flight, (3) movement and activity patterns, and (4) social interactions, and indirectly by (1) weight gain, (2) breeding success, and (3) mortality rates. Of the direct factors, (1), (2) and (4) are self-explantory, or have been previously discussed. Item (3), movement and activity patterns, refers primarily to a tendency among recently radio-tagged birds to become secretive for a short period of time after release with the transmitter. A good indication that a bird is adapting to the radio comes when it rejoins other birds and begins moving with them between roosting and feeding sites.

Of the indirect factors used to crudely measure adaptation to the transmitter, (1) and (2) deserve further elaboration. The comparison of mortality rates between the radio-tagged sample and the population as a whole was extensively discussed in the text. Weights were obtained each time an individual was handled. However, only 72 birds (of 245) were recaptured at least once so weight data were limited. Nonetheless, the weights of the recaptured birds never departed more than ±15 percent from the seasonal mean for initially captured birds of comparable age. This was well within the range of weight of roughly ±25 percent exhibited by the initially captured individuals. The only conclusion that can be made from these data is that no birds recaptured suffered excessive weight loss.

Johnson (1971) tested the survival of radioed and nonradioed game farm cocks from an early fall release to the hunting season. He found no significant difference in weight loss or survival between the two groups. Further details of this experiment can be found in the text (page 52).

Breeding success was also used as an indicator of the impact of radio-tagging on behavior. Fifty percent of tagged hen alive at the onset of the breeding season eventually produced broods. This compares favorably with a comparable figure of 52.8 percent computed for the Waupun breeding population by Gates (1971:489).

Although all evidence from the preliminary tests revealed pheasants adjusted to the transmitter within 48 hours, birds lost within 5 days of capture were disregarded in all mortality rates and factors analyses reported in the text. This reflects a conservative compensation for potential transmitter related mortality based on the experience of this investigation. However, the 5-day period was consistent with the findings of Boag (1972) who evaluated the effects of radio packages on activity, food intake and the use of different habitat types on penned red grouse. He found that differences in levels of activity and food intake between the radio-tagged and control groups were most apparent in the first week after tagging but became roughly comparable thereafter. The use of different habitats were similar among both samples of grouse during the entire test period. Boag also noticed a great amount of individual variation in behavioral response to handling and tagging. This confirms our findings from both pen and field studies.

The fates of 28 birds lost within 5 days of capture can be found in Table 28. Predation was the most important mortality factor among birds in this cohort with the importance of winter evident here as it was with the sample discussed in the text. The single example of death by cock fighting involved a male that was apparently successfully defending a territory until his aggresive behavior was greatly altered by radio-tagging. The rooster was found the day after tagging nearly dead from pecking wounds on the skull and spur wounds on the thighs and flanks.

TABLE 28. Fates of 28 Radio-equipped Pheasants Lost Within the First Five Days of Initial Capture*

Fate	January	February	March	April	September	October	December	Total Losses
Mammalian Predation	2	3	1	1		1		8
Avian Predation	3	1	1			1	1	7
Unknown Predation	1		1					2
Cock Fighting**				1				1
Unknown Cause	3		2				1	6
Technique Caused Death					1			1
Radio Failure[1]		1						1
Radio Contact Lost[1]				2				2
Total	9	5	5	4	1	2	2	28

*Sample includes 23 hens and 5 cocks.

**Case involving a radio-equipped cock that was found nearly dead from a fight with a rival cock. Bird was sacrificed by project personnel.

[1]These terms are discussed in Appendix III

APPENDIX III: Evaluation of Transmitter Performance

All 317 transmitters used in this study employed a circuit described by Cochran (1967) and a design modified from Brander (1968). Two hundred and ninety-three units were built by the University of Wisconsin Instrumentation Systems Center (I.S.C.), and 24 were provided by A.V.M. Instrument Company, Champaign, Illinois. Calculated or theoretical operational life for the radios constructed by the I.S.C. was about 120 days. Realized field life varied from 5-140 days, but most birds surviving 70 days were recaptured for transmitter replacement, and few radios were allowed to go full-term while on a bird. Transmitters built by A.V.M. were used during the final year of study and incorporated new innovations for prolonged operational life. Expected life for these units varied between 142 and 308 days while realized field life ranged from 128 to 328 days.

Among the radios constructed by the I.S.C., 53 examples of transmitter failure were reported, with 20 of them premature and 33 full-term (Table 29). In addition, faulty harness material resulted in 19 birds prematurely slipping their transmitters. Most of the premature equipment failures occurred when new components or harness systems were being tested. On one occasion Ray-O-Vac batteries were substituted for Mallory RM1 certified cells in 30 radios, and contact was lost with 12 birds within 15 days of radio-equipping. An intensive recapture program was immediately undertaken to re-equip the birds with reliable radios. Later it was discovered that the Ray-O-Vac cells were not designed to tolerate heat and were unknowingly damaged when they were soldered into the circuit. Harness failure occurred during the first year of this investigation with the use of conventional harness materials as well as experimental products. Modifications of harness design using the conventional plastic coated wire are described in Appendix I. The only experimental product which caused excessive harness failure was teflon-coated wire. It was used in a system with polyvinyl chloride tubing and became loosened allowing the bird to slip out of the harness.

In Table 29 the category of "Equipment Failure" includes all examples of transmitter or harness failure where the radio was recovered or intermittent signals from the unit revealed impending failure, and recapture of the bird was not possible. The category "Radio Contact Lost" includes cases where the bird completely disappeared and no evidence of equipment failure was noted. Six of the 31 birds in this classification were subsequently recovered, and a faulty radio was blamed for the bird's initial disappearance. However, among the remaining cases, could be (1) losses to a mortality factor where the transmitter was destroyed when the bird was killed or (2) birds that moved off the study area beyond regular search activities or (3) additional cases of transmitter failure. If all these examples involved a mortality, they would change the relative importance among the various mortality factors and the mortality rates among radio-tagged birds but only slightly.

TABLE 29. Summary of Transmitter Performance

Category	Number of Cases		
Equipment failure	72(9)*		
Transmitter failure		53	
Premature			20
Full-term			33
Harness Slippage		19	
Radio contact lost	31 (6)		
TOTAL	103		

*Birds in parentheses were subsequently recovered and their ultimate fates known.

APPENDIX IV: Mortality Factors of Radio-equipped Cock Pheasants

Twenty-five cocks were radio-tagged between September, 1968 and August, 1971. The methods of capture and procedures used in radio tracking were the same as those described in the text for hen pheasants. Whereas, 20,297 bird-days were accumulated among radio-tagged hens, only 1,909 bird-days were tallied among radio-equipped cocks. Most of the roosters were tagged after the hunting season, since the likelihood of an individual surviving the life of his transmitter was far greater at that time. Eleven males were radioed in the fall, whereas 14 cocks were equipped in the winter (9) and spring (5).

The fates of these individuals may be found in Table 30. Cause-of-death was determined for 16 cocks of which 12 were gunshot mortalities. Since the harvest of wild cock at Waterloo averages 83 percent (Table 6), it was not surprising to find 75 percent of the radio-tagged roosters in the hunter's bag. Mammalian predation accounted for 3 deaths, 2 during the breeding season and one during the late winter period. Mortality evidence found at the feeding site of Cock 90 was similar to that described for Hen 213 (page 28), and species identification of the predator was impossible. Field sign at the kill site of Cock 98 was the most unusual we encountered during the entire investigation.

Cock 98 was defending a territory centered along a brushy ditchbank in the Klecker Shrub Carr area when he was killed on May 28, 1969. The mostly intact carcass was found among jewelweed and canary grass under a canopy of dogwood at the focal point of the rooster's territory. The carcass was almost completely stripped of feathers including the wings. The head and neck were removed and the skull was found nearby completely cleaned of flesh and brain tissue. The lower mandible was not found. No other flesh or viscera was missing. Numerous feathers, most of which showed chewing, were scattered in a 5-foot circle around the carcass. Maggots were present along the legs and crop area. A den hole about 3 inches in diameter was located 3 feet from the carcass. No fresh tracks could be found at the carcass or den site but raccoon tracks were present along the ditch 10 feet from the remains.

Although the evidence appeared superficially like raptor feeding, mammalian predation was suspected based, primarily, on chewing of the feathers. "Dressing" of the carcass was not observed in any cases of mammalian predation but has been attributed occasionally to mustelids. Cock 243 was lost to a mink but "dressing" of the carcass did not occur.

Cock 243 was associated with the Abendroth Marsh prior to his death on April 1, 1971. The partially consumed carcass was found in a picked corn field among foxtail and quack grass. The head, neck, heart and liver were missing along with 80 percent of the breast. Very little flesh was removed from the wings and the legs were completely intact. A trail of blood and feathers showed the bird was killed in a nearby roosting site and pulled under a canopy of foxtail and quack grass where feeding took place. Mink tracks were present at the kill and feeding sites.

The only similarity between this case and the previous one is that feeding began with the head and neck region. Raptors also seemed to prefer feeding initially from the anterior portion of the bird.

One cock was lost to avian predation and that occurred during the period of snow cover. Most of the carcass was carried from the feeding site where the transmitter was found. Raptor tracks were present in the partially crusted snow.

Cock 98 found along a brushy ditchbank: unknown predation

TABLE 30. Fates of 25 Cocks Radio-equipped September, 1968 to August, 1971

Season*	Bird Days	Mortality: Mammalian Predation	Mortality: Avian Predation	Mortality: Gunshot	Mortality: Unknown	Mortality: Subtotal	Technique Caused Mortality	Radio Failure
Post-brood-rearing (Aug. 28–Oct. 15)	265						1	
Hunting (Oct. 16–Dec. 14)	220			12		12		4 (3)**
Snow cover (Dec. 15–Feb. 18)	244		1			1		1
Late winter (Feb. 19–Apr. 14)	522	1				1		2
Breeding (Apr. 15–June 28)	487	2			1	3		4(2)
Brood-rearing (June 29–Aug. 27)	171							2(1)
TOTAL	1,909	3	1	12	1	17	1	13(6)

*Seasons were established for hens and are not totally appropriate for cocks.
**Birds in parentheses subsequently recovered and cause-of-death determined (All were gunshot mortalities).

APPENDIX V:
Scientific Names of Plants and Animals Used in the Text

Scientific names of plants from Fernald (1950); birds, Gromme (1963); and mammals, Jackson (1961).

PLANTS

Aster	*Aster* spp.
Bromegrass	*Bromus intermis*
Canary grass	*Phalaris arundinacea*
Cherry tree	*Prunus* spp.
Giant ragweed	*Ambrosia trifida*
Goldenrod	*Solidago* spp.
Gooseberry	*Ribes* spp.
Jewelweed	*Impatiens biflora*
Nettle	*Urtica dioica*
Quackgrass	*Agropyron repens*
Red-osier dogwood	*Cornus stolonifera*
Sedge	*Carex* spp.
Shagbark hickory	*Carya ovata*
Tamarack	*Larix laricina*
Thistle	*Cirsium* spp.
Thornapple	*Crataegus* spp.
White Oak	*Quercus alba*
Willow	*Salix* spp.

BIRDS

Barred owl	*Strix varia*
Broad-winged hawk	*Buteo platypterus*
Cooper's hawk	*Accipiter cooperii*
Crow	*Corvus brachyrhynchos*
Goshawk	*Accipiter gentilis*
Great Horned owl	*Bubo virginianus*
Long-eared owl	*Asio otus*
Marsh hawk (Harrier)	*Circus cyaneus*
Pheasant	*Phasianus colchicus*
Red-shouldered hawk	*Buteo lineatus*
Red-tailed hawk	*Buteo jamaicensis*
Rough-legged hawk	*Buteo lagopus*
Ruffed grouse	*Bonasa umbellus*
Screech owl	*Otus asio*
Sharp-skinned hawk	*Accipiter gentillis*
Short-eared owl	*Asio flammeus*

MAMMALS

Badger	*Taxidea taxus*
Cottontail rabbit	*Sylvilagus floridanus*
Coyote	*Canis latrans*
Dog	*Canis domestica*
Gray fox	*Urocyon cinereoargenteus*
House cat	*Felis catus*
Mink	*Mustela vison*
Opossum	*Didelphis marsupialis*
Raccoon	*Procyon lotor*
Red fox	*Vulpes fulva*
Skunk	*Mephitis mephitis*
Weasel	*Mustela frenata*

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