MICROCLIMATIC FACTORS OF BLACKTOP ROADS AS THEY AFFECT BIRD BEHAVIOR, DIURNAL DISTRIBUTION AND RANGE

By

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A RESEARCH PAPER

Submitted to the

University of Wisconsin-Stevens Point

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in Natural Resources

College of Natural Resources

1976

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A paper submitted in partial fulfillment of the
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Master of Science
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College of Natural Resources
at the
University of Wisconsin-Stevens Point
March 1976

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Graduate School Approval ______ Date ______

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ACKNOWLEDGEMENTS

I wish to thank my retired major professor, Dr. Frederick M. Baumgartner, and Drs. Neil F. Payne, Daniel O. Trainer, and James G. Newman and all those who served on my graduate committee for their assistance and direction throughout the editing of this paper.

I gratefully acknowledge the help of Dr. Frederick Hilpert, Associate Director of Instructional Data Processing, University of Wisconsin-Stevens Point, in programming the computer for data analysis, for patient explanations of capabilities and limitations of computers and interpretation of the results.

Last in order, but not in gratitude, I wish especially to thank my parents, Dr. Philip B. Whitford and Kathryn Whitford, and my wife, Karen, for their patient and kind assistance in data collection and their subtle encouragement during the lengthy, often discouraging, process of data accumulation and analysis, and the final writing of this paper.

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Abstract

Between 11 May and 30 September 1974, 2127 birds were observed on the surface of blacktop roads. Relationships between the presence of birds on the road and air temperatures were evaluated against data from four microclimates: the road in the sun, the road in the shade, the litter layer under pines, and the ground layer in herbaceous vegetation. The presence of birds also was evaluated relative to varying cloud cover, wind velocity, precipitation, and dampness of the road surface. At the times when the maximum number of birds was present on the road surface, the temperature of the macadam road in the sun was significantly warmer than the ambient air temperature or the microclimates of the litter layer beneath the pines or the herbaceous ground layer.

It appeared that the birds used the macadam roads for warmth. The existence of the man-made microclimate of the macadam road appeared to influence bird behavior, diurnal distribution, and possibly the northward distribution of some species.

Introduction

Roads represent one of the major alterations of the original landscape and, among other changes, have altered the temperatures on and above them. To date I have found no specific investigations of the possible effects of such a microclimate upon bird life.

The objectives of this study have been (1) to define the temperature variations and relationships of the general climate and several microclimatic areas and (2) to determine to what extent temperature patterns of these various microclimates interact with the general climate to influence the daily distribution and behavior of birds.

Man only recently began to measure the differences between microclimates and the general climate and to evaluate their effects upon the biota. Rudolph Geiger assembled the available data on microclimates. The extent to which new microclimates have become available and their effects on animal populations are reflected in the following quotation (Geiger 1965: 480):

> Men are forever creating new kinds of microclimate. Every building constructed displaces the original climate with a warm, sunny, southern exposure on the one hand, and a cold, damp, and shaded northern climate on the other. A consequence of the way which animals live is that even in a small area their distribution, both by species and by number, will be adjusted to the microclimatic differences. It therefore appears that the distribution of animal life depends not only on the large scale climatic condition but on the microclimate also.

Grimms (1937) as quoted by Geiger (1965:474) stated:

> Animal geography is compelled to take the problems of

> microclimate into account. The limits of the area in which creatures are found to exist is the boundary zone where the creatures exist in pockets. In much the same way as plants, animals are able to exist in an unfavorable climate, only if they can find a place where the microclimate is favorable.

During the early 1960's biologists began to study microclimates as they related to the behavior and survival of animals. Verbeek (1964) studied the time and energy budget of the Brewer's blackbird (Euphagus cyanocephalus) on Vancouver Island, British Columbia. He found the time spent in feeding was inversely related to the temperatures. At -1.1°C the bird spent 54 percent of its time feeding during the nonroosting hours, and 56 percent at -2.2°C. Only 25 percent and 16 percent of time were spent in feeding during 2 days of 1.7°C weather. Verbeek theorized that the range of the Brewer's blackbird could not extend northward beyond that point where energy used for warmth required feeding 100 percent of daylight hours. The energy budget of the bird in times of stress, such as nesting, must allow for the energy required in reproduction. This limits the bird to locations warmer than its maximum northern survival range during non-breeding periods.

Dolnick (1971) supported Verbeek's theory. He felt that the energy expended on supporting the individual's existence approaches a linear dependence on temperature during stress-free periods.

Brewer (1963) concluded that starlings (Sternus vulgaris) were extremely temperature sensitive in the northern part of their range. As a result they are subject to mass die-offs (Forbush 1927; Odum and Pitelka 1939) in severe winter weather. Brewer believed this sensitivity was compensated for by behavioral modifications related to the specific microclimate of warm chimneys. He found a nearly linear relationship between decreasing air temperatures and increasing numbers of starlings perched on warm chimneys during winter in the Ann Arbor, Michigan, area.

During the 1960's, wildlifers began to study the importance of microclimates to nesting, and nesting success, of the ring-necked pheasant (*Phasianus colchicus*). The percent of hens nesting, density of nesting hens, and nesting success were all found to be affected by microclimates found in specific plant associations (Francis 1969).

Description of Study Area

This study was conducted in Marquette County, in central Wisconsin. The chief use of the area has recently changed from agriculture to recreation and many of the original farms are reverting to natural vegetation types. This has produced varied successional stages offering ideal habitat for many species of birds. Specifically, the study area included parts of Shields, Crystal Lake, Newton and Harris townships. Aerial photographs indicate the area is approximately $\frac{1}{4}$ white and black oak (*Quercus alba* and *Q. ellipsoidalis*) savannah remnants (Whitford and Whitford 1971) or plantations of red and white pine (*Pinus resinosa* and *P. strobus*) and $\frac{1}{2}$ open marshes and swamps of tamarack (*Larix laricina*).

Methods

Data Collection

Recorded observations of birds on the road surface were made daily from an auto traveling at a steady speed of 56 km/hr. Observations were made primarily between 1600 and 2100 hours with occasional morning and early afternoon samples. Collection of data was restricted to a standard route over roads of uniform asphalt gravel composition. Data records included the time of meeting oncoming vehicles and the time during which a vehicle ahead on the road had distrubed the birds. Data analysis used only those samples in which no other vehicles were observed.

The precise route, beginning at a farm driveway, (SE$\frac{1}{4}$, SE$\frac{1}{4}$ Sec. 31, T 17N, R 10E), was: 1.6 km west on Eagle Road; right on County Highway Y 2.4 km; 1.6 km north on 13th Court; 1.3 km north on 13th Avenue; left on County Highway Y 3.2 km to Duck Creek Road; west 5.6 km on Duck Creek Road; left on 10th Lane 2.4 km; jog left on County Highway E 130 meters and then right on County Highway B for 2.4 km. (See figures 1). The route ended at the village limits of Harrisville. The route was reversed following a 10-20 minute waiting period to allow birds to recover from disturbance caused by the author's vehicle.

Temperature data were collected using three maximum-minimum thermometers and two laboratory quality mercury bulb thermometers. The three max-min thermometers were placed as follows: one on the ground in a medium-density stand of herbaceous plants dominated by grasses, one on the litter layer in the shade of pines, and one on the north side of a pine trunk at a height of 2 m. The mercury bulb thermometers were placed on the road surface to measure road temperatures in the sun and shade. Temperatures were recorded at the beginning and end of each observation run.

Birds engaged in recognizable behavior such as eating and anting were not counted during data collection. Those whose posture or be-

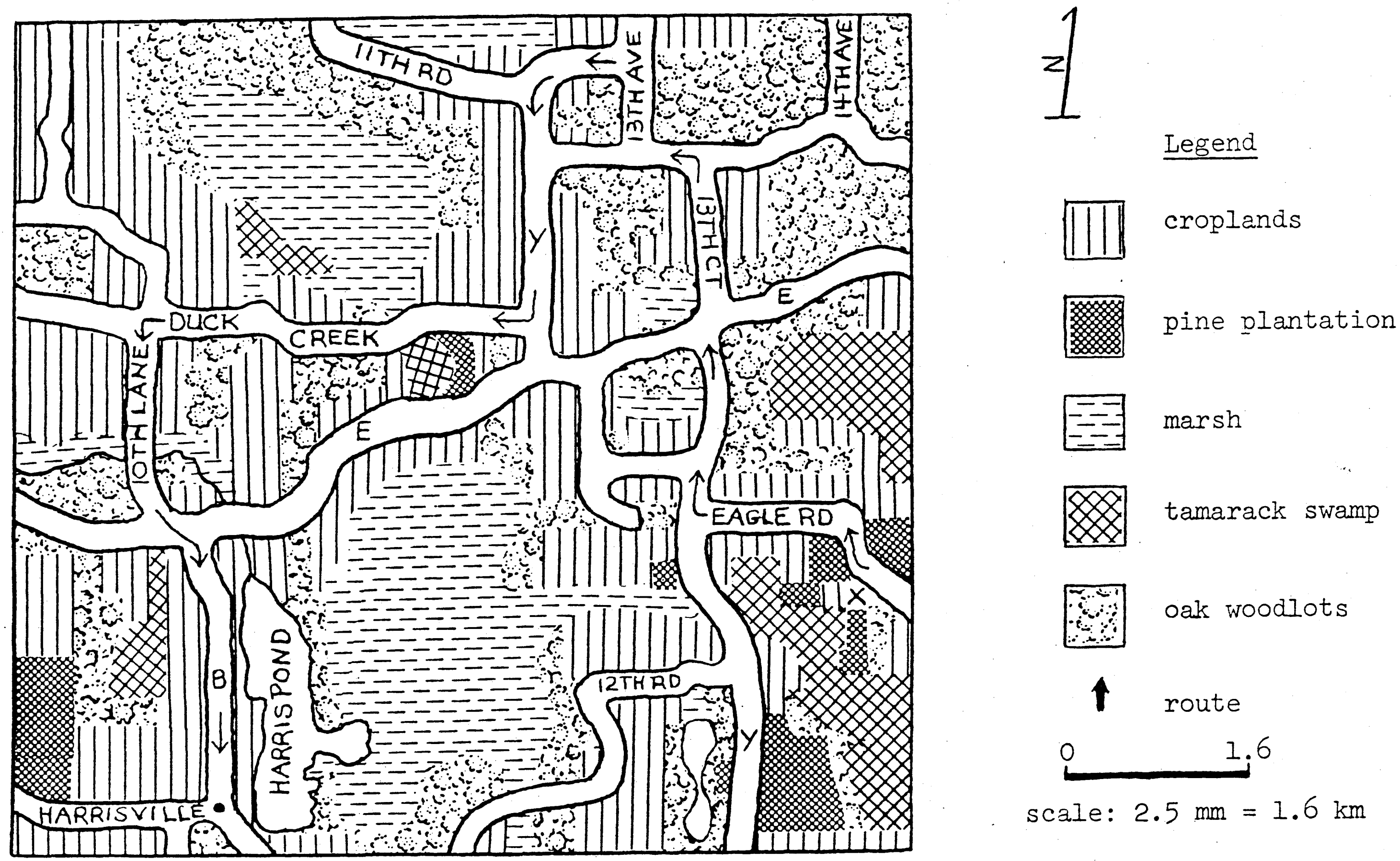

Figure 1. Map of the study area. R 10E T 17N. Marquette County, Wisconsin.

havior suggested that they were using the road as a source of heat were recorded. Criteria of behavior included 1) birds stationary until flushing, 2) head up, and 3) no searching behavior during observation.

Binoculars were used from a stationary observation site to record the length of time birds remained on the road at various air and road temperatures.

Cloud cover was classified into seven categories:

1. clear (less than 10 percent of the sky obscured)
2. hazy (no defined clouds)
3. scattered clouds (10 to 60 percent of the sky covered)
4. broken clouds (60 to 90 percent of sky covered)
5. overcast (90 percent or more of the sky covered)
6. cloud bank in East
7. cloud bank in West

The road surface was classified either as wet, dry, or damp (having puddles of standing water on an otherwise dry surface).

The wind velocity was estimated to fall into one of four categories: 0-7 km/hr, 8-13 km/hr, 14-19 km/hr, and 20 plus km/hr. Although the wind velocities were estimates, I used a single set of criteria adapted from the Beaufort scale (H. B. Woolf 1973).

Humidity and precipitation conditions were grouped into eight categories: rain, drizzle, mist and/or fog, heavy dew, light dew, humid air, rain ending within an hour before the time of data collections, and dry. These categories were subjective, but the judgments were made by a single observer and biases should be consistent.

The observations of birds and other animals on the road were recorded either by a passenger or by the driver speaking into a cassette recorder. Bird activity was recorded as the number of individuals observed during a 10 minute period. All birds were recorded by species.

Data Analysis

Significance of difference in temperature was established using an Olivetti programmable calculator. The program yielded the mean, standard deviation, and analysis of variance. All temperature records from 1973 and 1974 were used. Temperature data was grouped in monthly units, May-August. These groups were reduced to hourly groups, 0900-2100 hours, for each month. Analysis of variance was calculated for 19 hour groups each having seven or more observations.

An IBM 1130 computer was used for multiple linear regression and linear correlation analysis. Multiple regression analysis used a logarithmic expansion of time and temperature data as independent variables and the total number of birds observed as a dependent variable. Simple linear correlation was used for all weather and road condition factors.

The general trends of influence for various weather factors and microclimate temperatures were derived by comparing the mean number of individuals observed during all 10-minute periods for each weather condition or temperature range. The general trends concerning the number of minutes birds remained on the road during stationary observation periods at various road surface temperatures were analyzed in a similar manner. Analysis of optimum vehicle speed for data collection also followed the form of comparison of the mean. However, the range of flushing distances also was considered in deciding the optimum speed.

An *a priori* Chi-square test (temperatures arbitrarily grouped by 5°C units) was used to establish whether distribution of individuals was relative to the road surface temperature.

The overall mean temperature relative to the number of birds observed was calculated by multiplying the number of birds observed by the temperature for both the road in the sun and the air at the time of observation. The sum of these products was divided by the total number of birds observed.

Results

Analysis of variance of temperatures for various microclimatic areas indicated a significant difference between the road surface and the other microclimatic areas for all sample sizes larger than seven ($P < 0.01$)(Table 1). The temperatures of the air and the ground surface of both the herbaceous site and the pine litter layer were not statistically distinct.

The *a priori* Chi-square test of the distribution of birds on the road surface relative to temperature indicated that distribution was not rectangular (99% confidence level 6 d.f., 85.12).

The coefficients derived from multiple linear regression analysis were 31.85 for temperature of the road surface; 16.44 for time of day and 43.43 when time of day, temperature, and the interaction of these two factors was considered.

Simple correlation coefficients derived from weather and temperature data and the total number of birds were: road surface temperature

Table 1. Temperature relationships of microclimatic areas, 0900-2100 hours, May-August. Degrees of freedom and f-fatio are included for all samples seven or greater. Data from 1973 and 1974 records.

Month	Site	Time																				
		0900			1000			1100			1200			1300			1400			1500		
		N	$\bar{X}$ °C	SD °C	N	$\bar{X}$ °C	SD °C	N	$\bar{X}$ °C	SD °C	N	$\bar{X}$ °C	SD °C	N	$\bar{X}$ °C	SD °C	N	$\bar{X}$ °C	SD °C	N	$\bar{X}$ °C	SD °C
May	Aor																					
	Air	1	15.00														2	20.50				
	Hbg	1	16.70														2	20.50				
	Llp	1	15.60														2	19.40				
	Rds	1	21.10														2	19.40				
	Rsh	1	17.20																			
df, f-value																						
June	Aor							13	25.13	2.69										13	28.59	3.84
	Air				2	15.60		15	21.84	4.65							1	22.20		14	26.48	3.26
	Hbg				2	16.70		2	22.22								1	27.20		1	27.20	
	Llp				2	15.00		15	22.12	4.34							1	22.80		14	26.23	3.41
	Rds				2	23.90		15	30.03	4.04							1	31.10		14	38.43	5.10
	Rsh				2	22.20		2	21.11								1	29.40		1	29.44	
df, f-value								3, 54, 12.17												3, 51, 26.23		

N greater than 50 indicates that 2 temperature measurements were made during some 1 hour periods.

f-ratio from analysis of data, $\bar{X}$ and SD were converted to °C from °F.

Abbreviations: Aor-Air temperature 0.5 m above road (1973 data); Air-Air temperature at 2 m in shade; Hbg-Ground temperature, herbaceous site (1974 data); Llp-Litter layer surface temperature, pine site; Rds-Road surface temperature in sunlight; Rsh-Road surface temperature in shade (1974 data).

Table 1. Continued

Month	Site	0900 N	0900 X̄ °C	0900 SD	1000 N	1000 X̄ °C	1000 SD °C	1100 N	1100 X̄ °C	1100 SD °C	1200 N	1200 X̄ °C	1200 SD °C	1300 N	1300 X̄ °C	1300 SD °C	1400 N	1400 X̄ °C	1400 SD °C	1500 N	1500 X̄ °C	1500 SD °C
									Time													
July	Aor							24	26.92	3.62										23	30.17	3.12
	Air	3	18.14	0.85	1	22.20		26	26.00	3.63	6	25.92	5.47	1	28.80		4	25.00	3.21	27	28.66	3.05
	Hbg	3	17.59	0.85	1	21.10		2	32.80		6	30.37	7.42	1	29.40		4	33.92	6.10	4	30.28	0.96
	Llp	3	18.14	0.32	1	20.00		26	26.49	3.67	6	26.48	5.84	1	37.20		4	25.00	2.57	27	29.19	3.32
	Rds	3	27.78	1.47	1	25.00		26	34.67	5.16	6	35.92	8.23	1	44.40		4	36.39	4.17	27	34.21	5.62
	Rsh	3	19.26	0.85	1	23.30		2	31.66		6	26.26	5.22	1	29.40		4	26.67	1.28	4	29.44	4.49
d.f., f-value									2, 75, 34.18												2, 78, 14.86	
Aug	Aor							16	27.15	2.88										13	30.59	3.96
	Air	7	18.49	1.51	5	21.33	0.30	17	25.16	2.96				2	27.20					13	28.59	3.76
	Hbg	7	18.73	1.05	5	21.56	0.72	1	31.11					2	35.50							
	Llp	7	18.89	1.61	5	26.66	1.92	17	25.58	2.76				2	29.40					13	28.50	3.16
	Rds	7	25.47	1.99	5	30.11	2.27	17	34.34	3.36				2	36.60					13	39.60	5.06
	Rsh	7	20.00	1.54	5	24.56	2.64	1	27.22					2	32.20							
d.f., f-value			3, 24, 34.07						2, 48, 33.52												2, 36, 21.56	

Table 1. Continued

Month	Site	Time 1600 N	1600 $\bar{X}$ °C	1600 SD °C	1700 N	1700 $\bar{X}$ °C	1700 SD °C	1800 N	1800 $\bar{X}$ °C	1800 SD °C	1900 N	1900 $\bar{X}$ °C	1900 SD °C	2000 N	2000 $\bar{X}$ °C	2000 SD °C	2100 N	2100 $\bar{X}$ °C	2100 SD °C
May	Aor																		
	Air							2	13.30		9	12.40	2.56	5	11.56	1.49			
	Hbg							2	11.10		9	12.84	2.76	5	9.44	1.04			
	Llp							2	11.10		9	11.92	2.83	5	10.11	0.99			
	Rds							2	29.40		9	15.95	4.21	5	17.67	5.96			
	Rsh																		
d.f., f-value											3, 32, 33.33								
June	Aor													13	22.97	3.10			
	Air				4	19.44	4.16	5	18.11	4.62	19	20.73	4.43	62	17.57	4.10	4	14.03	3.34
	Hbg				4	21.53	3.52	5	20.66	4.28	19	20.82	4.01	49	16.92	3.42	4	14.03	3.41
	Llp				4	18.89	3.71	5	17.56	4.03	19	19.41	4.93	62	16.51	4.12	4	13.06	2.74
	Rds				4	25.83	5.16	5	24.67	4.62	19	27.34	5.01	62	22.82	4.73	4	19.58	5.58
	Rsh				4	24.72	4.41	5	23.11	4.06	19	24.88	5.34	49	21.24	4.14	3	20.92	3.26
d.f., f-value											3, 72, 9.12			3, 231, 30.22					

Table 1. Continued

Month	Site	Time																	
		1600			1700			1800			1900			2000			2100		
		N	X̄ °C	SD °C	N	X̄ °C	SD °C	N	X̄ °C	SD °C	N	X̄ °C	SD °C	N	X̄ °C	SD °C	N	X̄ °C	SD °C
July	Aor													24	23.19	2.49			
	Air	8	25.69	4.22	8	24.58	4.32	12	27.82	3.13	35	24.33	3.20	72	22.98	2.94	6	21.48	1.85
	Hbg	8	27.08	3.42	8	25.62	3.34	12	27.92	1.47	35	23.97	2.94	72	22.43	2.94	6	21.11	1.65
	Llp	8	27.01	4.63	8	24.37	4.21	12	27.27	3.36	35	23.93	3.54	48	22.36	3.07	6	20.83	2.01
	Rds	8	36.46	5.03	8	33.68	6.69	12	37.36	3.89	35	31.38	4.31	72	28.31	3.09	6	26.21	2.52
	Rsh	8	31.32	3.44	8	29.51	5.61	12	32.50	3.11	35	28.25	3.07	48	26.43	2.54	6	24.63	2.01
df., f-value		3, 28, 10.41			3, 28, 6.84			3, 44, 28.30			3, 136, 37.17			2, 213, 84.46					
Aug.	Aor													10	22.83	3.73			
	Air	9	24.40	3.83	2	23.61	1.96	20	21.22	3.08	22	20.76	2.31	24	19.93	2.86			
	Hbg	9	23.64	2.94	2	23.33	4.71	20	21.47	3.96	22	20.22	2.34	14	18.13	1.93			
	Llp	9	24.81	4.22	2	23.33	1.80	20	20.50	3.19	22	19.89	2.48	24	19.51	3.07			
	Rds	9	34.69	4.40	2	33.05	1.18	20	28.92	3.48	22	26.86	2.39	24	25.58	3.12			
	Rsh	9	29.01	3.16	2	28.61	3.53	20	26.14	2.74	22	25.00	1.96	14	22.97				
df., f-value		3, 32, 12.25						3, 76, 19.42			3, 84, 32.53			2, 69, 20.30					

0.187; road surface condition 0.168; wind velocity 0.168; litter layer surface temperature in the pines 0.167; air temperature 0.155; ground surface temperature at the herbaceous site 0.123; road shade temperature 0.084; cloud cover 0.064; precipitation 0.029.

The mean number of birds observed on the road per 10-minute period was greatest within the road surface and air temperature ranges 26.3 - 34.4°C and 19.4 - 24.3°C, respectively (Table 2). Stationary observations revealed the time length birds remained on the road surface was greatest when road surface temperatures were 26.5 - 32.5°C (Table 3).

The difference between the overall mean temperatures of the road (28.64°C) and air (21.43°C) at the time birds were observed was 7.21°C.

General trends of influence for various weather and road surface conditions, based on the mean number of birds observed for each factor (Table 4), were as follows: more birds were present when vegetation was damp from dew or rain than during dry conditions; scattered or broken cloud cover resulted in greater bird numbers being observed than clear or overcast conditions; bird numbers decreased steadily as wind velocity increased 0-19 km/hr, with increase occurring at wind velocities above 20 km/hr; bird numbers were greatest when road surfaces were wet and were lowest during dry periods.

The optimum vehicle speed for data collection, of the five tested, was 56 km/hr (Table 5). Traffic load of the data collection route averaged 5-10 vehicles per hour (personal observation).

The most commonly observed species were the vesper sparrow (<u>Pooecetes gramineus</u>), the robin (<u>Turdus migratorius</u>), and the house sparrow (Passer domesticus)(see Appendix 1).

Table 2. Mean number of birds observed per 10-minute period relative to air and road surface temperatures.

Temperature Range °C	Air N	Air X	Air SD	Road in the Sun N	Road in the Sun X	Road in the Sun SD
10.0-11.7	5	3.00	2.44	1	0.00	
11.8-13.7	7	4.57	2.14	2	2.00	1.00
13.8-15.6	13	1.92	2.07	3	3.67	3.06
15.7-17.4	5	6.20	5.80	2	0.50	0.71
17.5-19.3	6	4.83	1.72	9	3.55	2.30
19.4-21.2	12	8.50	7.97	4	3.25	2.06
21.3-23.1	22	5.23	5.24	4	4.75	1.95
23.2-24.3	22	5.91	8.61	6	5.50	3.73
24.4-26.2	21	5.43	5.56	9	4.66	4.69
26.3-28.7	7	2.29	1.15	17	7.11	7.46
28.8-30.5	15	4.87	3.56	16	4.62	4.86
30.6-32.4	10	2.40	2.32	21	7.09	8.94
32.5-34.4	6	0.83	0.98	14	6.14	6.13
34.5-36.2	5	1.60	1.44	11	3.09	3.76
36.3-38.1				11	3.58	3.58
38.2-39.9				9	4.00	1.58
40.0-41.8				7	1.28	1.25
41.9-43.7				2	0.50	0.71
43.8-45.6				4	1.50	0.87
45.7-47.4				0		
47.5-49.3				6	1.50	1.64
49.4-51.3				1	0.00	

Table 3. Time length birds present on road at various road surface temperatures. One hour of observation was conducted at each temperature level.

Temperature °C	Birds Observed	Length of Time (minutes)*		
		Range	Mean	Standard Deviation
40.0	4	1-3	1.75	0.96
35.0	7	1-4	2.14	1.21
32.5	13	2-9	4.69	2.39
30.0	18	1-11	5.39	2.57
26.5	9	1-7	4.44	2.23
23.0	2	1-2	1.50	0.71
19.5	1	NA	1.00	NA

* Times were recorded by 1-minute units with lengths of time over a minute recorded to the nearest minute.

Table 4. Mean numbers of birds observed per 10-minute period relative to various weather and road surface conditions. The mean number of birds present should reflect preferential use.

Precipitation				Cloud Cover				Wind				Road Surface			
Observed Condition	N	$\bar{X}$	SD	Observed Condition	N	$\bar{X}$	SD	Estimated Velocity* km/hr	N	$\bar{X}$	SD	Observed Condition	N	$\bar{X}$	
rain	1	4.00		clear+	42	4.64	5.15	0-7	79	5.92	6.62	wet	9	10.00	11
drizzle	3	3.00	1.41	hazy+	6	3.00	4.00	8-13	29	3.69	3.79	damp	14	4.43	2
mist/fog	3	5.33	3.31	scattered+	23	5.07	7.48	14-19	30	2.63	2.23	dry	134	4.40	4
h. dew	3	14.66	6.89	broken+	36	5.08	6.70	20+	19	4.53	5.14				
l. dew	4	6.00	8.72	overcast+	38	4.34	3.40								
dry	105	3.86	4.46	cloud bank in east	0										
humid	10	4.70	4.03												
veg. damp	27	9.07	8.16	cloud bank in west	12	3.92	5.28								

N-Number of data collection periods during which each weather condition was observed.

+ Standard aviation weather definitions from: U.S. Department of Transportation publication, Pilots handbook of aeronautical knowledge. 1971. U.S. government printing office, Washington, D.C.

* Estimates based on an adaptation of the Beaufort Scale. Beaufort, Sir Francis. Reprinted 1973 H. B. Woolf (ed.) Websters New Collegiate Dictionary.

Abbreviations: L. dew means light dew; H. dew means heavy dew; Veg. damp means vegetation is damp from rain ending less than 1 hour earlier.

Table 5. Bird flushing distance relative to approaching vehicle speed. Results are based on 5 nonconsecutive trials of each speed.

Speed km/hr	No. of Birds Observed	Range Meters	Mean Meters	Standard Deviation Meters
40	46	7.0-84	30.7	19.2
48	48	9.0-65	26.8	13.5
56	46	4.5-81	21.3	14.9
64	56	-3.0-72*	19.6	14.9
72	61	-7.0-85*	16.4	15.8

* Birds flushing from the edge of the road behind the passing vehicle, as indicated by negative values in the range at 64 and 72 km/ph.

Discussion

In all 19 variance analyses, using different time periods of different months, the road surface temperature in the sun proved to be significantly different from all the other environs considered. It can be assumed from the large sample size involved that a significant difference existed at all times between 0900 and 2100 hours. It was not possible to statistically differentiate the naturally occurring areas, the air, the ground in herbaceous cover, and the litter layer surface in the pines. With more precise equipment it is possible to statistically differentiate between these areas (Johnson and Davies 1927).

Rectangular distribution of an *a priori* Chi square is a form of null hypothesis which assumes one factor has no influence on another (Games and Klare 1967). The fact that distribution of birds relative to road surface temperature was not rectangular in form supports the theory that temperature was a factor influencing the presence of birds on the road surface. Both multiple linear regression and simple linear correlation coefficient values were largest when road surface temperature and total number of birds were compared. This information also supports the theory that road surface temperature is the primary factor influencing bird presence on black top roads.

Bird numbers observed per 10-minute period were greatest when air temperatures were 6.9 - 10.1°C below road surface temperatures. The length of time individuals remained on the road surface was greatest between 26.5 - 32.5°C. These results suggest there is a temperature range from approximately 26 - 33°C preferred by birds. Perhaps when the road surface temperature is within this range the air temperature is below the optimum temperature range for survival of bird species most commonly observed. This is definitely true for one species. Red-wing blackbirds were found to have an optimum temperature range of 25.6 - 38.1°C during environmental chamber studies (Lewis and Dyer 1969). At temperatures below 25.6°C a significant metabolic rate increase was observed in study specimens. Lewis and Dyer (1969) concluded that this increase in energy output was necessary to maintain proper body temperature. A significant increase was observed only during daylight hours. At night similar reduction of temperature produced only minimal increases in metabolic rate. If similar thermo-regulatory mechanisms exist in other species, individuals could conserve energy 1 - 2 hr per day by resting on blacktop roads when air temperatures are below their optimum range. Conservation of energy in this manner would allow species to extend the northern limits of their range.

A comment upon the influence of various weather conditions on other results is, I think, necessary. Each different weather or road surface condition exerts an influence not only upon the number of birds observed at that time, but on the correlation of temperature and bird numbers as well. It is generally accepted that the number of interacting variables involved in field research of this type functions to reduce the correlation evidenced in any one particular area studied. Under these circumstances, I believe that the correlation coefficients derived for the relationship of bird numbers observed to road surface and/or air temperature reflect a much higher degree of correlation.

Further investigation of the macadam road as a microclimate is is needed. This study began at a time when most of the migrant birds had arrived and concluded before they left. Further studies should be conducted to determine whether migrating birds and birds present in winter avail themselves of the temperature differences between the road and the air. Studies probably should be made of the effects on mammals, reptiles and amphibians.

Summary

A total of 869 birds was observed during 156 data collection periods when no other vehicles were observed--719 in the sun and 150 in the shade. Relationships between the presence of birds on the road and temperatures were evaluated for air temperature (macroclimate) and four microclimates. The temperature of the road surface was significantly different from temperatures of all the other areas at all times 0900-2100 hours May-August. Mean numbers of birds observed per ten minute period varied from 0.00 - 7.11 when compared to specific road surface temperatures.

The warm microclimate of the blacktop road surface was determined to be the primary factor influencing the presence of birds on the road surface. The effect was most evident when ambient air temperatures were below 25.6^{o}C. and the road surface temperature was above 25.6^{o}C.

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Appendix

Appendix 1. Total number of birds of each species observed on raod during study.

Names and spellings follow AOU Checklist revision in The Auk (1973), Peter's Checklist of the Birds of the World (1936-70).

Common Name	Scientific Name	Number
Vesper sparrow	Pooecetes gramineus	600
Eastern robin	Turdus migratorius	502
House sparrow	Passer domesticus	404
Other birds	Detailed below	621
Red-headed woodpecker	Melanerpes erythrocephalus	
Blud jay	Cyanocitta cristata	+
Common flicker	Colaptes auratus	125
Morning Dove	Zenaidura macroura	101
Red-wing blackbird	Agelaius phoeniceus	68
Meadowlarks *	Sturnella	45
Bob-white quail	Colinus virginianus	43
Brown thrasher	Toxostoma rufum	36
Catbird	Dumetella carolinensis	35
Cowbird	Molothrus ater	28
Starling	Sturnus vulgaris	25
Common goldfince	Spinus tristis	18
Indigo buntin	Passerina cyanea	14
Killdeer	Charadrius vociferus	14
Unidentified warblers		13

Appendix 1. (continued)

Common Name	Scientific Name	Number
Blue-winged teal	*Anas discors*	12
Barn swallow	*Hirundo rustical erythrogaster*	11
Crow	*Corus brachyrhynoches*	5
Eastern cardinal	*Richmondena cardinalis*	4
Ring-necked pheasant	*Phasianus colchicus torouatus*	3
Eastern kingbird	*Tyrannus tyrannus*	3
Brewer's blackbird	*Euphagus cyanocephalus*	2
Myrtle warbler	*Dendroica coronata*	2
Pigeon	*Columba livia*	2
Towhee	*Pipilo erythrophthalmus*	2
Mallard	*Anas platyrhynchos*	1
Least flycatcher	*Empidonax minimus*	1
Yellow-bellied flycatcher	*Empidonax flaviventris*	1
Veery	*Hylocichla fuscescens*	1
Wood thrush	*Hylocichla mustelina*	1
Song sparrow	*Melospiza melodia*	1
Cedar waxwing	*Bombycilla cedrorum*	1
Red-eyed vireo	*Vireo olivaceus*	1
Chipping sparrow	*Spizella passerina*	1
Whip-poor-will	*Caprimulgus vociferus*	1

* Eastern and Western Meadowlarks are both common in the study area but are distinguishable only by their call.

\+ These three species were recorded as a group.

Appendix 2. Total number of mammals of each species observed on road during study.

Common Name	Scientific Name	Number
Eastern cottontail	*Sylvilagus floridanus*	33
Cat	*Felis domesticus*	21
13-lined ground squirrel	*Citellus tridecemlineatus*	16
Eastern gray squirrel	*Sciurus carolinensis*	15
Chipmunk	*Tamias striatus*	14
Raccoon	*Procyon lotor*	10
Eastern fox squirrel	*Sciurus niger*	8
Dog	*Canis familiaris*	5
White-footed mouse	*Peromyscus leucopus*	3
Striped skunk	*Mephitis mephitis*	2
Vole	*Microtus sp.*	1
Red squirrel	*Sciurus hudsonicus*	1
Woodchuck	*Marmota monax*	1

Twenty-five of 33 Eastern cottontails were juveniles. Nine of 10 raccoons were juveniles. There was no attempt to estimate the age status of the other mammals involved in the study.

The mean and standard deviation respectively of the road surface temperature for species were: Eastern cottontail 75.30, 7.77; fox squirrel 86.25, 15.78; gray squirrel 83.4, 11.47; domestic mammals 77.62, 8.69; all other mammals 81.62, 10.04.

Appendix 3. Total number of each species of amphibian and reptile observed on road during study.

Common Name	Scientific Name	Number
Painted turtle	*Chrysemys picta*	5
Eastern tiger salamander	*Ambystoma t. tigrinum*	2
Grey-green tree frog	*Hyla versicolor*	20
Leopard frog	*Rana pipiens*	57
Garter snake	*Thamnophis s. sirtalis*	1

The mean road surface temperature and standard deviation, respectively, for amphibians were 79.47 and 2.92.

Appendix 4. Total number of each species of roadkill observed on road during study.

Common Name	Scientific Name	Number
BIRDS		
Eastern robin	Turdus migratorious	3
Red-headed woodpecker	Melanerpes erythrocephalus	16
Starling (juvenile)	Sturnus vulgaris	1
Blue jay	Cyanocitta cristata	1
English sparrow	Passer domesticus	7
Unknown		1
MAMMALS		
13-Lined ground squirrel	Citellus tridecemlineatus	4
Dog (juvenile)	Canis familiaris	1
Eastern fox squirrel	Scurius niger	4
Chipmunk	Tamias striatus	6
Eastern gray squirrel	Sciurus carolinensis	3
Eastern cottontail	Sylvilagus floridanus	2
Striped skunk	Mephitis mephitis	2
Mole	Scalopus aquaticus	1
White-footed mouse	Peromyscus leucopus	2
Short-tailed shrews	Blarina brevicauda	3
House mouse	Mus musculus	1
REPTILES		
Garter snake	Thamnophis sirtalis	2
Eastern Fox Snake	Elaphe vulpina	1
Smooth green snake	Opheodrys vernalis	1