AN INVESTIGATION OF THE INFLUENCE OF WEATHER
ON THE MOVEMENTS OF WHITE-TAILED DEER
IN WINTER

Thesis for the Degree of M. S.
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Robert Dale Semeyn
1963

ABSTRACT

AN INVESTIGATION OF THE INFLUENCE OF WEATHER ON THE MOVEMENTS OF WHITE-TAILED DEER IN WINTER

by Robert Dale Semeyn

The primary purpose of this study was to make a preliminary investigation of the affect of winter weather conditions on the behavior and movements of white-tailed deer (Odocoileus Virginianus). To this end, a field study was set up during the months of January, February and March, 1961. This study was conducted in Alcona County, Michigan, which is in the heart of Michigan's deer club country and consists of typical northern Michigan deer range.

The study area was divided into two microclimatic units: (1) the swamp (2) the open area. The swamp was an area of heavy cover typical of a coniferous deer-yard. The open area consisted of scattered cover and grass areas.

Weather conditions were recorded at weather stations located in each microclimatic unit. Wind velocity, maximum and minimum temperatures, and snow depths were recorded at the weather stations. Barometric pressure was recorded at the cabin. These weather data were supplemented with data recorded at the U.S. Weather Bureau, Alpena, Michigan.

Deer movements were estimated by means of transects in the swamp and in the open. Deer behavior was recorded by two observers in the field and supplemented with observations gleaned from literature. Measurements of deer movements and behavior were correlated to the weather conditions prevailing

at the same time.

The data and observations are presented in three sections: (1) Microclimatology; which compares the climate and shelter of the swamp and the open (2) Intensity effects of winter weather; which discusses the effects of changes in weather conditions on deer movement and behavior (3) Accumilative effects of winter weather; which discusses the seasonal effects of winter weather on deer through the periods of concentration, confinement, and dispersal.

A study of the microclimatology of the swamp and open area shows that the swamp apparently offers a more comfortable habitat during the winter. A comparison of "meaningful temperatures" estimated by means of a "meaningful temperature" nomograph, which considers the combined effect of heat loss due to wind and temperature, shows the swamp to average 25° F. warmer than the open. As the winter became more severe, the activities of the deer became confined to areas of the densest cover.

In general, this study shows a reduction of deer activity during heavy snowfalls and a retardation of deer movement with snow accumilation. There is a relationship between temperature and deer movement, and a relationship between wind velocity and deer movement; however, this relationship is best understood when the affect of wind and temperature is combined as "meaningful temperature". There is an indirect relationship between barometric pressure and deer movement, and relative humidity and deer movement through the weather variables of wind velocity, snowfall, and temperature.

Observations are presented which indicate deer occupy small microclimatic units in response to wind velocity and direction, and sunlight.

AN INVESTIGATION OF THE INFLUENCE OF WEATHER

ON THE MOVEMENTS OF WHITE-TAILED DEER IN WINTER

By

Robert Dale Semeyn

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Fisheries and Wildlife Dept.

A THESIS

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PREFACE

This thesis is based on a preliminary investigation of one phase of a white-tailed deer (Odocoileus Virginianus) behavior study that is being conducted by Dr. Leslie Gysel of the Fisheries and Wildlife Department, Michigan State University. This investigation is not intended to establish as fact the effects of the various aspects of weather on white-tailed deer movements, but to gain some in~~cite~~sight into the patterns and trends of deer behavior, resulting from the influence of winter weather.

The primary purpose of this investigation was to gather information pertinent to relationship of winter weather to deer behavior and movements. To this end, the information needed was obtained from data recorded in the field, from first-hand observations made in the field by myself and another observer under the direction of Dr. Gysel, and from literature research.

I am indebted to the Fisheries and Wildlife Department, Michigan State University, for the opportunity to conduct the research for this paper. I am especially grateful to Dr. Leslie W. Gysel, Dr. Gilbert W. Mouser of the Fisheries and Wildlife Department and to Dr. Peter I. Tack, head of the department, for his confidence and assistance. I would like to express my gratitude to Mr. Charles E.(Eric) Mezger for the use of photographs, trapping data and field notes, and his assistance in the field, and to Mr. Kenneth J. Linton and Dr. Philip J. Clark for their assistance with statistical analysis of the data. I would also like to thank Mr. Carl O. Basel, Management Forester, Abitibi Corporation, for contributing the observations that appear in the Postlog section of this paper.

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INTRODUCTION

Scope

There were three major focal points involved in the field research. One was to trap and mark deer to gather data on trapping and marking techniques for the purpose of individual identification. Another was to observe group and individual deer behavior. A third was to make a preliminary investigation of the possible relationship of deer movements to weather variables. This was done by experimenting with equipment, techniques and methods of recording weather and movement data. The results of the third focal point are the subject of this paper.

The scope of the field research consisted of recording indications of deer movement and recording the changes in the weather factors. The weather factors considered were wind, temperature, snow depth, barometric pressure, and relative humidity. The above data were subjected to a statistical analysis for possible correlations between movement and the weather factors. The results of the statistical analysis, general observations made in the field by both observers, and information gleaned from literature were used to evaluate the influences of winter weather on deer behavior and movements.

Time and Location

This study took place in the winter of 1962 from January 6th to March 10th. The Michigan winter of 1962 was one of the severest on record. The data used in this paper was recorded during the month of February which was the coldest on record since 1936, had the greatest snowfall on record since 1887, and the greatest monthly precipitation since 1943 (U.S.D.C.,1962).

The field research was done primarily on the property of the "Little North Club", a member of the Consolidated Hunting League Inc., Alcona County, Michigan. The league occupies a portion of the "Club Country" which in turn is made up of approximately the northern one half of Alcona County and large portions of the adjoining three counties of Oscoda, Montmorency and Alpena. A more precise description of the research area is as follows:

> N.$\frac{1}{2}$ of S.E.$\frac{1}{4}$ of Sec.31, N.E.$\frac{1}{4}$ of Sec.31, S.$\frac{1}{2}$ of S.E.$\frac{1}{4}$ of Sec.30, S.$\frac{1}{2}$ of S.W.$\frac{1}{4}$ of Sec.29, S.W.$\frac{1}{4}$ of S.E.$\frac{1}{4}$ of Sec.29, N.W.$\frac{1}{4}$ of Sec.32, N.$\frac{1}{2}$ of S.W.$\frac{1}{4}$ of Sec.32, W.$\frac{1}{2}$ of N.E.$\frac{1}{4}$ of Sec.32 and N.W.$\frac{1}{4}$ of S.E.$\frac{1}{4}$ of Sec.32, T-28-N, R-7-E, Alcona County, Michigan.

This area consists of a large coniferous swamp which follows the course of the Little North Creek and is used extensively as a winter deer-yard. The perimeter of the swamp is surrounded by gentle sloping land predominately open with scattered groups of numerous cover type variations of conifers and hardwoods. The gentle sloping land becomes rolling farther out from the swamp. The rolling land has a cover of second growth oak, aspen, and red maple mixed with stands of pure aspen. A complete inventory of the cover types found in the research area has not been taken. However, the predominant cover types and their approximate acreages are presented in Figure 1 which is an adaptation of a cover map of the "Little North Club" prepared by Mr. J. Lamy of the Abitibi Corporation, Alpena, Michigan. Portions of the research area outside of the boundries of the "Little North Club" were added to this map with the aid of an aerial photograph and field observations. The acreages of the projections were estimated by the use of a planimeter. The entire study area occupies one and one quarter square miles or 800 acres.

The study area was divided into two major cover types: (1) the "swamp" area, (2) the "open" area. The "swamp" area consisted of dense cover and was used as the winter deer yard. The "open" area consisted of scattered vegetation and totally open cover types. The "swamp" cover types in approximate order of amount of cover in acres are: coniferous swamp (northern white cedar; Thuja occidentalis, balsam fir; Abies balsamea, white spruce; Picea abies and black spruce: Picea mariana) - mixed lowland hardwoods and conifers (balsam fir, white and black spruce, northern white cedar, red maple: Acer rubrum, balm-of-gilead; Populus gileadensis, black ash: Fraxinus nigra and yellow birch: Betulea lutea) - marsh

(unidentified marsh grasses) - aspen balsam (balm-of-gilead, quaking aspen; Populus tremuloides, and balsam fir) - pine (white pine; Pinus strobus, red pine: Pinus resinosa, jack pine; Pinus banksiana). The "open" cover types in approximate order of amount of cover in acres are as follows: scattered trees (white oak; Quercus alba, black oak; Quercus velutina, red oak; Quercus rubra, jack pine, red pine, white pine, quaking aspen, balm-of-gilead, black cherry; Prunus serotina, sweetfern; Comptonia peregrina and unidentified grasses) - oak aspen (black, red and white oak, balm-of-gilead and quaking aspen) - pine (red, white and jack pine) - upland brush (juneberry; Amelanchier spp., willow; Salix spp., sumac; Rhus spp., hawthorn; Crataegus spp. and cherry; Prunus spp.) - oak (black, red and white oak) - grass (unidentified species). The coniferous swamp and the lowland hardwoods conifer mixture provided the bulk of the "deer-yard" cover. The deer used the scattered trees area extensively during the early stages of the study to browse heavily on sweetfern. The remaining cover types provided partial shelter and browse and were shunned as the deer became concentrated in the yarding area.

The "Little North Club" was selected for the research by Dr. Gysel, after making a careful survey of the "Club Country". The main reason for his selection was the amount of yarding area. Another important factor was that the uplands appeared to be "typical" of much of the range of the "Club Country". Of equal importance in the selection was the large number of deer on the area.

Fig. 1--Cover map of research area and acreages (from cover map by J. Lamy, Abitibi Corp.). Overlay of transects, weather stations, and cabin (base headquarters).

Cover Legend

A - Aspen
B - Balsam
Bw - Birch, white
C - Cedar
Gr - Open (grass, sweetfern, etc.)
J - Jack pine
LH - Lowland hardwoods (elm, soft maple, balm-of-gilead, b. ash, y. birch)
Ms - Marsh
O - Oak
S - Spruce
Ub - Upland brush (willow, sumac, juneberry, hawthorn, cherry)
W - White pine

0-1 Seedlings
1-5 Saplings
5-9 Poletimber
9-15 Small sawtimber
15+ Large sawtimber

' Poor stocking (0-40%)
'' Medium stocking (40-70%)
''' Good stocking (70-100%)

Overlay Legend

A B

Transect No. 1

Transect No. 2

Transect No. 3

Transect No. 4

Weather Station

Cabin (base headquarters)

<u>Area</u>: $1\frac{1}{4}$ sq. miles
800 acres

<u>Scale</u>: $1\frac{1}{2}$ inches = $\frac{1}{4}$ mile

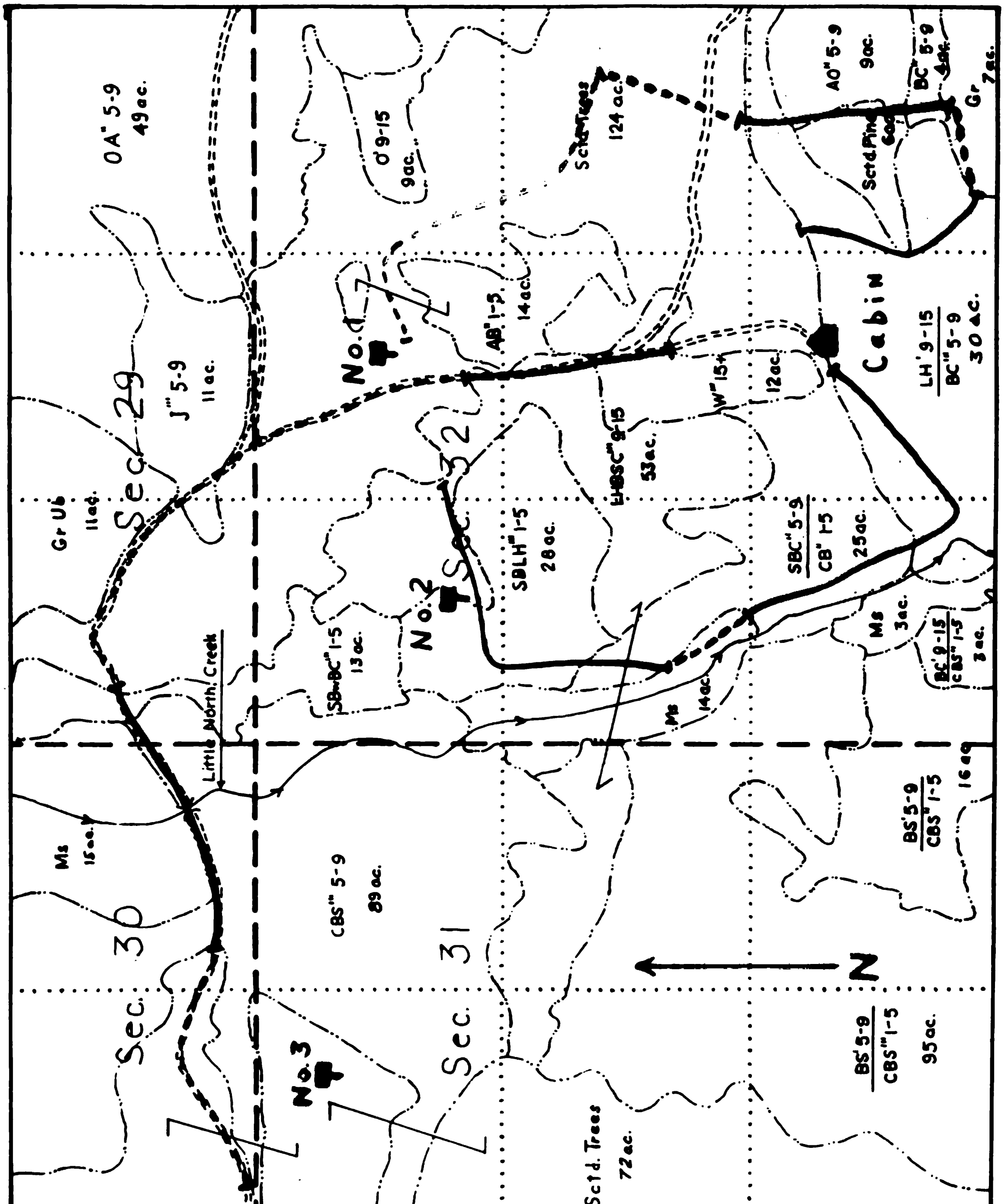
Sec. 29
Sec. 30
Sec. 31
Sec. 32
No. 1
No. 2
No. 3
Cabin
Little North Creek
N
Sctd. Trees
72 ac.
Gr Ub
11 ac.
Ms
15 ac.
CBS''' 5-9
89 ac.
Scttered
124 ac.
AB' 1-5
14 ac.
SBLH''' 1-5
28 ac.
LHBSC''' 9-15
53 ac.
SB-BC'' 1-5
13 ac.
LH' 9-15
BC'' 5-9
30 ac.
AO'' 5-9
9 ac.
BS' 5-9
CBS''' 1-5
95 ac.
16 ac.

Fig. 1--Cover map of research area and acreages (from cover map by J. Lamy, Abitibi Corp.). Overlay of transects, weather stations, and cabin (base headquarters).

Cover Legend N

A - Aspen
B - Balsam
Bw - Birch, white
C - Cedar
Gr - Open (grass, sweetfern, etc.)
J - Jack pine
LH - Lowland hardwoods (elm, soft maple, balm-of-gilead, b. ash, y. birch)
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0-1 Seedlings
1-5 Saplings
5-9 Poletimber No. 3
9-15 Small sawtimber
15+ Large sawtimber

' Poor stocking (0-40%)
'' Medium stocking (40-70%)
''' Good stocking (70-100%)

Cabin

Overlay Legend

	A	B
Transect No. 1		
Transect No. 2		
Transect No. 3		
Transect No. 4		

Weather Station

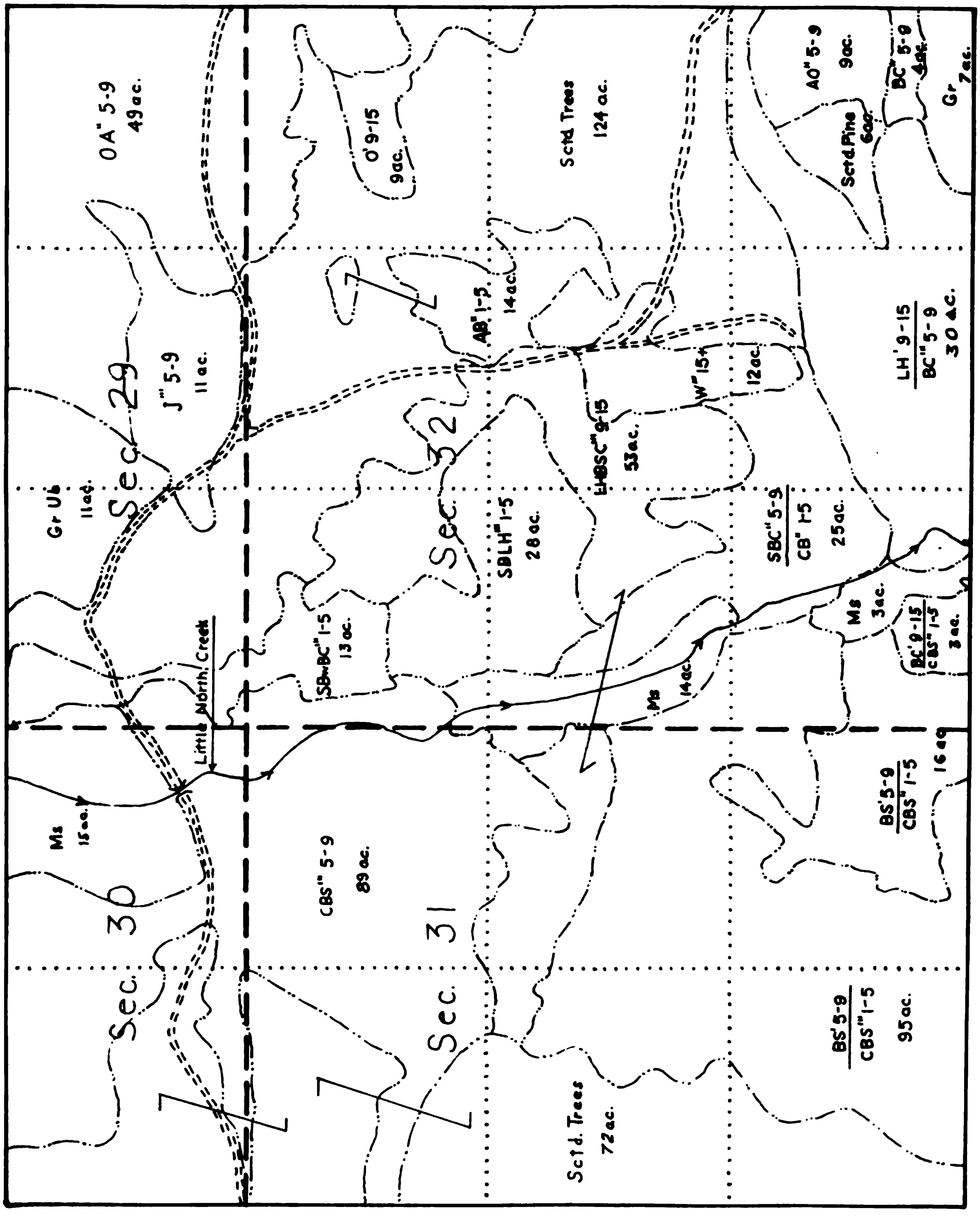
4

No. 5
Cabin (base headquarters)

No. 1

Area: $1\frac{1}{4}$ sq. miles
800 acres

Scale: $1\frac{1}{2}$ inches = $\frac{1}{4}$ mile


Sec. 29
Sec. 32
Sec. 30
Sec. 31
Little North Creek
OA" 5-9
49 ac.
O' 9-15
9ac.
Sctd Trees
124 ac.
AO" 5-9
9ac.
BC' 5-9
Gr
7ac.
Sctd Pine
6ac.
AB" 1-5
14ac.
J" 5-9
11 ac.
W" 15+
12ac.
LH' 9-15
BC" 5-9
30 ac.
Gr Ub
11ac.
LHBSC" 9-15
53ac.
SBLH" 1-5
28ac.
SBC" 5-9
CB' 1-5
25ac.
SB-BC" 1-5
13ac.
Ms
3ac.
BC' 9-15
CBS" 1-5
3ac.
Ms
14ac.
Ms
15ac.
CBS" 5-9
89ac.
BS' 5-9
CBS" 1-5
16ac.
BS' 5-9
CBS" 1-5
95ac.
Sctd. Trees
72ac.

METHODS

Transects

To establish an estimate of deer movement, transects were located in the swamp and in adjacent areas (Fig. 1). Transect number 1 was located in the swamp and was used to estimate deer movement in the swamp (Fig. 2). Transects number 2 and 3 were located in the open, following the perimeter of the swamp, and were used to estimate deer movement in the open, and to and from the swamp (Fig. 3). The deer movement counts taken on these three transects were used in the tables and graphs presented in this paper.

Transect number 4 was added when the trapping study was concluded and more time for observations was made available. This transect passed through both open and swamp areas and was used in this study primarily for visual observation of deer behavior. This transect was in operation for only a short time near the end of the field research, and the movement counts from this transect were not used in the tables and graphs.

Certain portions of the transects passed through areas of atypical cover types for that transect. It became obvious with the increasing effect of winter weather, especially snow accumilation, that deer were using the cover portions of transects when they were shunning the open portions. They were

Fig. 2--A typical view along a transect in the swamp (A portion of transect).

Fig. 3--A typical view along a transect in the open (B portion of transect).

also shunning the open portions of the swamp transect. The transects were then sub-divided into A and B portions: the A portions of a transect passed through cover and the B portions of a transect passed through open. Unfortunately, the transects were not sub-divided until considerable data had been recorded, and data from the sub-divisions could not be used in graphs and tables. The sub-division of the transects was a very useful aid in visual observation. I would recommend careful division of transects into cover and open segments in future studies.

The transects in the swamp and in the open were laid out to facilitate the checking of deer traps and the checking of weather stations which were located on the transects.

Transect counts were recorded in the morning and evening of each day. A count consisted of recording each new track crossing the transect and each deer sighted from the transect. Weather station readings were made at the same time as the transect run to correlate weather and movement data. Each transect run constituted the end of the preceding recording period and the start of a new recording period.

Although each new track crossing a segment was recorded, the direction the deer was traveling when the track was made was not. I believe that in future studies, the direction of tracks should be recorded on transects designed to sample movement to and from the swamp. Separate counts of deer moving towards the cover and away from the cover should be maintained. This would greatly aid the interpretation of data and the correlation of movements with weather conditions.

Deer movement counts taken on transects number 2 and 3 were used for movement in the open, and the counts taken on transect number 1 were used for movement in the swamp. For comparative purposes, the lengths of the transects should be the same (Table 1). The combined length of transects number 2 and 3 exceeded the length of transect number 1 by 57.14%. In this case, each count taken on transect number 1 was increased by 57.14% to make it equivalent to a count taken on the transect if it were of equal length to transects number 2 and 3.

TABLE 1

MEASURED LENGTH OF TRANSECTS IN FEET

Transect	Number 1	Number 2	Number 3	Number 4
A portion	4950	2750	0	1380
B portion	650	4050	2000	1800
Totals:	5600	6800	2000	3180

Combined length of transects number 2 and 3....8800 feet.

Length of Recording Periods

In the field, it was not possible to standardize the length of the time interval of each recording period. The night-time recording periods varied in length from 14 to 17 hours, and the daytime recording periods varied in length from 6 to 10 hours. In order to make an accurate evaluation of the deer movement and weather relationships, the values used must have an equal length of recording period. To compensate for the inequality in length of recording periods, each deer movement count and each weather recording was corrected to its equivalent 10 hour period by the following formula:

$$\frac{\text{original recording X 10}}{\text{original time}} = \text{corrected value for equivalent 10 hour period.}$$

<u>Weather</u> <u>Stations</u>

Three weather stations were used in the study (Fig. 1). Station number 2 was placed along transect number 1, well within the swamp and under typical swamp cover (Fig. 4). Data recorded at this station were correlated with the corresponding recording period of deer movement counts on transect number 1. These data were used to evaluate the deer movement and weather relationships in the swamp. Weather station number 1 was located in the open on the east side of the swamp, and weather station number 3 was located in the open on the west side of the swamp (Fig. 5). The weather data recorded at these stations were combined and their averages used for weather in the open. These averages were correlated with corresponding recording periods of deer movement counts on transects number 2 and 3. These correlated data were used to evaluate the deer movements and weather relationships in the open.

The weather data were recorded in the morning and evening of each day to correspond with the transect deer counts for the preceding recording period. Wind velocity and

Fig. 4--Weather station number 2 located in the swamp (Eric Mezger recording wind data).

Fig. 5--Weather station number 1 located in the open on the east side of the swamp.

maximum and minimum temperatures were recorded at each weather station for the preceding recording period. Snow depth was also recorded at each station.

Wind Recording

The wind counts were recorded by a 1/60th of a mile anemometer located at each weather station These anemometers register wind velocity with 1/60th mile electrical contacts (60 contacts per mile of wind) by a simple single contact mechanism. The velocity of the wind passing the instrument is indicated by the number of contact closings (1/60th of a mile) per minute of time (1/60th of an hour) directly in miles per hour. Gusts and short-time velocities can be measured by the interval of time between contact closings by a count by the observer. When connected to an electric impulse counter (as in this study) it will measure total hourly, daily, or weekly mileage of wind, from which average hourly or daily wind can be computed. This instrument does not record the fluctuations in wind velocity which occur during a recording time interval.

Six-volt dry cell batteries were tried as a source of the electrical impulse; however, they would not operate satisfactorily at the cold temperatures which prevailed during the study and would often go dead within twenty-four hours. Heavy duty six-volt automotive batteries were then used and proved to be satisfactory. These batteries would operate the counter for a minimum of two weeks; at this time they would be drained to 50% charge and had to be recharged.

Occasionally the single contact mechanism would become out of adjustment during operation, causing the counter to record two or more contacts instead of one. Whenever this was observed (to be happening or suspected), the mechanism was readjusted and the recording made during the faulty operation was not used in the study.

The microclimatic layer in which the daily activities of deer take place determined the height at which the hemispherical wind cups were placed. This height is not rigid, nor has it been clearly defined in literature, thus the height was arbitrarily and uniformly set at 6 feet. The selection of this height was based on the reasonable assumption that all normal deer activity would take place within this microclimatic zone.

The counts obtained from the anemometers were converted to average wind in miles per hour by the following formula:

$$\frac{C}{T \times 60} = \text{average wind in m.p.h.}$$

where: C = Total number of contacts.
T = Time in hours.
60 contacts per mile of wind.

There are two types of recording anemometers. The accumilative record type, used in this study, measures the velocity of the wind by recording the total number of miles of wind passing the anemometer during a given time interval. The total number of miles can then be converted to the average wind in miles per hour. The fluctuations in wind velocity during a recording time interval are not recorded by this instrument. The graphic chart record type records the change in wind velocity by means of a continuous inked line which fluctuates with a rise or fall in wind velocity. This type of instrument presents a permanent inked record of each lull or gust of wind and the time of its occurrence. The rotor of this type of instrument drives an electric generator. The speed of the rotor is determined by the velocity of the wind. A change in the velocity of the wind causes a change in the speed of the generator, which in turn produces a fluctuation in the electric impulse. This activates the recording pen and is reflected on the recording chart as changes in wind velocity in miles per hour. One type of recording device applicable to field research is the portable Esterline and Angus recorder which has a chart drive powered by a hand wound spring and will operate for 8 days.

The accumilative record type anemometer has its most useful application in macroclimatic studies, where the seasonal climate of a region or area is depicted by long term averages. Its application in microclimatic studies is limited, especially where an attempt is being made to correlate behavioral aspects of an animal to prevailing weather conditions. An accurate observation of deer activity must be correlated to a time interval determined by an accurate observation of a change in the wind conditions. An accurate measurement of the fluctuations, gusts and lulls during the time interval must also be recorded in order to study the relationship of deer movement and wind. Wind observations of this kind can only be approximated, by an observer in constant attendance, with the accumilative record type anemometer.

The graphic chart record type anemometer can be usefully applied in microclimatic studies because it records wind measurements in a manner lacking in the accumilative record type. It not only records the data necessary, but does so without an observer in constant attendance. The time when an observation of deer movement was made can be correlated directly to the wind conditions recorded at the same time by inspection of the inked wind record. The one drawback in using the graphic chart record type anemometer is the relatively higher cost.

Temperature

The temperature was recorded at each weather station with a maximum-minimum thermometer. These thermometers gave the maximum temperature and minimum temperature for each recording period. The average temperature was obtained, in the manner used by the U.S. Weather Bureau, by adding the maximum and minimum temperatures and dividing by 2.

A tempscribe was used alternately between the weather stations in the open and in the swamp. We had one tempscribe and we used it to get a comparison of temperature fluctuations in the open and in the cover. It would be desirable to have tempscribes at each weather station to keep a continuous record of the temperature fluctuation in each microclimatic unit.

Snow

The snow depth was taken at each weather station by walking in a circle around the station and taking 10 measurements. The average of the 10 measurements was the recorded snow depth. Periods of snowfall were recorded in each day's notes.

Barometric Pressure

Barometric pressure was recorded in the morning and evening of each day with a standard disc barometer kept at the cabin. Fluctuations in barometric pressure were also recorded with a recording barometer.

Humidity

I was not equiped to take humidity readings at the low temperatures which prevailed. The humidity values used were from Local Climatological Data, Alpena, Michigan.

Trapping

For the purposes of my study, six Clover or western style deer traps were used (Fig. 6). Three traps were placed on the north segment of transect number 1, and three traps were set on the south segment of transect number 1, in the swamp. Daily and weekly records were kept on the number of deer that entered each trap and the number of deer caught in each trap.

The deer caught in traps were marked with colored collars. The color of the collar indicated what trap line they were caught on and the sex of the animal. Two colored plastic streamers were attached to each collar for individual identification. Each trapped animal had a different color combination.

Fig. 6--Clover or western style trap used in the study.

MICROCLIMATOLOGY

Temperature

Refer to table 2 for the temperature data for the swamp and table 3 for the open area.

On the basis of the daily twenty-four hour average temperature, the open area averages 1.67° F. warmer than the swamp, with a daily average of 12.9° F. in the open and 11.23° F. in the swamp. The daily average minimum temperature in the open was 6.1° F. and in the swamp the daily average minimum temperature was 5.0° F., which indicates that the daily minimum temperature averages 1.1° F. warmer in the open. The lowest minimum temperature in the open was -20° F., while the lowest minimum temperature in the swamp was -17° F. The daily average maximum temperature in the open was 19.7° F. and the daily average maximum temperature in the swamp was 17.45° F. This indicates that the daily maximum temperature averaged 1.25° F. warmer in the open. The highest maximum temperature in the open was 33.5° F., while the highest maximum temperature in the swamp was 30° F. The daily average temperature fluctuated 13.6° F. in the open and 12.45° F. in the swamp, which indicates a greater daily fluctuation of temperature occurred in the open.

TABLE 2

TEMPERATURES IN THE SWAMP IN DEGREES F.

Date	Time*	Average	Minimum	Maximum
2- 1	A.M.	- 1.5	-15	12
2- 7	A.M.	- 4.5	-14	5
2- 7	P.M.	- 1.0	- 4	2
2- 8	A.M.	- 5.5	-17	6
2- 8	P.M.	8.0	0	16
2- 9	A.M.	13.5	12	15
2-10	P.M.	- 2.0	-12	8
2-11	A.M.	4.5	0	9
2-11	P.M.	11.5	9	14
2-12	A.M.	13.0	12	14
2-12	P.M.	21.5	16	27
2-15	P.M.	16.5	5	28
2-16	A.M.	24.5	23	26
2-16	P.M.	27.0	25	29
2-17	A.M.	22.0	14	30
2-22	P.M.	29.0	28	30
2-23	A.M.	8.0	-12	28
2-23	P.M.	15.0	12	18
2-24	A.M.	10.0	6	14
2-24	P.M.	15.0	12	18

	Av. Temp.	Av. Minimum Temp.	Av. Maximum Temp.
Daily	5.0	17.45	11.23
Daytime	9.1	19.00	14.10
Night-time	.9	15.90	8.40

* P.M. - daytime temperatures recorded in the evening of that day and corrected to equivalent 10 hour period.

A.M. - night-time temperatures recorded in the morning and corrected to equivalent 10 hour period.

TABLE 3

TEMPERATURES IN THE OPEN IN DEGREES F.

Date	Time*	Average	Minimum	Maximum
2- 1	A.M.	- 2.50	-14.5	9.5
2- 7	A.M.	- 5.00	-16.5	6.5
2- 7	P.M.	9.75	4.5	15.0
2- 8	A.M.	- 7.25	-20.0	5.5
2- 8	P.M.	12.75	6.5	19.0
2- 9	A.M.	9.75	4.0	14.5
2-10	P.M.	- 2.50	-15.0	10.0
2-11	A.M.	4.00	- 2.5	10.5
2-11	P.M.	12.25	9.5	15.0
2-12	A.M.	14.25	14.0	14.5
2-12	P.M.	24.75	16.5	33.0
2-15	P.M.	26.75	20.0	33.5
2-16	A.M.	25.50	23.0	28.0
2-16	P.M.	29.25	25.5	33.0
2-17	A.M.	20.75	14.0	27.5
2-22	P.M.	30.50	28.0	33.0
2-23	A.M.	9.25	- 6.5	25.0
2-23	P.M.	17.00	14.0	20.0
2-24	A.M.	9.75	4.0	15.5
2-24	P.M.	21.25	15.0	27.5

	Av. Temp.	Av. Minimum Temp.	Av. Maximum Temp.
Daily	6.1	19.7	12.9
Daytime	12.5	23.9	18.2
Night-time	- .1	15.7	7.8

* P.M. - daytime temperatures recorded in the evening of that day and corrected to equivalent 10 hour period.

A.M. - night-time temperatures recorded in the morning and corrected to equivalent 10 hour period.

The average daytime temperature (for corrected 10 hour periods) in the open was 18.2° F. while the average daytime temperature in the swamp was 14.1° F. The daytime temperature in the open averaged 4.1° F. warmer than the daytime temperature in the swamp. The daytime average minimum temperature in the open was 12.5° F. and the daytime minimum temperature in the swamp was 9.1° F. The daytime minimum temperature in the open averaged 2.4° F. warmer than the daytime minimum temperature in the swamp. The lowest daytime minimum temperature in the open was -15° F. while the lowest daytime minimum temperature in the swamp was -12° F. The daytime average maximum temperature in the open was 23.9° F. and the daytime average maximum temperature in the swamp was 19° F. The daytime maximum temperature averaged 4.9° F. warmer in the open than in the swamp. The highest daytime maximum temperature in the open was 33.5° F., while the highest daytime maximum temperature in the swamp was 30° F. The average daytime fluctuation of temperature in the open was 11.45° F. and the average daytime fluctuation of temperature in the swamp was 9.9° F.

The average night-time temperature (for corrected 10 hour periods) in the open was 7.8° F. and the average night-time temperature in the swamp was 8.4° F. The night-time temperature in the open averaged .6° F. colder in the open. The average night-time minimum temperature in the open was -.1° F., while the average night-time minimum temperature in the swamp was .9° F. The night-time minimum temperature averaged 1° F.

colder in the open than in the swamp. The lowest night-time minimum temperature in the open was -20° F. while the lowest night-time minimum temperature in the swamp was -17° F. The average night-time maximum temperature in the open was 15.7° F., while the average night-time maximum temperature in the swamp was 15.9° F. The night-time maximum temperature in the open averaged .2° F. colder than the night-time maximum temperature in the swamp. The highest night-time maximum temperature in the open was 28° F. and the highest night-time maximum temperature in the swamp was 30° F. The average fluctuation of night-time maximum temperature in the open was 15.8° F., while in the swamp it was 15° F.

The average temperature was 1.67° F. or 13.9% warmer in the open than in the swamp. The greatest differences in the temperature occurred during the daytime, with the average daytime temperature 4.1° F. or 28.4% warmer in the open than in the swamp. The difference in night-time average temperatures was very low, with the open area temperatures averaging .6° F. or .8% colder than the swamp. The greatest average fluctuation of temperatures always occurred in the open, with more stable temperatures occurring in the swamp. The greatest temperature fluctuation occurred during the night-time in both the open and the swamp, with an average temperature fluctuation of 15.8° F. in the open and 15° F. in the swamp. The greatest difference in temperature fluctuation occurred in the daytime, with an average temperature fluctuation of 11.45° F. in the open and 9.9° F. in the swamp.

The foregoing paragraphs point out the microclimatic differences in temperatures between the open area and the swamp. These differences are due to the insulating qualities of the vegetation in the swamp area. The overstory of the swamp area insulates against the gain or loss of heat by radiation. Light-meter readings taken in the swamp and in the open, on a cloudless mid-day, showed 261% more sunlight reaching the ground in the open than in the swamp. The swamp area resists warming by solar radiation during the day, while the open area is exposed to solar radiation. On the other hand, the overstory in the swamp area resists the loss of heat by radiation during the night-time. The density of the swamp area acts as a windbreak and reduces the transfer of heat by convections (the microclimatic differences in wind are covered in the following section on wind). The result of the insulating qualities is a more stable temperature in the swamp area than in the open area.

Wind

According to local climatological data from the U.S. Weather Bureau at Alpena, Michigan, the prevailing winds in the experimental area were from a westerly direction during December and January. During February, however, the prevailing winds were erratic and showed no predominant wind direction. The wind data used in this study were recorded during the month of February. Wind directions by days from

Weather Bureau records are as follows:

N	NE	E	SE	S	SW	W	NW
5	3	3	6	0	4	5	2

The wind did not blow from any one compass direction for more than two consecutive days.

Wind data from field recordings, presented in table 4 of this section, gives the following information. The daily average wind velocity in the open was 1.30 m.p.h. and the daily average wind velocity in the swamp was .23 m.p.h. The average daily wind velocity in the open was 1.07 m.p.h. or 465% greater than the average daily wind velocity in the swamp. The average daytime wind velocity in the open was 1.72 m.p.h. while the average daytime wind velocity in the swamp was .33 m.p.h. The daytime wind averaged 1.39 m.p.h. or 421% greater in the open than in the swamp. The average night-time wind in the open was .89 m.p.h., while the average night-time wind in the swamp was .12 m.p.h. The night-time wind averaged .77 m.p.h. or 642% greater in the open than in the swamp. The daytime wind in the swamp averaged .21 m.p.h. or 175% greater than the night-time wind in the swamp. The daytime wind in the open averaged .83 m.p.h. or 93% greater than the night-time wind in the open.

The greatest wind gust recorded in the swamp was 5 m.p.h. while the highest wind gust sampled in the open was 20 m.p.h. The wind gusts were not continuously recorded in each cover type but were periodically measured by an observer during periods of high wind.

TABLE 4

WIND VELOCITY

Date	Time*	Average Wind Velocity In Swamp In Miles Per Hour	Average Wind Velocity In Open In Miles Per Hour
2- 1	A.M.	.31	.90
2- 7	A.M.	.12	.84
2- 7	P.M.	1.14	3.83
2- 8	A.M.	.00	.05
2- 8	P.M.	.42	1.20
2- 9	A.M.	.01	.07
2-10	P.M.	.39	.91
2-11	A.M.	.01	.22
2-11	P.M.	.11	1.83
2-12	A.M.	.00	.20
2-12	P.M.	.02	.44
2-15	P.M.	.09	1.17
2-16	A.M.	.01	.36
2-16	P.M.	.10	1.51
2-17	A.M.	.40	3.72
2-22	P.M.	.31	2.99
2-23	A.M.	.09	.95
2-23	P.M.	.34	1.91
2-24	A.M.	.26	1.58
2-24	P.M.	.38	1.39

	Average Wind Velocity In Swamp In Miles Per Hour	Average Wind Velocity In Open In Miles Per Hour
Daily	.23	1.30
Daytime	.33	1.72
Night-time	.12	.89

* P.M. - daytime wind velocity recorded in the evening and corrected to equivalent 10 hour period.

A.M. - night-time wind velocity recorded in the morning and corrected to equivalent 10 hour period.

The swamp area offers protection from wind during the cold winter months. This can be seen by inspection of the wind data presented in this section. The extent of this protection will be realized in the following section on meaningful temperature.

There was a great deal more wind in the open during the test period than in the swamp, with a daily average of .25 m.p.h. in the swamp and 1.30 m.p.h. in the open. There is also a great deal of difference in the wind velocity sampled in the open at an elevation of 6 feet (height used in this study) and the average wind recorded for the month of February at the U.S. Weather Bureau, Alpena, Michigan. The average wind recorded at Alpena was 7.8 m.p.h. This wind velocity is recorded from an elevated tower and is relatively free from ground interference. The difference in wind velocity recorded in the open but near the ground, and wind velocity recorded in the open but from an elevated tower, is attributed to micro-habitat differences such as scattered vegetation, proximity to cover areas and topography, which have a greater affect on the wind velocity closer to the ground.

A microclimatic difference in wind velocities occurs at different locations in the open area. The following wind velocities were recorded in the open during the same time period:

Date	Time	Station #1	Station #3
2-5	A.M.	1.62 m.p.h.	2.69 m.p.h.
2-5	P.M.	5.74 "	5.82 "
2-6	A.M.	.65 "	.98 "
2-6	P.M.	1.17 "	1.95 "
2-7	A.M.	.65 "	1.04 "
2-7	P.M.	4.37 "	3.28 "
2-8	A.M.	.05 "	.05 "
2-8	P.M.	.97 "	1.44 "
2-9	A.M.	.03 "	.11 "
2-9	P.M.	1.66 "	.87 "
	totals:	16.91 m.p.h.	18.23 m.p.h.

The differences in the two sites were micro-habitat differences. Station #1 was on a west facing, very gentle slope, on the east side of the swamp. Station #3 was on an east facing, steeper slope, on the west side of the swamp. The scattered vegetation at both sites was located at a different relationship to the weather stations.

Meaningful Temperature

The discomfort that drives warm-blooded animals to shelter in cold weather is do to heat loss (Kleiber, 1961). Heat loss from a warm body is a function of the difference in temperatures, and the wind speed. Heat loss considered on the basis of thermometer temperature alone has little meaning. Under controlled laboratory conditions, heat loss due to differences in thermometer temperature could be evaluated. In the field, controlled laboratory conditions of zero wind movement are seldom encountered. The effect of wind speed on heat loss must be considered (Siple, 1945).

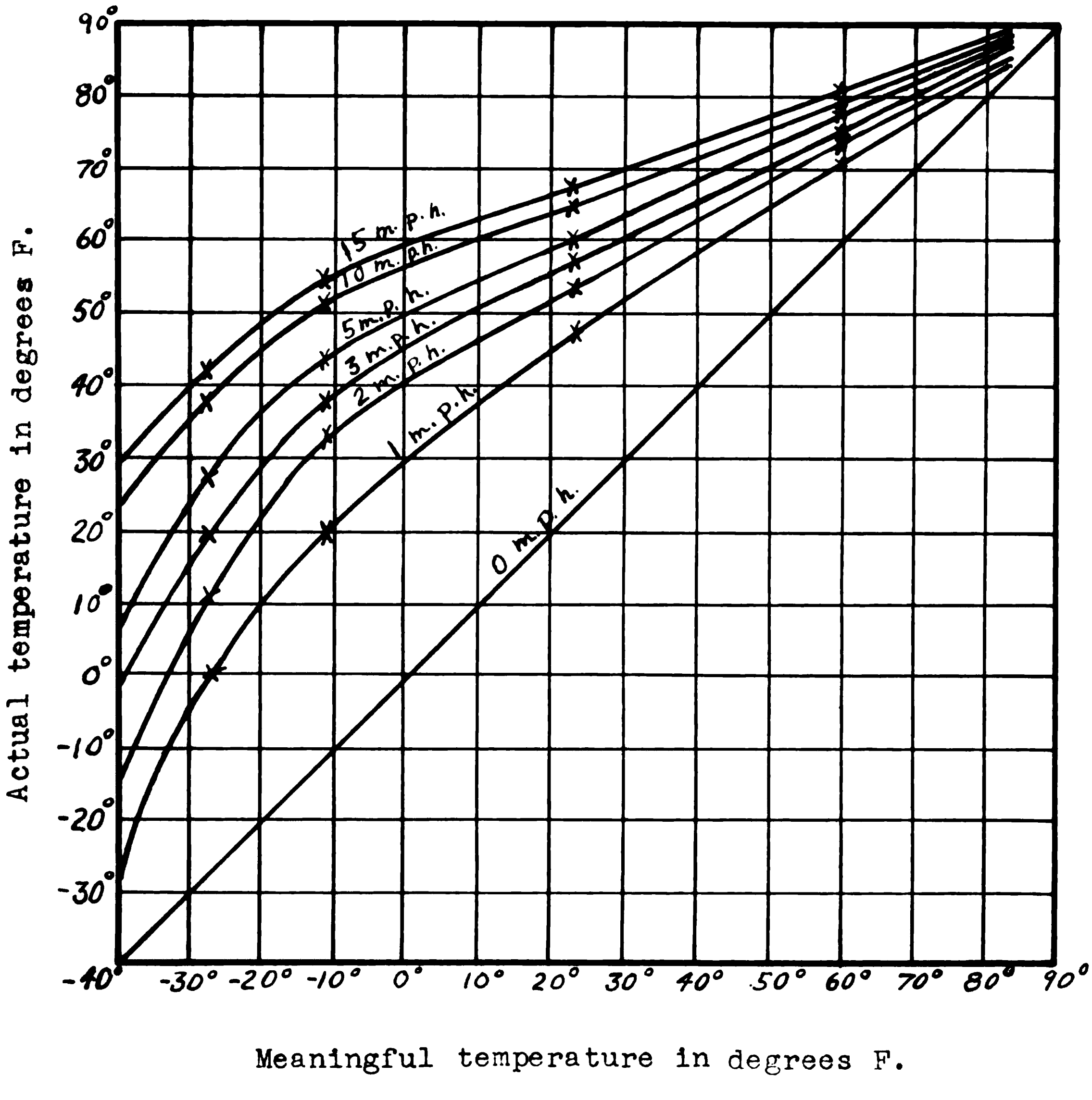
A factor affecting heat loss which considers the combined effect of temperature and wind has meaning. I call this factor the "meaningful temperature". Therefore, "meaningful temperature" can be defined as the effective temperature resulting from the combined affect of temperature and wind speed.

The nomograph (Fig. 7) for estimating the meaningful temperature is based on the "wind-chill chart" presented in the Air Conditioning, Heating and Ventilating, guide, March 1959. This chart is used by the Army Quartermaster Corps to estimate effective temperatures at cold weather installations. The original "wind-chill chart" has many gaps in both the temperatures used and wind speeds used, therefore, I have plotted the actual temperatures used against the corresponding effective temperature at a given wind speed. This graphing results in the nomograph shown in fig. 7. With this nomograph, effective temperatures and wind speeds not presented in the original "wind-chill chart" can be estimated. If the wind speed lies between two wind speed curves on the nomograph, the fractional distance between the two curves is estimated and this point is used to estimate the meaningful temperature on the horizontal scale.

The meaningful temperatures in table 5 were estimated with the nomograph from the average temperatures presented in tables 2 and 3 and from the average wind velocities presented in table 4. The following discussion is based on the meaningful temperatures found in table 5.

The average daily meaningful temperature in the open

Fig. 7.--Nomograph for estimating meaningful temperature based on the data presented in the "wind-chill chart" from the Air Conditioning, Heating and Ventilating, guide, March 1959.



Directions: Find the actual temperature on the vertical scale and project horizontally to the proper wind speed curve, then project vertically to estimate the meaningful temperature on the horizontal scale.

TABLE 5

MEANINGFUL TEMPERATURES IN DEGREES F.

Date	Time*	Av. Meaningful Temp. In Swamp	Av. Meaningful Temp. In Open
2- 1	A.M.	-10.0	-32
2- 7	A.M.	- 8.0	-32
2- 7	P.M.	-31.0	-38
2- 8	A.M.	- 5.5	-10
2- 8	P.M.	- 2.0	-30
2- 9	A.M.	13.0	5
2-10	P.M.	-13.0	-30
2-11	A.M.	4.0	-12
2-11	P.M.	10.0	-35
2-12	A.M.	13.0	8
2-12	P.M.	21.0	0
2-15	P.M.	14.0	-12
2-16	A.M.	24.0	-13
2-16	P.M.	23.0	-12
2-17	A.M.	10.0	-30
2-22	P.M.	23.0	-25
2-23	A.M.	7.0	-27
2-23	P.M.	6.0	-30
2-24	A.M.	6.0	-25
2-24	P.M.	5.0	-15

	Av. Meaningful Temp. In Swamp	Av. Meaningful Temp. In Open
Daily	5	-20
Daytime	0	-20
Night-time	10	-20
Daily Min.	0	-25
Daily Max.	10	-15
Daytime Min.	-10	-25
Daytime Max.	10	-15
Night-time Min.	10	-25
Night-time Max.	10	-15

* P.M. - daytime meaningful temperatures recorded in the evening.

A.M. - night-time meaningful temperatures recorded in the morning.

was -20°F. while the daily average meaningful temperature in the swamp was 5°F. The meaningful temperature in the open averaged 25°F. or 500% colder than the meaningful temperature in the swamp. The average daytime meaningful temperature in the open was -20°F. and the average daytime meaningful temperature in the swamp was 0°F. The daytime meaningful temperature in the open averaged 20°F. colder than the daytime meaningful temperature in the swamp. The average night-time meaningful temperature in the open was -20°F. and the night-time average meaningful temperature in the swamp was 10°F. The night-time meaningful temperature averaged 30°F. colder in the open than in the swamp. At no time during the February sampling period was the meaningful temperature in the open as warm as the meaningful temperature in the swamp. The smallest differential in meaningful temperature was 5°F., while the greatest differential in meaningful temperature was 48°F. The coldest meaningful temperature in the open was -38°F. while the coldest meaningful temperature in the swamp was -31°F. Both of these meaningful temperatures occurred during the same sampling time interval. It is interesting to note that the average meaningful temperature in the open remained constant at -20°F. during both the daytime and night-time, while the average meaningful temperature in the swamp fluctuated 10°F. between night and day. As a result, the meaningful temperature in the swamp averaged 20°F. warmer in the daytime and 30°F. warmer in the night-time.

Meaningful temperatures present a different picture of

the microclimatic differences of the two cover types considered in this study than does temperature or wind alone. On the basis of the temperature alone, the open area averaged 1.67° F. warmer than the swamp, but according to meaningful temperatures, the swamp averaged 25° F. warmer than the open area. The noticeable higher winds in the open (averaged 465% higher) result in much warmer meaningful temperatures in the swamp. Considering the great difference in meaningful temperature, the swamp area apparently offers a much more favorable habitat during the cold winter weather. Heat loss is proportional to the differences in temperature. According to Kleiber, 1961, in The Fire of Life, animals find relief from cold environmental temperatures by seeking warmer microclimatic conditions. In the swamp, with its higher meaningful temperature, deer would have a lower rate of heat loss.

Snow

A study of the snow profiles presented in table 6 (snow profiles in the swamp) and table 7 (snow profiles in the open) shows an interesting contrast in snow accumilation. The snow profile taken in the swamp, in a location of undisturbed snow, shows that for the period between February 17th and February 28th there was a decrease of ½ inch in total snow depth. In the open, during the same time interval, snow profiles showed an increase of 1 inch in total snow depth. The snow profiles in the swamp also showed a greater degree of icing, granulation and compaction of the lower snow layers,

TABLE 6

SNOW PROFILES IN THE SWAMP
MEASURED IN INCHES FROM TOP TO BOTTOM

Taken off of deer trail February 17, 1962		Taken off of deer trail February 28, 1962	
Layers	Description	Layers	Description
A $0-10\frac{1}{2}$"	Light fluffy snow	A $0-\frac{1}{4}$"	Light fluffy snow
B $10\frac{1}{2}-11$"	Granular snow crust	B $\frac{1}{4}-1\frac{1}{4}$"	Granular snow crust
C 11-16"	Granular snow	C $1\frac{1}{4}-9\frac{1}{4}$"	Granular snow
D $16-16\frac{1}{2}$"	Granular snow crust	D $9\frac{1}{4}-9\frac{1}{2}$"	Granular ice crust
E $16\frac{1}{2}-19\frac{1}{2}$"	Granular snow	E $9\frac{1}{2}-18$"	Varying from granular snow to icy granular snow
F $19\frac{1}{2}-22\frac{1}{2}$"	Compacted heavy granular snow	F 18-22"	Compacted icy granular snow
Total: $22\frac{1}{2}$"		Total: 22"	
190 lb. man penetrates 16".		190 lb. man penetrates 11".	

Taken on deer trail February 17, 1962		Taken on deer trail February 28, 1962	
Layers	Description	Layers	Description
A 0-8"	Light fluffy snow	A $0-\frac{1}{4}$"	Light fluffy snow
B 8-16"	Compacted granular snow	B $\frac{1}{4}-\frac{3}{4}$"	Granular snow crust
		C $\frac{3}{4}-8\frac{3}{4}$"	Granular snow
		D $8\frac{3}{4}-14\frac{3}{4}$"	Compacted granular snow
Total: 16"		Total: $14\frac{3}{4}$"	
190 lb. man penetrates 8".		190 lb. man penetrates $9\frac{1}{2}$".	
Deer penetrates 8".		Deer penetrates $9\frac{1}{2}$".	

TABLE 7

SNOW PROFILES IN THE OPEN
MEASURED IN INCHES FROM TOP TO BOTTOM

February 17, 1962		February 28, 1962	
Layers	Description	Layers	Description*
A 0-11"	Light fluffy snow	A 0-½"	Light fluffy snow
B 11-11¾"	Icy snow crust	B ½-3"	Icy snow crust
C 11¾-15¾"	Granular snow	C 3-12½"	Lightly compacted granular snow
D 15¾-16"	Icy snow crust	D 12½-13"	Icy snow crust
E 16-26½"	Granular snow	E 13-15"	Lightly compacted granular snow
		F 15-15½"	Icy snow crust
		G 15½-27½"	Granular snow
Total: 26½"		Total: 27½"	
190 lb. man penetrates 18".		190 lb. man penetrates 21".	

* This profile shown in Fig. 8.

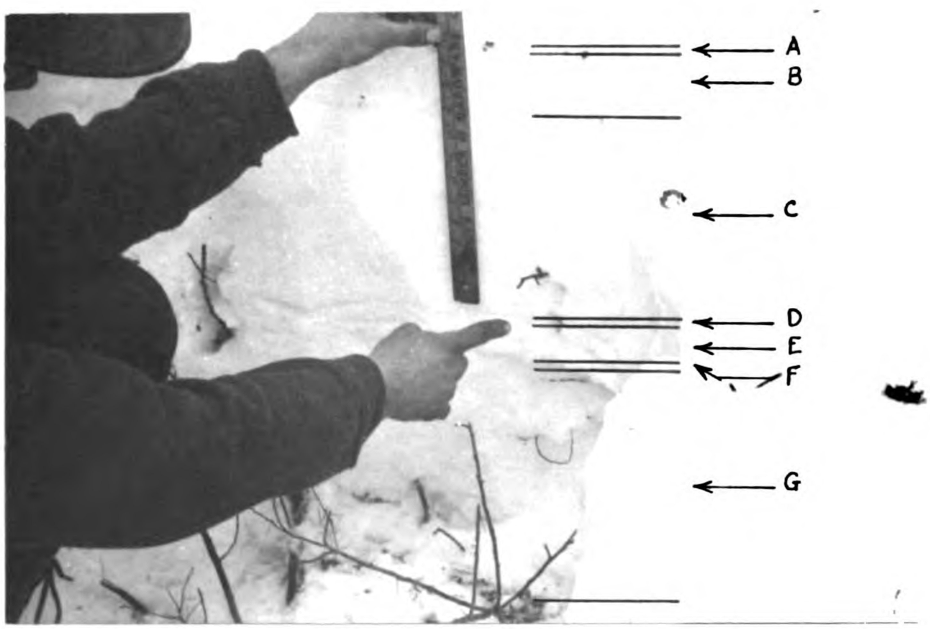


Fig. 8--Snow profile taken in the open at the end of study period. Author is pointing out the tops of sweetfern 10" below surface of snow.

especially close to the ground. This icing and granulation is caused by alternate melting and freezing of the snow and results in a more compact, solid mass. On February 17th, a 190 lb. man penetrated the snow in the swamp to a depth of 16 inches, while on February 28th the same man penetrated to a depth of only 11 inches. The same man penetrated the snow in the open 18 inches on February 17th, and 21 inches on February 28th. This difference in snow penetration is due to the greater degree of compaction in the swamp. As snow compacts it is better able to support weight and traveling becomes easier.

In the swamp the ground water table is very near or at the surface of the soil. Very moist soil lying at or near the ground water table resists warming in the spring and cooling in the fall (Schneider, I.F., 1962). In the swamp, the reduced cooling of the soil is enhanced by the insulating qualities of the vegetation (refer to Temperature section of Microclimatology in this paper).

I believe that the greater compaction of the snow in the swamp is due to the heat given off by the moist swamp soil. An interesting experiment on this point was discovered by accident. While making daily observations, I noticed that frost formed on the sides of deer prints that occasionally penetrated the snow to the soil. Acting on this clue, I used a stick to bore holes through the snow in the swamp, in the open on higher ground, and in a dense pine stand on high ground. Frost did form on the sides of the holes bored in the snow of the swamp but not in either location on high ground. Observing these results I postulated that water vapor from the moist swamp soil condensed on contact with cold air to form frost on the side of the holes.

A very important fact in understanding the microclimatic effects of snow in the two cover types is the drifting of snow. In the open, drifting snow was very prevalent due to the much higher winds (table 4), while in the interior of the swamp, drifting was practically non-existent. The drifting snow in the open kept filling deer trails and roads.

During periods of snow fall, much of the snow falling on the swamp area was caught by the overstory, especially by coniferous trees. Some of the snow caught in the overstory was dissipated by evaporation and wind without adding to the snow accumilation on the ground. The coniferous overstory also provided deer with protection from falling snow.

Three factors were observed which contributed to the maintenance of well defined, packed deer trails in the swamp (table 6); little or no drifting snow, greater compaction of snow, and reduced accumilation due to the protection of the overstory. The reduced compaction, heavy drifting of snow, and no protective overstory made the maintenance of deer trails and traveling much more difficult in the open.

Microclimatic Units

The major portion of my discussion of microclimatology has been devoted to the climatic differences between the two principle cover types studied, the open area and the swamp.

In each of these larger units there exists smaller microclimatic units. I feel that some of these smaller units play an important role in deer behavior and movements. Therefore, some of the more important smaller microclimatic units should be discussed before concluding this section.

An important microclimatic area exists along the borders of the heavy cover area. On the leeward side of vegetation, these areas offer protection from wind and increased exposure to solar radiation due to the lack of an overstory. This same condition exists in the open along leeward sides of hills and in depressions. Small and scattered stands of vegetation also afford some protection from wind in the open areas. Small stands of coniferous trees in the open also provide protection from falling snow.

The use of the study area as a private hunting club has produced a unique microclimatic unit in the swamp. The club has opened and maintains many trails within the swamp. These trails offer sunning places for deer while affording protection from the wind. Small, natural openings in the overstory of the swamp also offer sunning places and protection from the wind.

The main point to be brought out in this brief discussion of smaller microclimatic units is that in both of the two major cover types studied, there exists smaller microclimatic units which are modifications of the larger unit in which it is found. These smaller units often incorporate the better habitat conditions of the two larger units, such as, protection from wind and increased solar radiation. Therefore, it must be kept in mind that a winter observation of deer movements and behavior can not be delineated strictly to movements in the open and movements in the swamp, but must take in account the varying degrees of smaller microclimatic conditions which exist between the two extremes. The shaded forest and the sunlit open field differ materially and sensibly as to conditions of light, temperature and wind movement (Shreve, 1931).

INTENSITY EFFECTS OF WEATHER ON DEER MOVEMENTS

Temperature and Deer Movement

Deer movements and behavior are influenced by all levals of thermometer temperature, but different thermometer temperature ranges have different effects on deer movements and behavior. The influence of extremely cold (20 to 30 degrees below zero F.) temperatures on the nocturnal habits of deer were observed by Severinghaus (1953) three times, all on moonlight nights when there was little or no wind or snow. During these nights, the majority of the deer were walking slowly along heavily used deer trails although a few were seen standing motionless for a while, moving perhaps 10 to 50 yards or more and stopping again. Only a few deer were found in beds. This general activity led to the assumption that it was too cold for the deer to keep warm while bedded down. On one comparatively warm (10 to 20 degrees above zero F.) moonlight night, the bedding habits were quite different from behavior during these cold nights. Most of the deer were in beds; a few were wandering aimlessly along trails; some others were standing still. On several occasions deer jumped from beneath the low-hanging branches of conifers where they had bedded down. This reduction of nocturnal movement in more moderate winter temperatures may indicate less need for exercise to maintain body heat and ward off chilling (Taylor, 1956).

On several occasions Mezger and I observed similar behavior in deer. The location of the cabin in which we stayed during the field research afforded an excellent view of a portion of the swamp area. On the morning of March 1st, the temperature was -17°F. and no wind was blowing. From the cabin, shortly after dawn, deer were observed moving aimlessly along well defined trails in the swamp area. Some of the deer observed would disappear from our sight into the swamp only to reappear later, moving slowly in the opposite direction. Positive identification could be made on some of the deer by their collars. One large doe was repeatedly identified by her greatly receded lower jaw and was nicknamed "Roman Nose". On March 2nd with the temperature at -24°F. and no wind, and on March 3rd with the temperature at -18°F. with no wind, the same behavior pattern was again observed.

The effect of temperature on the movements of deer into open country was described by Halloran (1943). "The morning counts showed a close correlation between the temperature and the number of deer seen; discrepancies probably are due to such variables as the percentage of overcast and the velocity and direction of the wind. With the average morning temperature of 42°F., an average of 11.6 deer were seen. On the 8 days when 20 to 37 deer were seen the temperature was 44 to 58 degrees F., the sky partially overcast, and there was little or no wind." Halloran noted that the evening counts, starting at approximately 5:45 P.M., indicated that more deer were seen on evenings of higher temperature. On the 9 days when 50 or more deer were seen, temperature was moderate, 44 to 73 degrees F., the sky partly overcast and there was little or no wind.

There is an interesting relationship between deer movement (table 8) and average temperature in the swamp (table 2) for the study period. The average daily temperature in the swamp was 11.23^{0}F. and the average daily movement in the swamp was 84.6. On the 3 days when the deer movement count was very low (below 10), the average movement was 7.1, well below the average daily movement. On the same 3 days, the average temperature was -1.0^{0} F., well below the average daily temperature. On the 6 days when the deer movement count was very high (over 100), the average count was 193.5, well above the daily average. On the same 6 days, the average temperature was 20.7^{0}F., well above the daily average temperature. These observations include only thermometer temperature and do not include the influences of wind. This same pattern of deer movement and temperature relationship occurs in the open area; however, in the open area anomalies occur which are deviations from the general pattern. Two factors seem to be prevalent when these anomalies occur: (1) they occurred during periods of heavy snowfall, (2) they occurred at the tail-end of the field research when the snow depth was a limiting factor to travel in the open.

The pattern of deer movement in response to temperature changes in February (Fig. 9) does not show either a direct

TABLE 8

DEER MOVEMENT COUNTS

Date	Time*	In Swamp	In Open	Entire Study Area
2- 1	A.M.	7.6	4.4	12.0
2- 7	A.M.	51.1	8.9	60.0
2- 7	P.M.	89.9	18.1	108.0
2- 8	A.M.	9.8	10.2	20.0
2- 8	P.M.	47.1	52.9	100.0
2- 9	A.M.	42.2	13.1	55.3
2-10	P.M.	30.5	102.3	132.8
2-11	A.M.	31.9	7.6	11.5
2-11	P.M.	18.2	40.8	59.0
2-12	A.M.	32.1	17.7	49.8
2-12	P.M.	160.0	90.9	250.9
2-15	P.M.	252.9	73.5	326.4
2-16	A.M.	36.6	5.4	40.0
2-16	P.M.	137.7	103.6	241.3
2-17	A.M.	67.7	9.8	77.5
2-22	P.M.	136.5	42.9	179.4
2-23	A.M.	60.2	10.7	70.9
2-23	P.M.	183.6	47.6	231.2
2-24	A.M.	25.5	8.1	33.6
2-24	P.M.	290.1	1.3	291.4
	Totals:	1,683.2	669.8	2,351.0

	Av. in Swamp	Av. in Open	Av. in Study Area
Daily	84.60	33.45	117.50
Daytime	134.65	57.39	192.04
Night-time	33.67	9.59	43.26

* P.M. - daytime movement counts recorded in the evening of that day and corrected to equivalent 10 hr. periods.

A.M. - night-time movement counts recorded in the morning and corrected to equivalent 10 hr. periods.

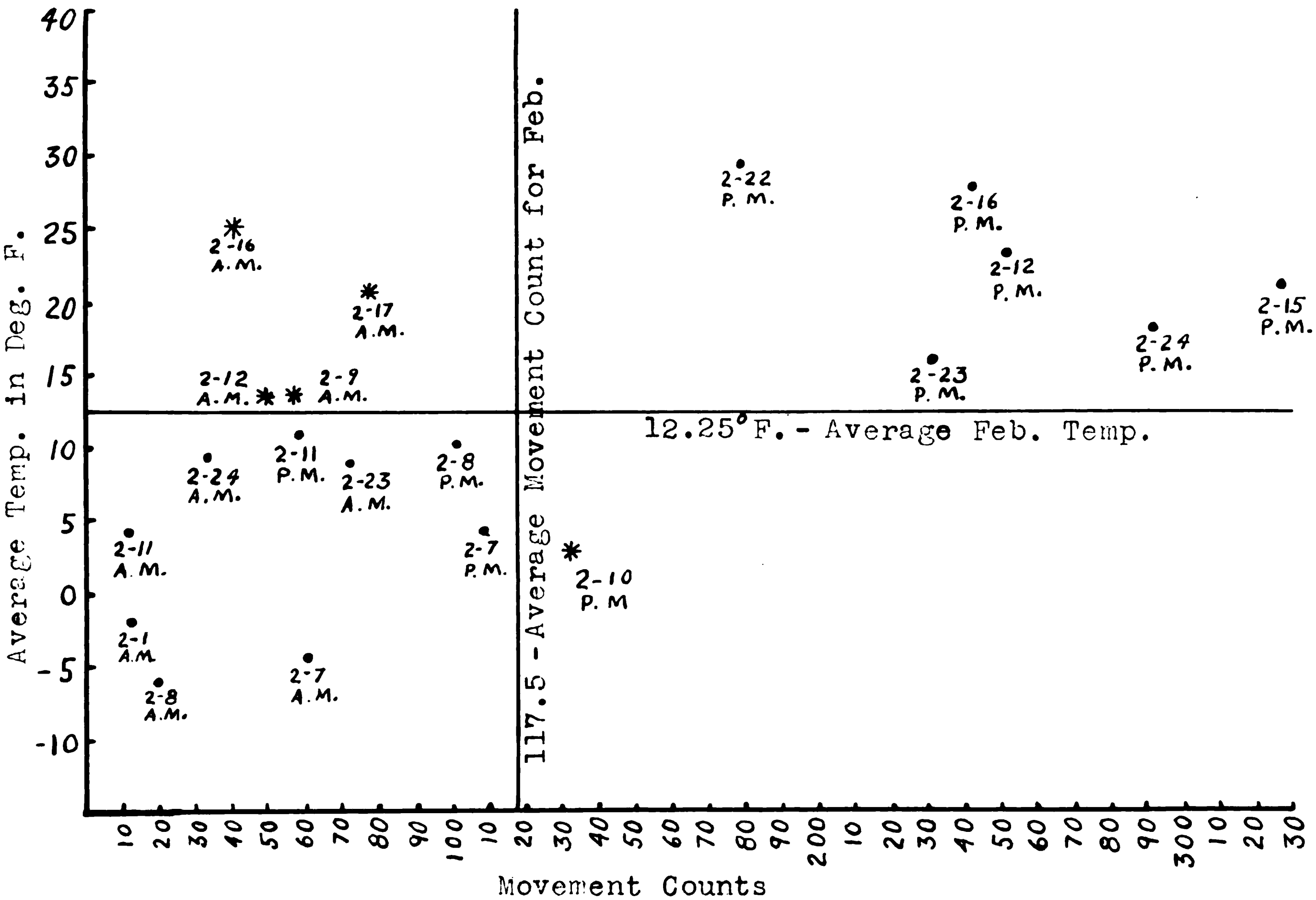


Fig. 9--Relationship of total 10 hr. movement count to the av. 10 hr. temp. for study area Feb. 1962 **with recording** date and time. When the temp. was below av. the movement count was below av. When the temp. was above av. the movement count was above av.

* These 5 anomalies occurred during the 4 heavy snow storms in Feb.

rectilinear or curved line relationship. This pattern is related only to thermometer temperature and does not consider the "meaningful temperature" resulting from the combined heat loss effect of wind and temperature. However, there is a trend in the actual temperature deer movement relationship. When the temperature was below average, the deer movement was below average. When the temperature was above average, the deer movement was above average. The deviations from this pattern caused anomalies to appear in the graph (Fig. 9). These anomalies were related to periods of heavy snowfall and are discussed further in the section on snow and deer movement.

The evidence presented in this section shows that there is a relationship between temperature and winter deer movements. This evidence would also support a hypothetical curve of a deer movement and temperature relationship for the temperature range encountered in this study. At the extreme low temperature range, deer would be moving and active to keep warm. As the temperature moderated, deer activity would lessen and normal bedding and loitering would take place. With an increased temperature rise, the activity and daily movements of deer would increase. This increase in deer activity would continue until the highest temperature for the test period was reached. Here the hypothetical curve would end, with deer movements increasing with a rise in temperature. The degree of the curve is altered by the influence of other weather factors.

I computed a Pearsonian-product-moment correlation coefficient (r_{yx}) for deer movements and temperature in the open and in the swamp (Simpson, Roe, and Lewontin, 1960). The correlation coefficients showed a low probability (greater than .1) of a rectilinear relationship between temperature and deer movements. This computation would not take into consideration the influence of the other weather variables. While all factors that make up a given set of climatic conditions have a possible effect on the influence of temperature, I failed to find evidence in this study with which to evaluate this effect, with the exception of wind and snow. The altering of the effect of temperature by wind has long been recognized. This modification of the effect of temperature can be expressed by the estimate of a meaningful temperature as previously stated. The change in the effects of temperature by snowfall can be visualized in fig. 9, where the deviations from the general pattern of deer movement and temperature relationship occurred during sampling periods with heavy snowfall.

Wind and Deer Movement

Wind has an important effect upon winter deer movements and behavior. Deer respond to both fluctuations in wind velocity and changes in wind direction. Darling (1937) has pointed out the many vagaries of wind and their effect on red deer behavior. Deer move about from hour to hour to find the most comfortable weather conditions and wind plays an important part in determining the weather conditions (Taber and Dasman, 1958). Wind is a component of "meaningful temperature". Wind accentuates the effects of cold; and on cold, windy days deer retire from otherwise favorable feeding places to leeward hillsides or protected clearings (Linsdale and Tomich, 1953).

When deer seek shelter from the wind, not only is the velocity of the wind important but also the direction. The relationship of cover, either vegetational or topographical, to the direction of the wind determines the value of the shelter provided by that cover. It is logical that deer seek the leeward side of cover when seeking shelter from the wind. I made many observations, during the course of this study, of deer in groups and singles, either standing or bedded in microclimatic situations that provided shelter from the wind and exposure to sun. In one instance, 23 deer beds were counted in a small open area. This area was protected from the wind by the surrounding vegetation and also provided warming from the sun due to the lack of an overstory.

In the field, it was exceedingly difficult to locate deer in the open during periods of high winds. There was also a general retardation of all deer movement during periods of high winds. On January 15th during the morning, a gusty wind was blowing and no deer were sighted; however, in the afternoon the wind abated and deer were observed. On January 29th an observation run was made while a bitter cold wind was blowing, and no deer were moving. On February 16th a westerly wind was blowing and it was quite warm. Deer were moving in groups but always near cover (these observations were taken from daily log maintained during the field research).

Halloran (1943) observed his highest deer counts, in the open, when there was little or no wind. When there was a distinct air movement, the deer tended to spend more time in the brush. In Vermont, Severinghaus and Roger Seamans watched 30 deer move from one slope that was being swept by a cold west wind to another slope that was completely protected from the wind (Taylor, 1956). The following observation was made by Linsdale and Tomich (1953):

"On January 9, 1949, the minimum temperature was 18°. During the day a cold wind blew from the west and northwest and the sky was partly overcast. The maximum temperature of the day was 35°. All deer seen that day were in situations protected from the wind."

Other such observations were also made by these authors substantiating this observation.

On February 6th and 7th I observed what I believe were the same three deer (One was positively identified by the collar she wore from the previous year's research) bedded in the same location. There was a cold wind blowing from the southwest and the sky was clear with a bright sun shining. These deer were bedded in an open depression that gave cover on the north, south, and east by a steep slope, and on the west by a dense conifer stand. On the third day under similar weather conditions, excepting a west wind, two deer were jumped from their beds in the same location. These observations point out that deer shrink from cold winter winds and move to find shelter from it.

The daily average wind velocity in the open was 1.30 m.p.h. and the daily average wind velocity in the swamp was .23 m.p.h. (Table 4). There was 465% greater wind velocity in the open, and there was also a greater fluctuation of wind velocities in the open. Changes in wind direction have a greater effect on microclimatic units in the open. The average daily movement count in the open area was 33.45, while the average daily movement count in the swamp was 84.6 (Table 8). The swamp with its lower average wind, less fluctuation in wind velocity and less effected by changes in wind direction, had an average daily deer movement count 152% greater than the open. The average daytime wind in the open was 421% greater than in the swamp, while the average daytime deer movement count in the swamp was 135% greater than in the open. The average night-time wind in the open was 642% greater than in the swamp, while the average night-time deer movement count in the swamp was 251% greater than in the open.

I computed a Pearsonian-product-moment coefficient of correlation (r_{yx}) for deer movement and wind velocity in the swamp and for deer movement and wind velocity in the open (Simpson, Roe and Lewontin, 1960). The correlation coefficients failed to show a significant probability (greater than .1) of a rectilinear relationship between deer movement and wind velocities. The relationship between wind and deer movements is probably a multiple correlation involving one or more of the other weather variables. Darling (1937) gives the factors of temperature, humidity, wind, rainfall, snow, and frost as contributing to weather conditions which effect deer movements. He also states that wind can never be considered apart from its quarter, the season, other atmospheric conditions, and the particular piece of country.

Meaningful Temperature and Deer Movement

The combined effect of low temperature and wind on deer movement has long been recognized. Darling (1937) stated that in summer, red deer moved to areas exposed to cooling winds, but in winter the effect was the opposite, with the deer seeking shelter from cold winds. Taylor (1956) cites several examples of observations, by different observers, of deer responding to cold winter winds by seeking shelter from it and a lessening of daily activity. Linsdale and Tomich (1953) state that deer seek shelter from cold winds, and the seeking of shelter from wind is heightened by the lowering of temperature.

Although the combined effect of wind and temperature is recognized, little has been done in wildlife research to correlate a combined value for wind and temperature to animal behavior and movements. I made a thorough search of literature and research pertaining to deer and failed to find one instance of an estimated value set for the combined affect of wind and temperature.

The combined effect of wind and temperature is being considered in studies of environmental conditions for man. Siple (1939), in his experiments at Antarctica, calculated the heat loss of water in a plastic container at different temperatures and wind speeds. The term "wind chill" was first introduced by Siple (1945) as a term describing the relative discomfort resulting from the heat loss due to the combined affect of wind and temperature. Falkowski (1958) presented methods of estimating "wind chill" and a "wind chill" nomograph. The "wind chill chart" (presented in <u>Air Conditioning, Heating and Ventilating</u>, guide, March 1959) was based on the work of Siple (1939) and Falkowski (1958) and gives effective temperatures for different actual temperatures and wind speeds. By plotting the values given in this chart, I constructed the meaningful temperature nomograph (Fig. 7).

Data for movement in the swamp (Table 3) and "meaningful temperature" in the swamp (Table 5) were used to compute the bargraph of the "meaningful temperature" and deer movement relationship (Fig. 10). These data were used because well established deer trails in the swamp allowed the deer to move freely throughout the study period, while in the open the accumilated snow depth was a main factor in restricting deer movement. In constructing the bargraph, the data were grouped in 10 degree temperature segments. The height of each segment was determined by the average deer movement which occurred in each 10 degree temperature range. Two points of criticism of the bargraph are: (1) the small number of samples (N = 20), (2) the lack of samples in the -10° to -20° F. "meaningful temperature" range.

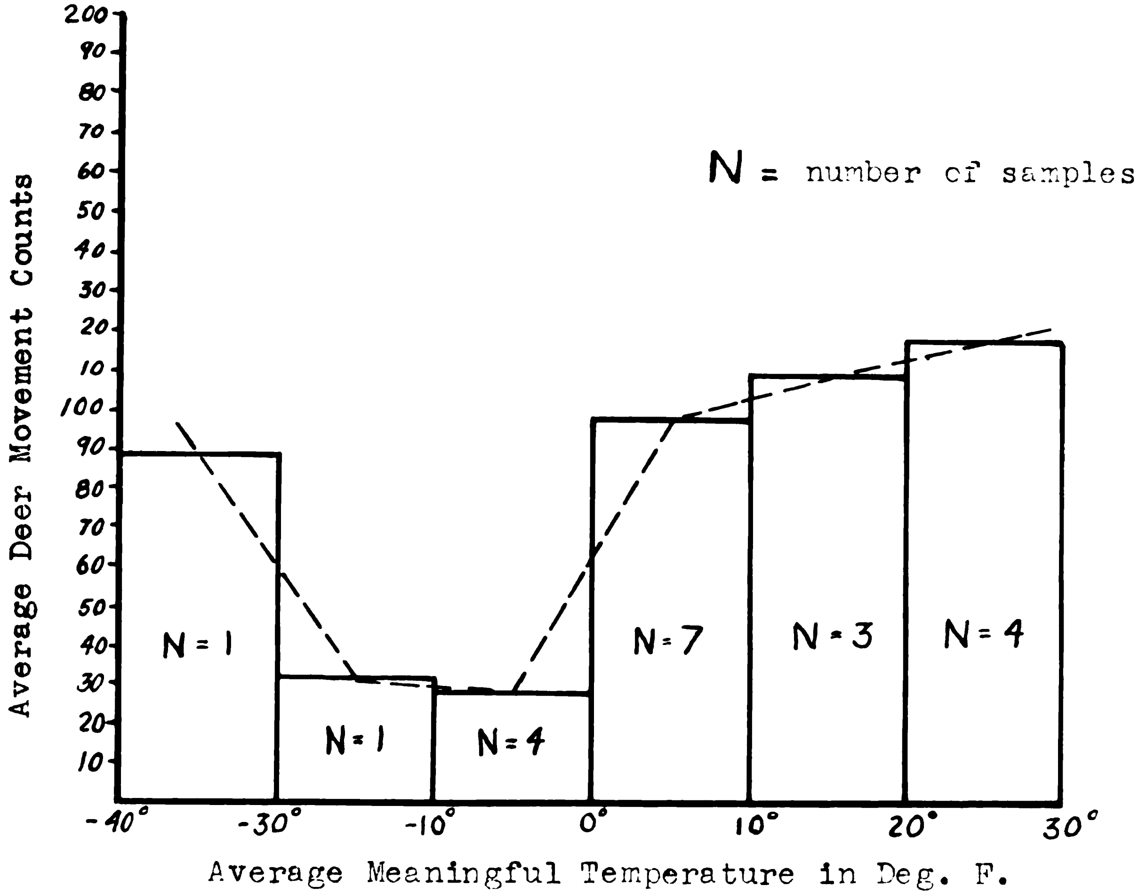


Fig. 10--Bargraph of average meaningful temperature and average deer movement counts in swamp. Broken line connects the mid-points of the segments and follows the pattern of the hypothetical deer movement and temperature curve proposed in the section on temperature and deer movements.

There was a definite pattern for the deer movement and meaningful temperature relationship in the swamp (Fig. 10). This pattern followed the general description of the hypothetical deer movement and temperature curve presented in this paper under temperature and deer movements. When the hypothetical curve was proposed, it was done on the basis of field observations made by Mezger and myself and from the observations of others presented in the literature. The hypothetical curve could not be corroborated by the movement and temperature data. The meaningful temperature and deer movement relationship, which uses the effective temperature resulting from the combined factors of actual temperature and wind, does corroborate the hypothetical deer movement and temperature curve.

A comparison of "meaningful temperatures" illustrates the difference in winter shelter provided by the swamp and open area. The open area had an average meaningful temperature of -20^{o} F. (Table 5), an average daily movement of 33.45 and a total movement count of 669.8 (Table 8). The swamp had an average meaningful temperature of 5^{o}F. (Table 5), an average daily movement of 84.6 and a total movement count of 1,683.2. I believe that the great differences in deer movements in the open or in the swamp are caused by the deer seeking shelter from winter weather, and that they selected the most comfortable microclimate which was provided by the swamp area.

Snow and Deer Movement

This section is concerned primarily with the effects of snowfall on the daily movements and behavior of deer. The aspects of snow depth or snow accumilation are discussed in a following section under The Accumilative Effects of Winter Weather on Deer Movement.

Linsdale and Tomich (1953) state that mule deer seek shelter from falling snow by bedding beneath dense trees, live oaks in particular. But following the snow there was heavy feeding activity on the branches of trees and shrubs bent down and made available by the weight of the snow. In a heavy northern snow storm a deer may hole up below the branches of a dense conifer for as long as three days (Madson, 1961).

One particular observation made during the field research illustrates very well the behavior of deer during a snow storm. On February 21st it was snowing and a moderate east wind was blowing. While making the morning transect run on transect number 2, I headed west along the road at the northern edge of the swamp. I was just leaving an open segment of the transect and entering a cover segment when I observed a deer bedded under a balsam at the edge of the swamp about 75 feet from the road. As I observed the deer for about 5 minutes, it raised its head, stared at me, but remained calm and made no move to leave. This deer was observed in its bed three times during that day and was still bedded when the evening transect run was made. On the following day (February 22nd) it was again snowing, the wind was still moderate but had shifted to the west. The same deer was observed still bedded under the balsam in the morning, and again during the evening transect run. On the following two days the snowing had subsided and the deer was not observed in the bed. On February 25th a light snow fell during the evening. The following morning it was snowing and raining heavily, and what appeared to be the same deer was observed bedded under the balsam on both the morning and evening transect runs.

On the morning of February 15th, following a 6 inch snowfall which occurred the preceding night, no deer were observed nor were there any fresh deer tracks indicating movement had taken place. During the morning, a gusty wind continued to blow snow from the trees and the deer remained inactive. However, by evening the wind had abated and the deer began to move. This indicated that the deer were inactive while snow was in the air.

These observations typify the deer behavior during periods of snow storms. During periods of snowfall, extra observation runs were made along the transects. Only occasionally was a fresh deer track found. Most of the deer seen on these runs were bedded under conifers. When deer were seen standing, closer observation showed that, with few exceptions, these deer had been alerted and had risen from their beds.

The five anomalies that occurred in the temperature and movement pattern (Fig. 9) were related to snowfall. On February 9th* and 10th*, traces of snow were falling. February 9th followed a day of no snowfall and normal deer movement. On the 9th, snow began to fall, and although the temperature was above average, the movement was well below average. On the 10th, traces of snow were still falling, the temperature was far below average, but the movement was above average. On February 11th, during the night, it began to snow and 2.5 inches of new snow fell. At this time, the movement count was very low (11.5, lowest night-time count). On

* Anomalies that appear in Fig. 9.

February 12th* traces of snow still fell in the morning, and although the average temperature was 13.63°F. (above daily average) the movement count of 49.8 was below the daily average of 117.5. In the afternoon the temperature rose to 23.13°F. and there was a very high movement count of 250.9. On the 13th, 7 inches of snow fell, and on the 14th, 4 inches fell (total of 11 inches made the heaviest snowfall of test period). During these two days, a very low movement occurred, with all tracks counted and deer sighted in cover. On February 15th the snowing subsided, and the highest deer movement count of 326.4 was made. During the night (February 16th*) it again snowed heavily (2.5 inches) and the movement decreased. However, the snowing stopped early in the day, and in the evening the deer movement count was high (241.3). During the night (February 17th*) more snow fell and movement decreased.

The general pattern of deer movement and snowfall indicates that deer move prior to a snow storm, move very little during the snowfall (regardless of other weather factors), and are very active following a snow storm. An exception to this was the morning of February 15th, when a gusty wind was blowing snow from the trees and the deer were not moving. However, when the wind abated, deer began to move and a record evening deer movement count was made (326.4). The deer had a definite aversion to heavy snowfall and sought shelter from it in the coniferous swamp. The deer did occasionally

* Anomalies that appear in Fig. 9.

move during a light snowfall, especially if the period had been preceded or followed by a heavy snow storm.

Barometric Pressure, Relative Humidity and Deer Movement

Darling (1937) in A Herd of Red Deer states: "Considered apart from its prognostic value when measured by ourselves, I have been unable to notice an influence of barometric pressure on the movements of red deer." In carefully scanning the data concerning deer movements and behavior, and barometric pressure, I found no pattern or trend directly related to barometric pressure. Changes in barometric pressure generally indicate a change in weather conditions and in this way, barometric pressure would have an indirect relationship to deer movement.

During February, each heavy snowfall occurred during a rapid fall in barometric pressure. In fact, each rapid fall in barometric pressure was accompanied by a heavy snowfall. The effects of a heavy snowfall on deer movements have already been discussed. This effect is characterized by high deer activity before and after a heavy snowfall and very little activity during a heavy snowfall; therefore, there is an indirect relationship between a sudden drop in barometric pressure and deer movements through the third factor, heavy snowfall.

On each occasion (in February), a very low barometric pressure was accompanied by an increase in high winds, and a high barometric pressure was accompanied by lower winds. High winds, in the winter, have an adverse effect on deer movements, curtailing movement in the open and reducing it in the swamp area. Thus, there is an indirect relationship between barometric pressure and deer movements through the third variable, wind. Low barometric pressures were also accompanied by higher than average temperatures, and high barometric pressures were accompanied by average to low temperatures (mostly below average temperatures). Thus, low barometric pressures would have an indirect relationship to deer movements through the third variable, temperature.

In the literature, I found many references to effects of humidity on deer movements and behavior, but these references did not deal with this relationship at the low temperatures encountered in my research. The U.S. Weather Bureau does not consider humidity to be of importance in the Discomfort Index at these temperatures (Eichmeier, 1962). Robinson (1960), in a study of winter shelter requirements of penned white-tailed deer, found that humidity had a minor influence on activity and selection of bedding sites.

I could not find a direct relationship between deer movements and humidity. However, there is an indirect relationship between humidity and deer movements. During periods of higher temperatures and snowfall, there is a relatively higher humidity.

THE ACCUMILATIVE EFFECTS OF WINTER WEATHER

Introduction

The purpose of this section is to present the overall seasonal effects of winter weather conditions on the movements and behavior of white-tailed deer at the "Little North Club". The overall pattern of deer movement and behavior in winter is as follows:

(1) The advent of adverse winter weather leads to the seeking of shelter.

(2) The increased frequency and intensity of adverse winter weather increases the use of shelter areas and restricts the activities of a greater number of deer to these areas.

(3) Large concentrations of deer remain in the swamp when the accumilated snow is deep.

(4) Large concentrations of deer result in competition for food; unsuccessful competition or lack of food can result in death from starvation.

The Winter Story

The movements of white-tailed deer are seasonal and daily. Their seasonal movements are responses to the changing climatic conditions which are unfavorable to their comfort so that they move to more favorable habitats (Taylor, 1956). Winter cover use is influenced more by the deer's need for protection from low temperatures and wind than by their food requirements. Deer commonly concentrate at sites characterized by fairly mature, dense stands of coniferous cover. The habit of deer concentrating and limiting their winter activities to a portion of their normal range is commonly called "yarding" (Banasiak, 1961). Deer movements related to yarding were classified by Hammerstrom and Blake (1939) into three phases; concentration, confinement, and dispersal. The period of confinement overlaps the other two. Concentration occurs in December after hunting season and following the rut. Deer group together, often in bands of four or five, and gradually drift toward the winter yard.

When we arrived at the "Little North Club" on January 8th, the period of concentration had begun. The first heavy snows of the season had just occurred and had accumilated to a depth of 16 inches. This also proved to be the base snow for the winter's accumilation, and the ground remained covered until spring. Deer activity was centered around the swamp. Deer were ranging out from the swamp to forage but returned quickly to the shelter during adverse weather.

On January 16th the snow was between 16 and 20 inches deep, but it was loose and drifting. The deer were ranging freely from the swamp, but well defined trails had been established in the swamp area, especially in the fingers of cover that led from the swamp. By February 1st, well defined, packed trails had been established in the swamp and fingers of cover leading from the swamp. The snow depth averaged 16 inches in the open, but the snow was packed and dense. Most of the deer movement to and from the swamp was restricted to the trails in the fingers of cover, with very few deer venturing into the open. At this point, the swamp became the heart of all deer activity with arteries of trails leaving the swamp in fingers of cover.

With the increased snow accumilation and drifting of snow, as the season progressed, the trails following the fingers of cover gradually diminished until February 26th when deer ceased to move from the swamp (Fig. 11) except for an

Fig. 11--With the first heavy snow accumilations, there were 6 well defined trails crossing this segment of transect number 2. With increased accumilation and drifting, the trails diminished to 1 at A. This trail was abandoned on February 26th when crust formed.

occasional individual that ventured out a short distance on hard packed trails maintained by the observers. On February 26th it rained and snowed most of the day. The rain formed 3 inches of breaking crust on a total average snow depth of 28 inches in the open (Fig. 8). Without snowshoes a man was unable to travel in the open under these conditions. At this point, the period of confinement was fully established.

A Search for Comfort

According to Severinghaus (1953), deer choose a winter area by experimenting. They try first one area, then another. After trying various locations each winter, they finally discover the place which provides them with the protection they want. If this protection is not uniform over the entire area, and the winter becomes more severe, the deer in the poorer shelter zones work into the best shelter. A study of many deer wintering areas suggests some, but not always all, of the following requirements:

(1) The topography of the land provides escape from the cold winds.

(2) Coniferous trees provide protection from cold winds, shelter from accumilating snow, or least depth of snow.

(3) Topography of the land and distribution of trees and shrubs provide good sunning places.

The microclimatic data presented in this study indicates that the swamp has the best combination of winter shelter requirements as presented by Severinghaus.

There were individual examples of deer selecting small microclimatic units for winter shelter. Just east of the swamp, and connected by a narrow finger of cover to the swamp, was a small cover area of mixed hardwoods and conifers about 3 acres in area. Throughout most of the winter, one lone deer was observed repeatedly in this area until the formation of the crust on February 26th. To the north of this area and separated from it by 200 yards of open area was a small stand of mixed aspen and jack pine. This stand was approximately 2 acres in area and was surrounded by open area but had a steep slope along the north border. Three deer were seen repeatedly in this area (I believe it was the same group although the deer were unmarked) until February 26th when the crust formed. I assumed that the deer in these small areas had left their small microhabitats and sought out the better shelter of the swamp.

Within the swamp itself, a shift of deer concentration to a more favorable microhabitat occurred with the increased severity of winter conditions. At the onset of deer concentration in the swamp, activity along the north and south traplines was about equal. Movement counts taken on these segments of transect number 1 indicated no trend towards heavier deer activity at either point. By the end of the study, most of the tracks counted and deer observed were on the south segment and the south portion of north and south segment of transect number 1 (Fig. 1). Early trapping records indicate that an equal number of deer were trapped on the north and south traplines. By the end of the trapping study 63.5% of the deer trapped were taken on the south line, while only 34.7% were trapped on the north trapline, indicating a shift of deer activity to the vicinity of the south line. It was thought that the cutting of cedar in the vicinity of the south line (to observe deer behavior at cuttings) might have had an influence on the concentration of deer. However, cutting cedar along the north line did nothing to alter this concentration.

A cover profile was taken on the north and south traplines. The profile showed that the south line had a frequency of 84% conifers and 17% lowland hardwoods, a density of 15.2 trees per quadrate and an estimated closure of 70-90%. The north trapline had a frequency of 74% conifers and 26% lowland hardwoods, a density of 16.9 trees per quadrate (many sapling and pole size hardwoods) and an estimated closure of 30-40%. I then assumed that the shift in deer concentration to the vicinity of the south line was in response to the better shelter provided by more closed, nearly pure coniferous stand found there (Fig. 12 and Fig. 13).

Competition

With the confinement of deer activity to the swamp ("yarding"), competition for the available food became a problem. The well established "browse line" in the swamp indicated the past history of food shortage. There was some food made available by cedar boughs bent with snow. The porcupines provided some food by dropping litter from trees. Porcupine trees were heavily frequented by both deer and snowshoe

Fig. 12--Typical dense coniferous cover along south trapline.

Fig. 13--Typical cover along north trapline.

hares until an extensive shooting of porcupines by club members. However, a thorough survey of the swamp made it quite evident that there was not enough food for a concentration of deer, a frequent problem in yarding areas.

The scarcity of food was made evident by other observations. Undesirable food species such as balm-of-gilead, balsam fir and white and black spruce were being heavily utilized (Fig. 14). The pangs of hunger also overcome the deer's fear of man. The first time I cut cedar to observe deer behavior, I had just felled the first tree and moved to the second (about 20 feet from the first) when the first deer moved in and began feeding on the cedar. When I had finished

Fig. 14--Balsam browsed on by deer.

cutting the second cedar, I moved off about 30 feet and leaned against a tree to observe. Within 20 minutes, there were 18 deer feeding on the cedar. Deer were also fed at the cabin for purposes of observation and picture taking. Some of these deer would come to within 10 feet of a standing man to obtain pieces of apple. At both feeding sites deer were quarreling and fighting for desirable food, striking with forefeet, with the larger deer driving fawns from food.

Trapping records show an increased susceptibility to trapping as the accumilative effects of winter weather and food shortage were felt by the deer. The following 5-week record shows the increase in trapping success:

Week Beginning	Jan. 14	Jan. 21	Jan. 28	Feb. 4	Feb. 11
Deer Trapped	1	2	6	13	17

The first evidence of starvation became apparent on January 29th. A small fawn was injured in a trap and had to be dispatched. An autopsy revealed early signs of starvation; there was very little body fat although the bone marrow showed good fat content. During the first two weeks of February, the deer began to show early signs of starvation, especially the fawns. Deer were observed standing humpbacked with hip bones visible and coats rough; they had a fuzzy-head look. On February 15th a dead buck fawn was found (Fig. 15). An autopsy confirmed death from starvation. There was no body fat and the bone marrow was devoid of fat.

The accumilated effects of severe winter weather created great demands on the metabolism of the deer to provide

Fig. 15--Starved buck fawn found on February 15th.

heat energy. When the demand cannot be met by an adequate food supply, the heat must be furnished by katabolic processes. When the katabolism exceeds the anabolism, weight is lost. The loss of too much weight results in starvation (Kleiber, 1961).

Postlog

We left the research area on March 9, 1962. Being very interested in the final outcome of the accumilated effects of the winter weather on the deer in the area, I requested Carl Basel, Management Forester for the Abitibi Corporation, Alpena, Michigan, to keep notes on the deer situation after I left. This section is based on the notes generously sent to me by Mr. Basel.

On Sunday night, March 11th, and Monday morning, about

10 inches of new very wet snow fell. The temperature on these dates was in the low thirties. The heavy snow storm was accompanied by very strong winds, and tons of branches were broken off per square mile. This damage was especially heavy around swamp edges and open grown trees. Cedar, spruce, balsam and all pines were damaged. This fact saved many deer which faced certain starvation.

The temperatures on March 11th, 12th, 13th, and 14th were in the 27° to 37°F. range at night and 32° to 38°F. in the daytime. Deer on these dates were still in rather tight groups or pockets. The old snow was so soft that it, together with the new snow, made travel outside the swamp impossible. Deer were, however, moving off established trails within the swamp to feed on browse furnished by the recent storm. Deer were so hungry that they were not selective on these broken branches. Spruce, balsam and cedar were all being eaten. The deer were not moving out of the swamp edges to get white pine boughs as close as 200-300 feet away.

As of March 14th, the two tagged deer (yellow and white ribbons) were still hanging out next to the road crossing Little North Creek. The three-legged deer frequently seen in this vicinity was still alive. Two dead fawns were found at the north end of "Little North" swamp. No special effort was made to look for dead deer. The snow depth on both sides of the swamp was 28 inches.

On March 15th and 16th the weather was balmy, 30° to 33°F. at night and 45°F. in the day. Deer were still keeping to the swamp, eating the broken boughs; spruce, balsam, and cedar. On March 20th, two more dead fawns were found. Although deer were working the edge of the swamp to browse on broken white and jack pine branches, they still were not working out in the open. The snow depth outside of the swamp was 21 inches. Temperatures from March 15th to 20th were in the high twenties to low thirties at night and middle thirties to 40°F. in the day.

From March 20th to 31st, the night temperatures were in the low thirties, the daytime temperatures were in the high thirties and low forties. On March 28th, the daytime temperature was 50°F. By March 31st, the snow was down to 8-10 inches in openings. The ground was showing under jack pine and on knolls. The deer were spreading out from the swamp to get at anything, such as herbs and dead grass showing up in these spots; also to browse on sweetfern. They had been able to roam quite freely within the swamp to get at bent and broken boughs of cedar, white pine, and balsam.

During the period from April 1st to 7th, the temperatures ranged in the low thirties at night to high forties in the daytime with no inclement weather (low precipitation). The deer looked ragged but were moving out of the swamp to browse. The ground was 60% bare outside of the swamp. A look around the swamp edges disclosed quite a few dead deer which appeared to be last spring's fawns. No dead adult deer were seen. The one big single factor which saved many deer was the breaking of branches during the March 11th storm.

Also, after the cold weather on March 15th, temperatures, sunshine and low precipitation had all been favorable.

From April 8th to 25th, the weather was ideal for that time of year. Very little precipitation, cool nights with pleasant daytime temperatures were the general rule. There was no prolonged nasty weather that would have an adverse effect on deer. The deer were completely out of the swamp, feeding on rye fields, on old cuttings, and on new cuttings on the Hubbard Lake, Gerke, Smith and Wolf Ridge Clubs. They were bedding at night on slopes and under conifers at the edges of openings.

During the period from March 11th to April 25th, the period of concentration became overlaped with the period of dispersal. With the favorable weather and loss of snow, the period of concentration gave way and the period of dispersal occurred.

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