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Effectiveness of Shelterbelts In Improving Microclimatic Conditions for Pheasants In Eastern South Dakota

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EFFECTIVENESS OF SHELTERBELTS IN IMPROVING MICROCLIMATIC CONDITIONS FOR PHEASANTS IN EASTERN SOUTH DAKOTA

BY

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EFFECTIVENESS OF SHELTERBELTS IN IMPROVING MICROCLIMATIC CONDITIONS FOR PHEASANTS IN EASTERN SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

To evaluate wintering habitat for ring-necked pheasants (Phasianus colchicus), this study compared microclimate regimes, as determined by wind and temperature, between shelterbelts containing 1 or 2 rows of coniferous tree species with shelterbelts comprised entirely of deciduous tree species and between wetland and shelterbelt habitats. Maximum temperatures within both shelterbelt types, particularly deciduous shelterbelts, were cooler than outside ambient air temperature during summer. Throughout November, December, and January, minimum temperatures in coniferous shelterbelt types were significantly ($P \leq 0.04$) warmer than deciduous shelterbelt types. Effectiveness of shelterbelts in reducing wind velocity decreased from an average of 71% during summer to 28% during winter. Horizontal vegetation density at roost sites in wetlands was significantly ($P = 0.001$) more dense than that found in shelterbelts. Wind velocity at roost sites in wetlands was reduced 95% more than that found in shelterbelts. Management implications concerning design of shelterbelts for improving microclimatic conditions for pheasants during winter are discussed.

Key words: ring-necked pheasant, South Dakota, shelterbelt, wetlands, microclimate, cover use

INTRODUCTION

The Timber Culture Act of 1873 and South Dakota's tree planting bounty laws of 1890 and 1920 were the initial monetary incentives for planting 0.4-16.0 ha tracts of trees, called tree claims, on the prairies of South Dakota (Griffith 1976). Passage of The Prairie States Forestry Project of 1935-1942 resulted in the subsequent planting of 32,000 km of multi-row shelterbelts in 6 of the Great Plains States including South Dakota. Shelterbelts were designed to protect topsoil from wind erosion, control drifting snow, protect crops from hot drying wind during summer, and add beauty to South Dakota's prairie landscape. An unplanned benefit of these shelterbelt plantings has been their value to many species of wildlife (Walker and Suedkamp 1977).

Although farmstead shelterbelts, field windbreaks, and other wooded habitats comprise < 3% of the total area in the Great Plains (Griffith 1976), the value of these wooded habitats has been demonstrated for several species of wildlife (Popowski 1976, Martin 1978). Many field windbreaks are being removed to make more land available for agricultural production or to make way for the installation and use of irrigation systems. In South Dakota, 99,190 ha of shelterbelts have been established during the last 60 years. Over the past 22 years, 7,287 ha of shelterbelt habitat have been allowed to deteriorate into marginal or poor condition. An additonal 16,600 ha will similarly deteriorate or be removed during the next 10 years unless actions are taken to rejuvenate these shelterbelts (Walker and Suedkamp 1977).

The effects of shelterbelts on pheasant numbers have been reported for many states (Lyon 1959, Hanson and Labisky 1964, May 1978, Yahner 1981, and Warner and David 1982). In Illinois, Hanson and Labisky (1964) found that shelterbelts were used in winter primarily for shelter, while the cool and moist microclimate offered by woody cover was beneficial for brood rearing. They felt autumn woody cover was more important to pheasant survival than the protection offered by woody cover during winter.

Warner and David (1982) found that mortality and the subsequent decline in pheasant populations were due in part to exposure to precipitation and severe wind chill during winter. Pheasants use woody cover as loafing sites in winter because it provides protection from adverse weather, predators, and man (Robertson 1958). During periods of low temperatures and moderate to high winds, shelterbelts modify the microclimate, thus affecting foraging strategies, habitat use, and metabolic demands of birds (Grubb 1977, Mayer et al. 1979). Small trees and shrubs, which offer more protection because of plant growth form and irregular distribution, were used by pheasants during the winter in Illinois (Hanson and Labisky 1964). Although Warner and David (1982) observed that mortality was evident even in dense deciduous plantings, survival of pheasants may have been enhanced where multiple row plantings of conifers and other dense cover plantings were abundant.

The extent of pheasant use of shelterbelts may be a function of snow depth, fluctuations in pheasant population densities, or proximity to alternative food sources (Gates and Hale 1974, May 1978, Yahner 1981). Bue (1949) determined a maximum of 0.8 km travel radius around pheasant winter loafing areas in South Dakota, and Grondahl (1953) and

Weston (1954) reported winter travel radii of 0.63 km and 0.74 km, respectively, in Iowa.

Sather-Blair and Linder (1980) evaluated use of wetlands by wintering pheasants in eastern South Dakota. They found that wetland size and presence of emergency cover (tall woody and herbaceous cover) around a wetland were the most important factors influencing the amount of pheasant use. In years of heavy snowfall, pheasants move into coniferous and dense deciduous shelterbelts after wetland areas become filled with snow (Hanson 1958, Trautman 1982). Shelterbelts can be an important form of emergency cover for pheasants in South Dakota, particularly during cold winters with abnormal amounts of snow (Trautman 1982).

While shelterbelts and riparian woodlands are generally recognized as important habitat components for ring-necked pheasants (Yahner 1981, Walker and Suedkamp 1977), there is a need to identify specific shelterbelt characteristics important to pheasants in order to improve management efforts and generate wildlife habitat criteria for shelterbelt design.

OBJECTIVES

This study was initiated to compare seasonal characteristics of shelterbelts containing 1 to 2 rows of coniferous tree species with shelterbelts comprised entirely of deciduous tree species and to evaluate wetlands and shelterbelts as wintering habitat for pheasants. Microclimate regimes, as determined by wind and temperature, in relation to habitat structure of shelterbelts and wetlands were evaluated and compared. The following null-hypotheses were formulated to test differences in shelterbelt and wetland habitats.

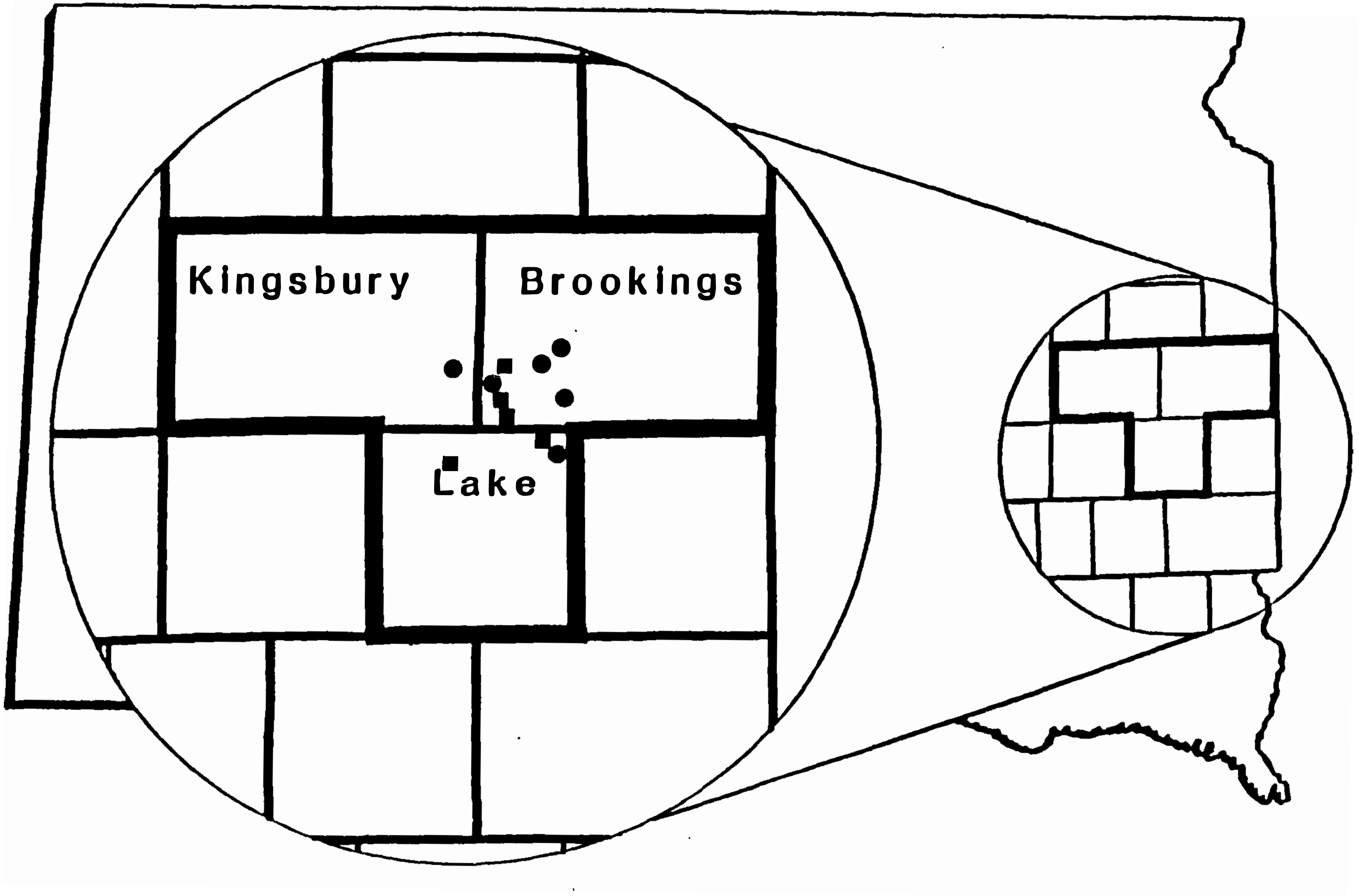
1. The effects of vegetation structure on microclimate are not significantly different ($P \leq 0.05$) between conifer and deciduous shelterbelt types.
2. Microclimate within a shelterbelt, as determined by wind and temperature, is not significantly different ($P \leq 0.05$) than microclimate at roosting sites of pheasants in wetlands.

Several field objectives were identified to provide the data necessary to test these null-hypotheses. To evaluate shelterbelt quality as winter habitat for ring-necked pheasants, microclimate and habitat characteristics of shelterbelts containing coniferous trees were compared with shelterbelts comprised of deciduous trees only. Microclimate was quantified in wetlands at roosting sites and was compared to general shelterbelt habitats. Long axis orientation of all shelterbelts was evaluated to determine drifting patterns of snow and its effects on pheasant use. Ground cover, tree density, shrub density, and sapling density were evaluated for the shelterbelts.

STUDY AREA

The study area lies in the Coteau des Prairie region of eastern South Dakota. Shelterbelts used in the study were located in Brookings, Lake, and Kingsbury counties in east-central South Dakota (Fig. 1). Topography varies from flat to undulating hills. Shelterbelt densities in these 3 counties are among the highest in South Dakota ranging from 4.1 shelterbelts planted per 2.6 km^2 (1 mi^2) in Lake county to 2.9 per

Fig. 1. Location of shelterbelt study plots in east-central South Dakota. Squares (■) indicate location of deciduous shelterbelt types and circles (●) indicate location of coniferous shelterbelt types.



2.6 km^2 in Brookings county (Walker and Suedkamp 1977). Land use in eastern South Dakota is primarily livestock production and cultivation of small grain and corn. The growing season extends from April through September.

The region is dominated by a continental climate with annual temperature extremes ranging from -29 C during winter to 38 C in the summer (Spuhler et al. 1971). The mean annual temperature range in the state is 9 C in the south to 7 C in the north. Subhumid conditions prevail with mean annual precipitation of 63.5 cm. Average annual snowfall is 60.1 cm per year (Spuhler et al 1971).

Soils vary from level, medium to fine-textured in the bottomlands to gently sloping, medium-textured in the central upland. Soil types in the area are Entisols, Mollisols, and Inceptisols (Westin and Malo 1978).

Tree species planted in shelterbelts vary according to soil types. Shelterbelts vary in size and composition and are comprised of a variety of tree and shrub species. Green ash (Fraxinus pennsylvanica), Siberian elm (Ulmus pumila), and Tartarian honeysuckle (Lonicera tartaria), are found in the majority of shelterbelts throughout South Dakota (Walker and Suedkamp 1977).

METHODS AND MATERIALS

Microclimate Measurements

Microclimate measurements were recorded within shelterbelts from 11 July 1983 through 30 March 1984. Each month during the summer (July - September) and fall (October - November), maximum/minimum thermometers and a recording thermograph (WEATHERtronics Inc., West Sacramento, CA) were placed in 2 coniferous and 2 deciduous shelterbelt types for a period of 10 to 12 days. During the winter (December - March), thermometers also were placed in 2 deciduous and 2 coniferous shelterbelt types for a period of 10 days, but then moved to 4 other randomly choosen shelterbelts for continuous monitoring of temperature differences. Maximum and minimum temperatures were recorded every 24-hours during each study period. To reduce bias in the maximum reading due to reflectance of the sun, thermometers were placed on the north side of trees 0.3 m above ground level. Maximum and minimum temperatures at each roosting site in a wetland were taken for 1, 24-hour period and compared to shelterbelt temperatures during the winter. Data from the climatological station at South Dakota State University were used to compare microclimate temperatures in shelterbelts with ambient air temperature outside shelterbelts.

Wind velocity was recorded using 2 totalizing anemometers (WEATHERtronics Inc.) with 1 anemometer being located at randomly chosen areas in the center of each shelterbelt and the other being placed 75 m on the windward side of the shelterbelt to get an unobstructed wind reading. Six wind readings of 2 min. each were taken at 2 min.

intervals inside shelterbelts that contained thermometers. A simultaneous wind reading was taken outside the shelterbelt on the windward side. Wind readings were taken once a month during summer and fall in each shelterbelt that contained thermometers and in all shelterbelts during the winter. Wind velocity also was measured at roosting sites in wetlands and was compared with randomly chosen sites in the center of the nearest shelterbelt. All wind velocity measurements were made at 0.3 m above ground level.

Vegetation

Vegetation data for shelterbelts were collected from 8 August, through 10 September, 1983. Vegetation measurements consisting of Robel-pole, number and average heights of saplings and shrubs, and canopy cover were obtained for 15 randomly-located 0.001 ha circular plots in each shelterbelt. Placement of the first plot was determined by walking a random bearing and distance, as determined by a random numbers table, from the northeast corner of each shelterbelt. Successive plots were located by walking a random distance and bearing from the center of the preceeding plot. Bearing and distance combinations may have been modified to keep the entire plot within the shelterbelt. This process was repeated until 15 plots were completed in each shelterbelt.

All shrub stems and saplings with a diameter at breast height (DBH) < 7.7 cm were counted within the 0.001 ha plot and an average shrub and sapling height was obtained for each plot. Canopy coverage was estimated using a single Model C densiometer (Lemmon 1957) which was read at waist level in each of 4 cardinal directions from the center of the plot. Four Robel-pole (Robel et al. 1970) readings were obtained to estimate herbaceous horizontal density. Each reading was taken at a distance of 3 m and a height of 1 m in each of 4 cardinal directions from the center of the plot.

The point-centered quarter technique (Cottam and Curtis 1956) was used to obtain a sample of 4 trees in which tree species, frequency, density, and DBH were obtained. The center of each 0.001 ha plot was used as the starting point for all measurements. A condition class rating ranging from 1 to 5, with 1) indicating no apparent sign of insect, disease, or mechanical injury, through 5) all 4 trees dead, was assigned subjectively to the 4 trees utilized for the point-centered quarter technique. Height of the tallest of the 4 trees was measured using a clinometer.

At 50 random locations throughout each shelterbelt, herbaceous vegetation cover was sampled using a 20 cm x 50 cm Daubenmire frame (Daubenmire 1959). A transect was established running parallel to, and in the center of each shelterbelt. A random bearing and distance was used at increments of 14 m along the transect to determine the location of each Daubenmire plot. Within the plot, grass species were identified and recorded. Coverage of each forb and grass species was visually estimated to the nearest cm^2 . Height of the tallest grass and forb species within the plot was measured with a meter stick.

Winter vegetation density measurements in wetlands and shelterbelts were estimated using a 1 m x 1 m checkerboard. One hundred squares, each 100 cm^2, were included on the board. Density measurements were taken at each roost site in wetlands and at random locations in shelterbelts. At each site and location a density measurement was taken from a distance of 5 m and at a height of 1 m above the snow in each of 4 cardinal directions. Total number of squares obstructed were counted for each sample. A square was considered obstructed when any part of the square was covered by vegetation.

Cover Mapping

Land-use types were cover-mapped for the entire study area. Agricultural Stabilization and Conservation Service (ASCS) aerial photographs (1:8000) were used to delineate field boundaries on the cover maps. Land-use types were field verified using the cover maps and later transfered to the ASCS aerial photographs for telemetry plotting.

Capture and Marking

Attempts were made to capture pheasants with hand-held nets in conjunction with a spotlight powered by a backpack generator from February through May 1983. After 55 man-hours of spotlighting, this method was determined to be ineffective. On every occasion pheasants flushed before we were close enough to capture them with hand-held nets.

From May through August 1983, pheasant nests were located by dragging a cable and multi-layered chain between 2 vehicles through upland cover (Higgins et al. 1969). Hen pheasants found on nests were later captured using spotlighting and hand-held nets. Four hen pheasants weighing greater than 800 g were fitted with a backpack radio transmitter, Model RB5 (Telonics Inc., Mesa, AZ) using this technique.

Nightlighting, using a four-wheel drive truck with a cluster of 6 roof-mounted floodlights was used during the fall (Labisky 1968). The floodlight cluster consisted of four 150,000 candlepower and two 300,000 candlepower floodlights. The floodlights were adjusted to yield a semicircle of light extending approximately 10 m on either side of the vehicle and 30 m forward. Pheasants were located at night by cruising, at about 2.4 m/s (5 mph), through fields that offered roosting cover, such as hayfields, edges of wetlands, and idle upland cover. When a roosting bird was observed in the arc of the floodlights, an additional hand-held spotlight was switched on, pinpointing the location of the bird with the spolight beam, and the overhead floodlights were switched off. Hand-held nets were then used to capture the blinded pheasants. Twenty-one hen pheasants were fitted with a backpack radio transmitter using this method.

Walk-in traps baited with corn were used to capture pheasants during the winter of 1983. Backpack radio transmitters were placed on 2 hens captured using this method.

Sex, tarsus length, wing length, and weight were recorded for each pheasant captured. An aluminum leg band, size 16, was placed on 1 leg and a plastic bandette leg band (National Band and Tag Co., Newport, KY) was placed on the other leg of each pheasant. Pheasants that had transmitters attached were anesthetized using methoxyflourine to reduce handling trauma (Smith et al. 1980). An elastic loop was placed around each wing to attach the transmitter to the pheasant. The lithium battery powered transmitters were equipped with mortality sensors and weighed 33 g.

Telemetry

Pheasants were monitored using vehicle-mounted, double-yagi, antenna systems in conjunction with a null-peak combiner (Telonics Inc., Mesa AZ) attached to scanning recievers (Model TR-2 and Model TS-1, Telonics Inc.) Frequency range was from 150.000 to 152.000 MHz. A majority of the data was obtained using 2 trucks each having a dual, 2-element yagi antenna system mounted in the bed (Hallberg et al. 1974). Winter data were obtained using antenna systems mounted through the roof of each pickup (Greig D. Jones, Boone, IA, pers. comm.). Each antenna system consisted of a dual, 4-element yagi (Advanced Telemetry Systems, Inc., Bethel MN) in conjunction with a null-peak combiner. Winter weather severity made telemetry readings difficult with the original antenna system. Three simultaneous triangulations from known positions were made on each pheasant to increase location accuracy. Accuracy of the first antenna systems were calibrated at ± 2.45 degrees ($P \leq 0.05$) up to a distance of 1.6 km using 4 transmitters placed at known angles from given locations. Accuracy of the second system which was mounted through the roof was calibrated at ± 1.45 degrees ($P \leq 0.05$) using the same methods as described earlier. Although both systems utilized a compass rose to obtain bearings, the latter system used during the winter was more efficient, accurate, and durable.

Telemetry observations for each radio-tagged pheasant were made once every 48 hours during 1 of 3 time periods: morning (0500-1000), noon (1030-1600), and evening (1630-2200). Observation periods were rotated in a random systematic manner to reduce bias. Telemetry data on each pheasant were collected as a series of 6 fixes which resulted in 3 pairs of simultaneous readings.

Telemetry Plotting

All telemetry fixes were first manually drawn to scale on cover maps. Each map contained land-use data for the area occupied by each pheasant. If an aberrant fix was noted, that fix was not used in the analysis, whereas if multiple aberrant fixes were noted, the entire set of 6 fixes was not used in the analysis. The remaining sets of fixes, for individual birds, were then plotted using the computer program TELEM (an interactive computer system to analyze radio telemetry data) (Koeln 1980) in conjunction with a Model 8 IBM 3031 computer and a CALCOMP 1051 drum plotter. To locate each pheasant location, TELEM combined the usable fixes and plotted 1 average location from every combination of pairs of possible fixes using the CALCOMP drum plotter. The CALCOMP plots, at the same scale as the cover maps were overlaid on the land-use cover maps. The respective placement of each pheasant location was plotted on the cover map and land-use was recorded. Land-use by pheasants was recorded by season and time period. Distances from the plotted pheasant locations to the nearest shelterbelt (any tree lot consisting of 4 or more rows) and wetland (edge of semipermanent wetland) were measured and distances were recorded.

Data Analysis

Data were analyzed using Statistical Analysis Systems (SAS) software packages (Ray 1982) in conjunction with a Model 8 IBM 3031 computer at South Dakota State University, Brookings, South Dakota. Tests with $P \leq 0.05$ were considered statistically significant.

RESULTS

Microclimate Measurments

During periods of low temperatures and moderate to high winds in winter, sheltered habitat can reduce energetic and food requirements for birds (Grubb 1976). The ability of 2 shelterbelt types to moderate winter temperature and wind velocity was analyzed. Differences between average maximum (avemax) and average minimum (avemin) temperatures inside coniferous and deciduous shelterbelt types were tested using nested analysis of variance for each 10 to 12-day study period (Table 1). In July, avemax temperatures were significantly ($P = 0.013$) higher in coniferous than in deciduous shelterbelt types. The temperature discrepancy may be due to the dense overhead canopy found in deciduous shelterbelt types resulting in more shade during the day. Avemax temperature in October was significantly ($P = 0.009$) warmer in deciduous shelterbelts than in coniferous shelterbelt types. Throughout November, December, and January, avemin in coniferous shelterbelt types remained significantly ($P \leq 0.04$) warmer than deciduous shelterbelt types. Leaf drop may allow more light to penetrate deciduous shelterbelts during the day and also allow more heat to escape through the now reduced overhead canopy at night (McLennon and Robinette 1976).

Reduced vertical diffusion and mixing of the air usually results in higher daytime air temperatures and lower nightime temperatures in sheltered habitat than ambient air temperature during summer (Rosenberg 1976). Differences between avemax inside shelterbelts and maximum ambient temperature were tested using a paired t-test to determine if

Table 1. Mean maximum and minimum temperatures recorded inside shelterbelt types for 10-12 day periods in eastern South Dakota, 1983-84. F-values are from analysis of temperature differences between coniferous and deciduous shelterbelt types.

		MAXIMUM			MINIMUM		
DATE	TYPE	N	$\bar{x}$ (s.e.)	F-value	N	$\bar{x}$ (s.e.)	F-value
July	Conifer.	20	30.3 (0.57)	9.94*	20	20.1 (0.55)	0.40
	Decid.	20	29.6 (0.60)		20	20.0 (0.53)	
Aug.	Conifer.	22	29.2 (0.36)	0.00	22	19.0 (0.43)	0.16
	Decid.	22	29.1 (0.48)		22	19.1 (0.47)	
Sept.	Conifer.	20	16.0 (1.14)	4.69	20	4.7 (1.16)	1.39
	Decid.	20	15.3 (0.99)		20	4.9 (1.09)	
Oct.	Conifer.	20	13.8 (1.18)	10.90**	20	4.2 (0.75)	0.17
	Decid.	20	14.3 (1.14)		20	4.3 (0.64)	
Nov.	Conifer.	20	2.9 (0.48)	0.87	20	-0.4 (0.30)	8.04*
	Decid.	20	3.1 (0.61)		20	-1.0 (0.39)	
12/3-12/12	Conifer.	20	-5.2 (1.06)	0.00	20	-17.1 (0.83)	19.6**
	Decid.	20	-5.2 (0.94)		20	-18.1 (0.94)	
12/13-12/22	Conifer.	20	-15.7 (2.13)	0.02	20	-24.9 (1.77)	8.25*
	Decid.	20	-15.7 (2.15)		20	-25.3 (1.76)	
12/30-1/10	Conifer.	20	-0.5 (1.16)	7.00*	20	-9.3 (1.71)	7.00*
	Decid.	20	0.7 (0.91)		20	-10.2 (1.80)	
1/11 1/21	Conifer.	20	-13.5 (1.07)	1.90	20	-22.1 (1.29)	10.15*
	Decid.	20	-14.0 (0.88)		20	-23.6 (1.30)	
1/24 2/4	Conifer.	24	0.5 (0.45)	3.94	24	-7.9 (0.72)	0.09
	Decid.	24	1.0 (0.49)		24	-7.9 (0.70)	

Table 1. Continued.

		MAXIMUM			MINIMUM		
DATE	**TYPE**	**N**	**$\bar{x}$ (s.e.)**	**F-value**	**N**	**$\bar{x}$ (s.e.)**	**F-value**
2/19-	Conifer.	20	3.3 (0.65)		20	-2.7 (1.15)	
2/28				0.92			0.14
	Decid.	20	3.5 (0.75)		20	-2.6 (1.15)	
3/8-	Conifer.	20	-2.0 (0.85)		20	-14 7 (1.86)	
3/17				1.30			0.46
	Decid	20	-2.1 (0.83)		20	-14.5 (1.85)	
3/21-	Conifer.	20	4.4 (0.48)		20	-2.4 (0.53)	
3/30				11.82**			4.29
	Decid.	20	4.0 (0.44)		20	-2.6 (0.57)	

* $P \leq 0.05$
** $P \leq 0.01$

daytime temperatures inside shelterbelts were higher due to decreased air movement and reflected and reradiated solar warmth. Although both shelterbelt types had significantly ($P \leq 0.03$) lower avemax temperatures than outside ambient air temperatures, in July and August, avemax temperatures in deciduous shelterbelt types were consistently lower than avemax temperatures in coniferous shelterbelt types (Table 2). Avemax in both shelterbelt types was usually warmer than maximum ambient temperatures from October 1983 through March 1984. Avemax in deciduous shelterbelts were significantly ($P \leq 0.04$) warmer within the shelterbelt than ambient air temperatures during November, 3 December through 12 December, and 24 January through 4 February. Both shelterbelt types were significantly ($P \leq 0.005$) warmer within the shelterbelts than ambient air temperatures from 8 March through 17 March 1984. In order to determine if shelterbelts allowed less heat to escape during evenings, a paired t-test compared differences between avemin and minimum ambient temperatures (Table 3). No difference was found between minimum temperatures except for one 10 day study period in January.

Wind velocity is a major factor in the severity of wind chill. For example, a -18 C (0 F) ambient temperature with a calm wind has no appreciable wind chill whereas a wind speed of 7.2 m/s (15 mph) has a wind chill of -32 C (-26 F) with the same ambient temperature. In order to determine if shelterbelts effectively reduced wind velocity, a paired t-test was used to compare average wind speed in coniferous and deciduous shelterbelt types with wind speed on the unobstructed windward side of each shelterbelt. Shelterbelts of both types significantly ($P \leq 0.04$) reduced wind velocity during all 3 seasons (Table 4).

Table 2. Mean maximum temperatures taken inside and outside shelterbelt types for 10-12 day periods in eastern South Dakota, 1983-84. Paired t-values are from analysis of temperature differences between inside maximum and outside maximum temperatures

		INSIDE MAXIMUM		OUTSIDE MAXIMUM		
DATE	TYPE	N	$\bar{x}$ (s.e.)	N	$\bar{x}$ (s.e.)	t-value
July	Conifer.	20	30.3 (0.57)	10	31.6 (0.89)	3.88**
	Decid.	20	29.6 (0.60)			8.84**
Aug.	Conifer.	22	29.2 (0.36)	11	30.8 (0.68)	2.50*
	Decid.	22	29.1 (0.48)			2.98*
Sept.	Conifer.	20	16.0 (1.14)	10	17.4 (2.26)	0.68
	Decid.	20	15.3 (0.99)			1.33
Oct.	Conifer.	20	13.8 (1.18)	10	12.6 (1.40)	0.44
	Decid.	20	14.3 (1.14)			1.16
Nov.	Conifer.	20	2.9 (0.48)	10	2.4 (0.93)	1.60
	Decid.	20	3.1 (0.61)			2.45*
12/3-12/12	Conifer.	20	-5.2 (1.06)	10	-7.7 (0.75)	2.02
	Decid.	20	-5.2 (0.94)			2.34*
12/13-12/22	Conifer.	20	-15.7 (2.13)	10	-18.5 (2.25)	1.57
	Decid.	20	-15.7 (2.15)			1.50
12/30-1/10	Conifer.	20	-0.5 (1.16)	10	-0.8 (1.79)	0.63
	Decid.	20	0.7 (0.91)			1.94
1/11-1/21	Conifer.	20	-13.5 (1.07)	10	-13.9 (1.27)	1.82
	Decid.	20	-14.0 (0.88)			1.09
1/24-2/4	Conifer.	24	0.5 (0.45)	12	0.4 (0.64)	0.26
	Decid.	24	1.0 (0.49)			2.25*

Table 2. Continued.

		INSIDE MAXIMUM			OUTSIDE MAXIMUM			
DATE	TYPE	N	$\bar{x}$	(s.e.)	N	$\bar{x}$	(s.e.)	t-value
2/19-2/28	Conifer.	20	3.3	(0.65)	10	2.5	(1.06)	1.98
	Decid.	20	3.5	(0.75)				1.94
3/8-3/17	Conifer.	20	-2.0	(0.85)	10	-4.0	(1.30)	3.72**
	Decid.	20	-2.1	(0.83)				3.65**
3/21-3/30	Conifer.	20	4.4	(0.48)	10	4.0	(0.82)	1.38
	Decid.	20	4.0	(0.44)				0.33

* $P \leq 0.05$
** $P \leq 0.01$

Table 3. Mean minimum temperatures taken inside and outside shelterbelt types for 10-12 day periods in eastern South Dakota, 1983-84. Paired t-values are from analysis of temperature differences between inside minimum and outside minimum temperatures

		INSIDE MINIMUM		OUTSIDE MINIMUM		
DATE	TYPE	N	$\bar{x}$ (s.e.)	N	$\bar{x}$ (s.e.)	t-value
July	Conifer.	20	20.1 (0.55)	10	20.3 (0.93)	0.43
	Decid.	20	20.0 (0.53)			0.91
Aug.	Conifer.	22	19.0 (0.43)	11	18.9 (0.68)	0.00
	Decid.	22	19.1 (0.47)			0.53
Sept.	Conifer.	20	4.7 (1.16)	10	5.3 (1.70)	0.74
	Decid.	20	4.9 (1.09)			0.46
Oct.	Conifer	20	4.2 (0.75)	10	3.1 (1.00)	0.76
	Decid.	20	4.3 (0.64)			1.33
Nov.	Conifer.	20	-0.4 (0.30)	10	-1.0 (0.41)	1.83
	Decid.	20	-1.0 (0.39)			0.50
12/3-12/12	Conifer.	20	-17.1 (0.83)	10	-17.6 (1.65)	0.55
	Decid.	20	-18.1 (0.94)			0.31
12/13-12/22	Conifer.	20	-24.9 (1.77)	10	-25.3 (2.59)	0.84
	Decid.	20	-25.3 (1.76)			0.22
12/30 1/10	Conifer.	20	-9.3 (1.71)	10	-11.1 (2.64)	1.45
	Decid.	20	-10.2 (1.80)			0.58
1/11-1/21	Conifer.	20	-22.1 (1.29)	10	-20.6 (1.68)	3.77**
	Decid.	20	-23.6 (1.30)			0.73
1/24-2/4	Conifer.	24	-7.9 (0.72)	12	-8.6 (1.14)	1.25
	Decid.	24	-7.9 (0.70)			1.39

Table 3. Continued.

		INSIDE MINIMUM		OUTSIDE MINIMUM		
DATE	TYPE	N	$\bar{x}$ (s.e.)	N	$\bar{x}$ (s.e.)	t-value
2/19-2/28	Conifer.	20	-2.7 (1.15)	10	-4.3 (0.71)	1.30
	Decid.	20	-2.6 (1.15)			1.39
3/8-3/17	Conifer.	20	-14.7 (1.86)	10	-14.3 (2.49)	0.77
	Decid.	20	-14.5 (1.85)			0.31
3/21-3/30	Conifer.	20	-2.4 (0.53)	10	-2.0 (0.84)	1.73
	Decid.	20	-2.6 (0.57)			2.84

** $P \leq 0.01$

Table 4. Means and paired t-values of average wind speed (m/sec) in coniferous and deciduous shelterbelts as compared to unobstructed wind speed outside of each shelterbelt in eastern South Dakota, 1983-84.

		CONIFEROUS			DECIDUOUS		
DATE	LOCATION	N	$\bar{x}$ (s.e.)	t-value	N	$\bar{x}$ (s.e.)	t-value
July	Inside	12	1.20 (0.26)	7.16**	12	0.40 (0.26)	15.07**
	Outside	12	2.20 (0.50)		12	1.90 (0.008)	
Aug.	Inside	12	0.70 (0.09)	9.29**	12	0.40 (0.01)	28.99**
	Outside	12	3.60 (0.61)		12	2.71 (0.12)	
Sept.	Inside	12	0.20 (0.00)	5.37**	12	0.36 (0.04)	6.53**
	Outside	12	1.22 (0.40)		12	0.90 (0.05)	
Oct.	Inside	12	0.98 (0.16)	4.62**	12	0.56 (0.14)	18.21**
	Outside	12	2.09 (0.47)		12	2.47 (0.17)	
Nov.	Inside	12	0.58 (0.03)	4.27**	12	0.15 (0.05)	11.35**
	Outside	12	1.39 (0.49)		12	0.70 (0.03)	
Dec.	Inside	36	1.73 (0.71)	13.45**	30	2.22 (0.66)	7.62**
	Outside	36	4.55 (0.35)		30	4.94 (0.45)	
Jan.	Inside	36	1.67 (0.36)	2.24*	30	1.30 (0.18)	4.70**
	Outside	36	1.96 (0.21)		30	2.18 (0.32)	
Feb.	Inside	36	2.51 (0.42)	2.14*	30	2.33 (0.11)	5.12**
	Outside	36	2.72 (0.47)		30	2.90 (0.23)	
Mar.	Inside	36	1.28 (0.07)	5.90**	30	0.98 (0.13)	8.65**
	Outside	36	1.72 (0.17)		30	1.56 (0.18)	

* $P \leq 0.05$
** $P \leq 0.01$

Proportional wind reduction was tested between shelterbelt types using a 2 x 4 contingency table (Table 5). Coniferous and deciduous shelterbelt types each reduced wind velocity an average of 67.9% and 73.5%, respectively, during the summer. In fall, deciduous shelterbelts reduced wind velocities (78.4%) significantly ($P = 0.001$) more than coniferous shelterbelt types (50.0%). The effectiveness of shelterbelts to reduce wind velocity decreased in winter to 32.6% in deciduous and 24.3% in coniferous shelterbelt types. Wind reduction capabilities of both shelterbelt types changed significantly ($P = 0.001$) during the 3 seasons. Leaf drop during fall, and snow accumulating in shelterbelts during winter, may have decreased the effectiveness of shelterbelt habitat to reduce wind velocity.

Analysis of variance was used to determine if there were differences in microclimate variables between roosting sites in wetlands and random locations in shelterbelts. Wetland habitat reduced wind velocity significantly ($P = 0.001$) more than shelterbelt habitat (Table 6). Maximum temperatures at roost sites in wetlands were significantly ($P \leq 0.04$) warmer than maximum temperatures in shelterbelts. No significant ($P \geq 0.22$) differences were found between minimum temperatures (Table 7). Maximum temperatures may have been biased by reflectance of the sun.

Vegetational Measurements

Nested analysis of variance was used to determine if there was a structural difference in vegetation variables measured in coniferous and deciduous shelterbelt types (Appendix 1). No significant ($P \geq 0.44$) structural difference was found in any of the variables except forb

Table 5. Mean wind speed reduction (%) from unobstructed wind outside shelterbelts to inside shelterbelts at a height of 0.3 m in eastern South Dakota 1983-84. Chi-square values are from analysis of proportional wind speed reduction between shelterbelt types and seasons.

	CONIFEROUS		DECIDUOUS		CHI-SQUARE
	$\bar{x}$	(N)	$\bar{x}$	(N)	
Summer	67.9	(6)	73.5	(6)	2.28
Fall	50.0	(4)	78.4	(4)	15.92**
Winter	24.3	(24)	32.6	(20)	19.08**
Season	58.75**		66.61**		

** $P \leq 0.01$

Table 6. Mean wind speed (m/sec) of simultaneous readings taken in shelterbelts and at roost sites in wetlands during February, 1984 in eastern South Dakota. F-values are from analysis of wind speed differences between shelterbelt and wetland habitat types.

COVER TYPE	N	x̄	(s.e.)	F-value
Nielson Shelterbelt	8	1.07	(0.05)	353.14**
Nielson Wetland	8	0.08	(0.01)	
Peterson Shelterbelt	9	0.86	(0.08)	113.98**
Peterson Wetland	9	0.04	(0.01)	
Stime Shelterbelt	7	1.88	(0.15)	140.31**
Stime Wetland	7	0.08	(0.03)	
Thompson Shelterbelt	5	2.35	(0.04)	433.78**
Thompson Wetland	5	0.17	(0.09)	
Madsen Shelterbelt	6	0.91	(0.15)	37.22**
Madsen Wetland	6	0.00	(0.00)	

** $P \leq 0.01$

Table 7. Mean maximum and minimum temperature readings taken at roost sites in wetlands and at random locations in the center of shelterbelts in eastern South Dakota, February, 1984. F-values are from analysis of temperature differences between shelterbelt and wetland habitat types.

	MAXIMUM			MINIMUM		
COVER TYPE	N	$\bar{x}$ (s.e.)	F-value	N	$\bar{x}$ (s.e.)	F-value
Nielson shelterbelt	3	2.0 (0.00)	5.58*	3	0.3 (0.33)	1.57
Nielson wetland	8	3.2 (0.31)		8	0.7 (0.16)	
Peterson shelterbelt	3	7.3 (0.67)	56.26**	3	0.3 (0.34)	1.71
Peterson wetland	9	11.3 (0.22)		9	0.9 (0.22)	
Stime shelterbelt	2	0.5 (0.50)	302.76**	2	-12.5 (0.50)	1.65
Stime wetland	7	12.8 (0.34)		7	-13.4 (0.32)	
Thompson shelterbelt	2	1.0 (0.00)	29.97**	2	-13.5 (0.50)	0.04
Thompson wetland	5	6.1 (0.56)		5	-13.6 (0.25)	

* $P \leq 0.05$
** $P \leq 0.01$

height ($P = 0.02$) and forb density ($P = 0.01$). Deciduous shelterbelt types had a mean forb density of 21.8% as compared to a mean of 10.4% for coniferous shelterbelt types. Since few structural differences were found between shelterbelt types, it would indicate that only 1 row of coniferous tree species in a shelterbelt did not alter the structural characteristics of the entire shelterbelt.

Dense horizontal cover reduces wind velocity and can enhance survival of pheasants during periods of high winds and low temperatures (Grubb 1976). In order to determine if wetlands provided more horizontal cover during winter than shelterbelts, nested analysis of variance was used to test differences in density board readings (Table 8). Wetland vegetation density was significantly ($P = 0.001$) more dense than that found in shelterbelts.

Telemetry and Cover Use

Thirty-seven hen pheasants and 25 cock pheasants were captured and marked during summer, fall, and winter, 1983-84. Transmitters were placed on 27 hens during the 3 seasons (Table 9). One hundred and forty-five telemetry locations were determined for hens during summer, 100 during fall, and 23 during winter. The small sample size during winter was due primarily to transmitter failure and a high pheasant mortality rate during severe winter storms.

Contingency tests were utilized to determine if hen pheasants used cover types in equal proportions during 3 designated time periods (morning, noon, and evening) or during 3 seasons. No significant difference ($P \geq 0.11$) was found for cover-use in any time period or season.

Table 8. Mean density board readings taken randomly in shelterbelts and at roost sites in wetlands in eastern South Dakota, February 1984. F-values are from analysis of density board readings between shelterbelt and wetland habitat types.

COVER TYPE	N	$\bar{x}$	(s.e.)	F-value
Shelterbelt	5	24.96	(2.38)	221.9**
Wetland	5	96.58	(0.49)	

** $P \leq 0.01$

Table 9. Fate of 27 pheasant hens fitted with radio backpacks in eastern South Dakota 1983-84.

ID NUMBER	DATE RADIOED	TRANSMISSION TERMINATED	TRANSMISSION LONGEVITY (Days)	CAUSE OF TERMINATION
2002	06/08/83	06/29/83	21	Avian predator
2003	06/08/83	10/08/83	122	Transmitter fell off
2005	06/27/83	01/07/84	194	Transmitter failure
2004	06/20/83	01/07/84	187	Transmitter failure
2045	10/08/83	01/20/84	104	Mammalian predator
2046	10/08/83	11/29/83	52	Unknown
2048	10/08/83	01/14/84	98	Transmitter failure
2039	09/30/83	01/07/84	99	Transmitter failure
2027	09/24/83	12/24/83	91	Transmitter failure
2011	09/16/83	12/24/83	83	Transmitter failure
2010	09/16/83	12/24/83	83	Transmitter failure
2009	09/14/83	01/07/84	115	Transmitter failure
2030	09/29/83	01/09/84	102	Unknown
2054	10/29/83	01/31/84	94	Unknown

Table 9. Continued.

ID NUMBER	DATE RADIOED	TRANSMISSION TERMINATED	TRANSMISSION LONGEVITY (Days)	CAUSE OF TERMINATION
2059	10/29/83	11/04/83	6	Unknown
2060	10/29/83	11/18/83	20	Mammalian predator
2055	10/29/83	01/31/84	94	Unknown
2024	09/22/83	01/07/84	107	Transmitter failure
2018	09/22/83	11/20/83	59	Unknown
2019	09/22/83	10/17/83	25	Mammalian predator
2020	09/22/83	01/07/83	107	Transmitter failure
2051	10/27/83	12/07/83	41	Unknown
2052	10/27/83	01/07/84	72	Exposure
2062	11/02/83	01/09/84	68	Exposure
2063	11/03/83	01/07/84	65	Unknown
2067	01/30/84	02/05/84	6	Exposure
2066	01/30/84	02/07/84	8	Exposure

Contingency tests were used to test if hen pheasants were closer to wetlands or shelterbelts. Hen pheasants remained significantly ($P = 0.04$) closer to wetlands than shelterbelts. No difference was found when distances to shelterbelts and wetlands were tested against time periods (morning, noon, and evening).

Contingency tests were used to determine if pheasant use of certain cover types is related to wind velocity or wind chill factors. No significant difference ($P \geq 0.09$) was found indicating that pheasants exhibited no land-use preference during periods of high winds or low wind chills. The small sample size (23) of telemetry locations during winter may have been partially responsible for the lack of a significant difference in cover-use.

DISCUSSION

Ring-necked pheasants need 4 discrete types of winter cover: roosting, loafing, emergency, and feeding areas. Shelterbelts, if designed properly, can provide pheasants with emergency cover from predators and snow and with roosting and loafing cover during periods of deep snow (Trautman 1982). Although shelterbelts are generally considered an important source of shade during the summer and cover in winter, several authors have found that shelterbelts did not enhance survivability of pheasants during winter (Lyon 1959, Warner and David 1982). Warner and David (1982) concluded that the establishment of linear woody plantings (especially those comprised entirely of deciduous tree species) should not be encouraged to prevent pheasant mortality during severe winter storms. Lyon (1959) found that woody windbreaks did not function effectively as winter cover in northeastern Colorado.

In this study, shelterbelts containing coniferous tree species were compared with shelterbelts comprised entirely of deciduous tree species in order to determine which shelterbelt type provided a more favorable microclimate for pheasants during winter. Actual tree species composition varied between shelterbelts with green ash, and american elm (Ulmus americana) being found in all shelterbelts (Table 10).

Both shelterbelt types, particularly deciduous, had avemax temperatures cooler within the shelterbelt than maximum ambient air temperature during summer. Dense overhead canopy and horizontal cover offered pheasants an area protected from avian predators and a cool habitat in which to raise broods. Hanson and Labisky (1964) found that cooler temperatures and moist microhabitat within shelterbelts during the intense heat of summer was beneficial to brood rearing.

From November 1983 through 21 January 1984 minimum temperatures in coniferous shelterbelts were warmer than minimum temperatures in deciduous shelterbelt types. Coniferous tree species reduce air movement and create a zone of placid air in shelterbelts. In dense cover where there is little or no air movement, the temperature within the vegetation will approach that of the ground surface, which during winter is warmer than the surrounding vegetation (Geiger 1965). Warmer temperatures are beneficial in reducing energetic and food requirements for pheasants during winter.

As the earth emits heat back to the environment in the form of long-wave radiation, obstructions such as tree limbs or canopy cover will absorb and reradiate the heat back to the earth, therefore creating

Table 10. Tree and shrub composition of shelterbelts studied in eastern South Dakota 1983-84. Numbers indicate row placement of tree species from north to south.

Species	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	SB9	SB10	SB11
Siberian elm (<u>Ulmus</u> <u>pumila</u>)	1		3,4		2	1			1,3,7		4
American elm (<u>Ulmus</u> <u>americana</u>)	2	5	5	3,4,5	3,4,5	6,7	2,5,6	6,7,8	4	3,4	2,3
Green ash (<u>Fraxinus</u> <u>pennsylvanica</u>)	3,4,5	3,4,7	1,2,6,7	1,6	1,6,7	3,9	1,3,4,7, 8,9,10	3,4,5	2,6	2,5,6	5,6
Cottonwood (<u>Populus</u> <u>deltoides</u>)		6		2		4,5					
Russian olive (<u>Elaegnus</u> <u>commutata</u>)		8				2				1	1
Burr oak (<u>Quercus macrocarpa</u>)					8						
Box elder (<u>Acer negundo</u>)						8			5		
Ponderosa pine (<u>Pinus</u> <u>ponderosa</u>)	6							2			
Eastern red cedar (<u>Juniperus virginiana</u>)		1,2		7							7
Tartarian honeysuckle (<u>Lonicera</u> <u>tatarica</u>)				8		10			8	7	8
Common lilac (<u>Syringa vulgaris</u>)	7		8		9			1			

a microclimate with a higher minimum temperature. Radiation is a form of thermal energy exchange between an animal and its environment (Moen 1973) with each surface radiating energy at wavelengths that are dependent on the temperatures of the emitting surface (Geiger 1965). Moen (1973) found that unobstructed clear sky condition provided the least amount of downward radiation while cedar (Thuja occidentalis) had the most amount of downward radiation. Ozoga and Gysel (1972) found that use of dense coniferous cover by white-tailed deer (Odecoileus virginianus) increased during periods of low temperatures and severe wind chill.

Wind velocity is the major factor effecting wind chill (the amount of heat lost from a unit of area per unit of time). Coniferous and deciduous shelterbelt types reduced wind velocity during summer an average of 67.9% and 73.5%, respectively. Whereas in winter, wind velocity was reduced only 32.6% in deciduous and 24.3% in coniferous shelterbelt types. Shrub and sapling stems can be effective in reducing wind velocity within the shelterbelt by providing horizontal cover. Leaf drop as well as shrub and sapling stems having been buried by snow accumulation resulted in lowered wind reduction capabilities of shelterbelts. An average of 82 cm of snow had accumulated in the shelterbelts by February 1984.

Heat stored in an animal is a factor of metabolic energy, heat gained or heat lost by radiation, convection, conduction, and evaporation (Robbins 1983). As ambient temperature decreases, the animal is initially able to remain within its thermoneutral zone (temperature range in which thermoregulation can occur without increasing metabolic heat production). As continued reductions in ambient temperature occur, an increase in metabolic heat production is needed if body temperature is to remain constant. In January, a pheasant needs an average of 504 kcal/day for warmth and maintenance, whereas in September only 114 kcal/day are needed (Solomon 1984). In a review on pheasant bioenergetics Solomon (1984), noted that if the habitats pheasants utilize were 3 C warmer than the surrounding air during winter, pheasants would expend 3% less energy. Three percent less energy expenditure during the winter could make the difference between survival or death, and between good or poor breeding success. With an ambient temperature of -18 C (0 F) and a wind velocity of 7.2 m/s (15 mph), wind chill in a shelterbelt exhibiting average winter wind velocity reduction (31%) would be -31 C as compared to -35 C outside the shelterbelt. Decreased wind chill in shelterbelts can allow pheasants to expend less energy and have a better chance of survival. Edwards et al. (1964) found that in some years the reproductive success and mortality of hens is partially effected by the severity of winter weather.

Wetland vegetation at roost sites reduced wind velocity an average of 95% more than shelterbelt vegetation. Reduced wind velocity in wetlands is due to the horizontal cover, consisting of cattails (Typha spp.) and phragmites (Phragmites communis). If the reduced wind velocity was 7.2 m/s in a shelterbelt with an ambient temperature of -18 C, wind chill would be -36 C, while at the same time in adjacent wetlands the wind chill would still be -18 C. During periods of moderate wind velocities, wetlands can provide pheasant habitat with a reduced wind chill resulting in a decreased energy demand during winter. Wetlands may be a preferred roosting cover during winter due to heavy vegetative protection, but shelterbelts become increasingly important to pheasants as wetlands become filled with snow (Hanson 1958, Trautman 1982)

Analysis of telemetry data indicated that transmittered hens were associated more closely to wetlands than shelterbelts. Cover density may have caused pheasants to remain in proximity of wetlands during winter weather. Transmittered hens did not appear to be selecting for specific cover types during periods of high wind velocities that would have caused severe wind chills. Sheltered habitat can reduce excessive energetic requirements by providing an area with little or no wind chill (Grubb 1976). The small sample size (23) of telemetry locations during winter may have been partially responsible for the inability to distinguish a difference in cover use. Hen pheasant movements in Wisconsin during fall and winter were not found to be related to ambient air temperature or survival, but were related to year, snow depth, and age of the hen (Gatti et al. 1983).

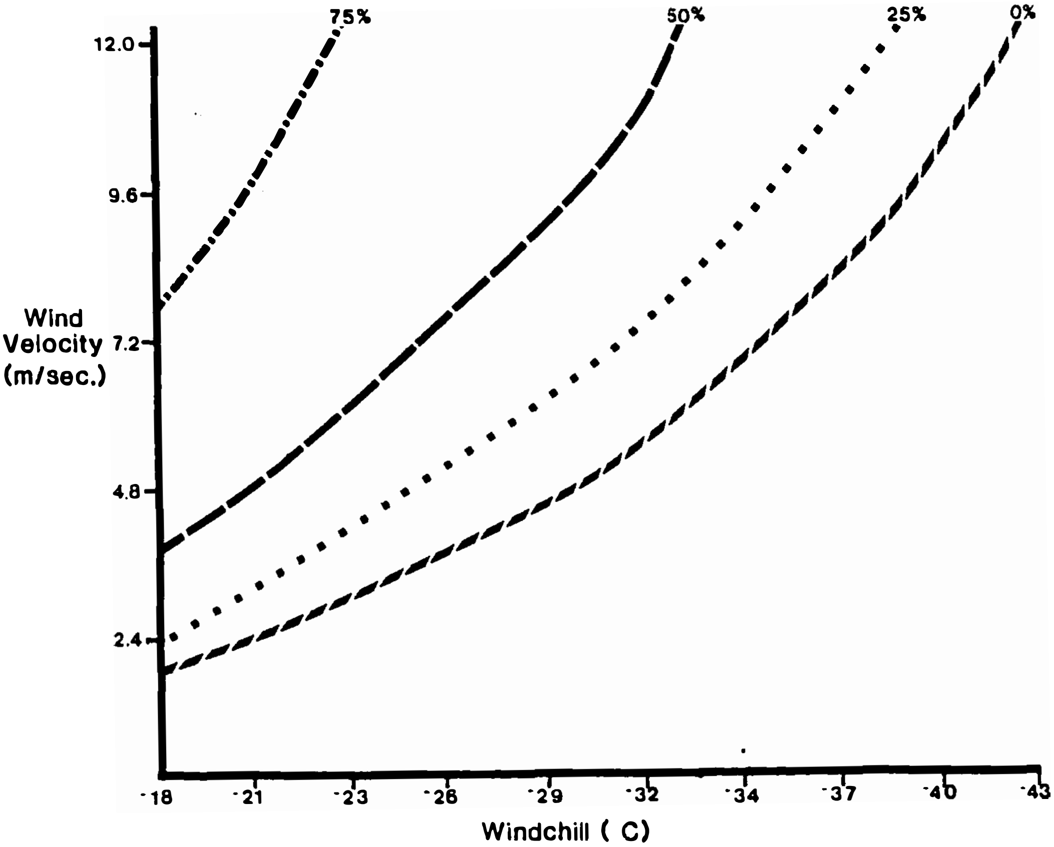
Movement and survival of transmittered hens may have been affected by the weight of the transmitter packages, since no transmittered hens survived the winter. Warner and Etter (1983) observed that reproductive success or survival beyond 3 months was unlikely for hens equipped with radio packages weighing more than 27 g.

In South Dakota, severity of winter weather to a large extent determines the proportion of the autumn pheasant population that survives to participate in the spring breeding season. Hen pheasants in poor condition at the end of winter may exhibit delayed reproduction, lower reproductive success, and higher rates of mortality (Gates and Hale 1974). Chances of survival are much better in areas with abundant, good-quality habitat dispersed throughout the winter range of pheasants. Wetlands are considered the primary winter cover type for pheasants, whereas shelterbelt cover is important for emergency cover when wetlands become filled with snow. Although shelterbelts did not reduce wind velocity as much as wetlands, shelterbelts did however reduce wind velocity an average of 31% during winter. Additional wind velocity reductions and warmer avemin temperatures could result if at least 2 to 3 rows of coniferous tree species, along with several rows of shrubs were planted in each shelterbelt. Decreased wind velocity caused by dense horizontal cover would provide a subsequent reduction in wind chill in shelterbelts (Fig. 2).

Robbins (1983) found that the insulating quality of a birds plumage is dependent on the extent to which air movement is reduced. Reduced air movement by coniferous tree species would therefore act as an additional insulating layer for pheasants during winter. Ozoga (1968) studied several white-tailed deer habitats during winter and found that warmer average temperatures, little wind movement, and minimal snow depth were characteristic of a densely stocked even age stand of mature conifers. Reduced energetic requirements during winter would allow more pheasants to survive and enter the breeding season in better condition. Hen pheasants in better condition during the breeding season would have a better chance of a successful hatch.

Properly designed shelterbelts could reduce the amount of winter

Fig. 2. Windchill at 0, 25, 50, and 75% wind velocity reductions at an ambient air temperature of -18 C.

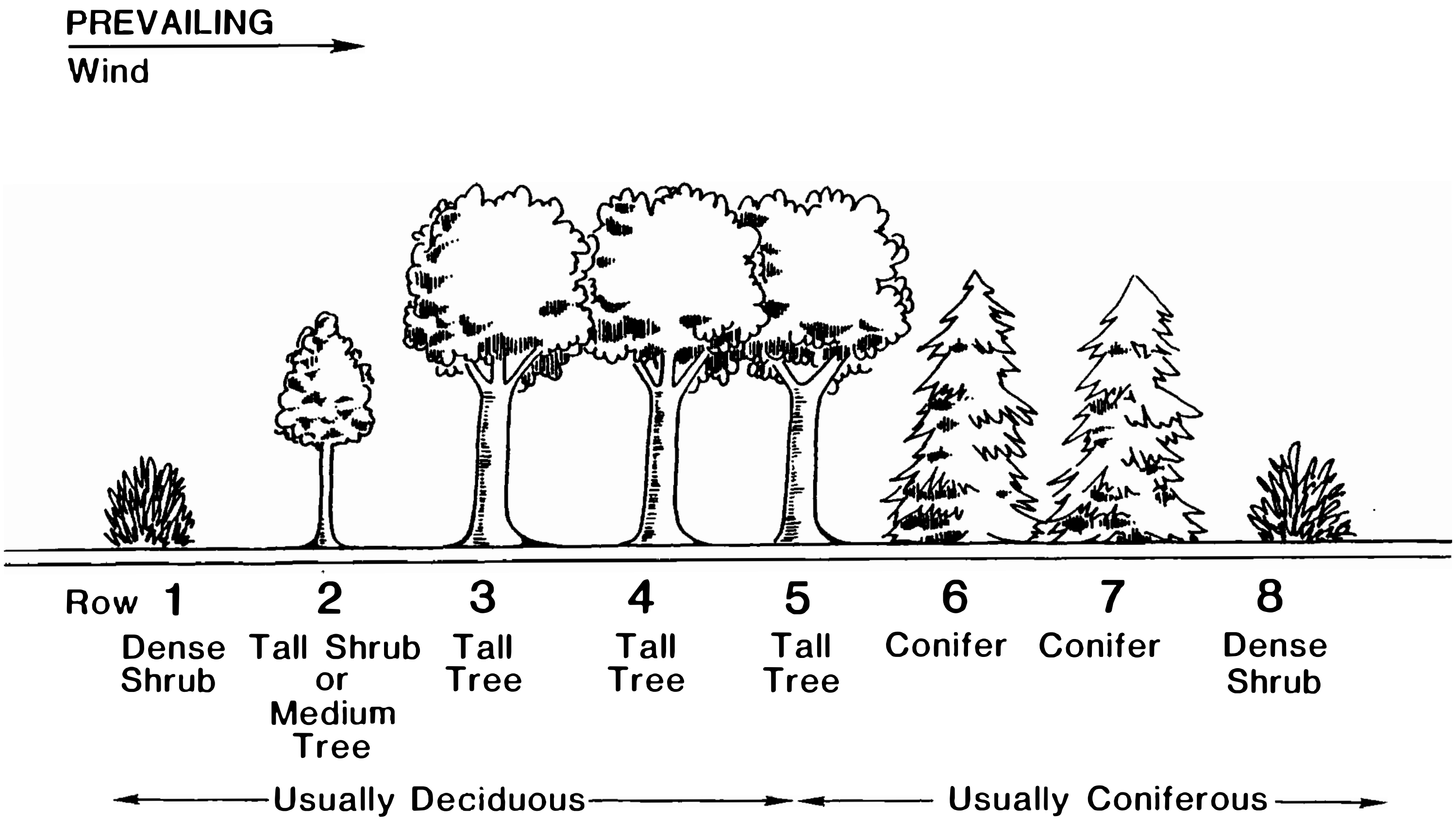


mortality and allow pheasants to enter the breeding season in better condition. Increased good quality shelterbelt habitat could result in a more stable pheasant population due to decreased winter mortality.

MANAGEMENT IMPLICATIONS

Shelterbelts designed for pheasant use should be no less than 6 to 10 rows wide and should contain at least 2 rows of coniferous tree species to provide dense cover near ground level (Fig. 3). Low dense woody vegetation is needed on the windward side of shelterbelts in order to keep wind and snow from being funneled at high speed beneath open vegetation. Shrub and tree species that provide dense cover during winter at a height of 0 to 3 m above ground level should be promoted in the outer 2 rows on the prevailing wind side of shelterbelts. Dense shelterbelts which allow little wind to penetrate would be more beneficial to pheasants than sparsely vegetated shelterbelts. However, wind reduction extends further on the leeward side of sparsely vegetated as compared to dense shelterbelts (McLenon and Robinnette 1978). Three to 4 rows of tall deciduous trees including both fast-growing and long-lived species should be promoted for the center rows of each shelterbelt. Leeward sides of shelterbelts should consist of 2 rows of coniferous tree species followed on the outside by a dense shrub row. These remaining rows on the leeward side of the shelterbelts would provide the necessary cover for pheasants during severe winter storms. The slope of the upper canopy profile should face in the direction of the prevailing winds therefore forcing the wind over the top and reducing wind velocity within the shelterbelt (Woodruff and Zingg 1953).

Fig. 3. Profile of an 8 row shelterbelt for winter protective cover of pheasants.



To benefit pheasants and other wildlife volunteer shrub growth should be promoted after shelterbelts are established. Species which provide a food source for pheasants during winter such as smooth sumac (Rhus glabra), skunkbrush sumac (Rhus aromatica), wild plum (Prunus americana), and russian olive (Eleaghnus angustifolia) should be promoted (VanBruggen 1976). Croplands, rather than pastures should be adjacent to the shelterbelt for maximum benefit to wildlife. Several rows of crops such as corn or sorghum should be left on the leeward side to provide a food source during the winter. Crop plantings should be placed on the leeward side of shelterbelts since reduced wind velocity will cause less stress to pheasants. Johnson (1953) examined placement of food plots during winter in relation to various winter cover types and found that food plots should be located within 400 m (1/4 mile) of the wintering areas.

Additional Research Needs

Additional studies should include microclimate comparisons between areas showing heavy, little, or no use by pheasants, and microclimate studies near dense cover species such as cedar and shrubs. Microclimate measurements at specific sites within a shelterbelt would indicate if there are areas within the shelterbelt that provide suffucient cover to eliminate any wind chill factor. Winter telemetry studies using light, non-metal transmitters would be useful to determine if pheasants utilize shelterbelts and wetlands in proportion to what is available.

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Appendix 1. Means of vegetation variables sampled in coniferous and deciduous shelterbelt types in eastern South Dakota, August through September 1983.

	CONIFEROUS			DECIDUOUS		
VARIABLE	N	$\bar{x}$	(s.e.)	N	$\bar{x}$	(s.e.)
Robel pole	90	1.0	(0.11)	75	1.3	(0.15)
Saplings (no./plot)	90	13.2	(2.18)	75	14.7	(1.62)
Shrubs (no./plot)	90	9.6	(1.51)	75	14.8	(2.01)
Sapling height (cm)	90	50.4	(5.26)	75	75.9	(8.52)
Shrub height (cm)	90	79.3	(8.78)	75	84.3	(7.31)
Canopy coverage (%)	90	86.8	(1.08)	75	86.3	(1.11)
Woody stems (no./plot)	90	22.8	(2.68)	75	29.5	(2.65)
Bluegrass[a] density (%)	300	0.3	(0.53)	250	0.4	(0.76)
Brome grass[b] density (%)	300	23.5	(1.54)	250	16.5	(1.46)
Grass height (cm)	300	22.1	(1.34)	250	23.8	(1.72)
Forb density (%)	300	10.4	(0.76)	250	21.1	(0.99)
Forb height (cm)	300	10.8	(0.72)	250	25.9	(1.33)
Ground cover (%)	300	43.0	(1.64)	250	48.2	(1.55)
Grass density (%)	300	27.0	(1.61)	250	20.1	(1.59)

[a] *Poa pratensis*

[b] *Bromus inermis*