W-0003

WINTER RESPONSE OF DEER TO SNOWMOBILES AND SELECTED NATURAL FACTORS

By Gerald Robert Lavigne

An Abstract of the Thesis Presented in Partial Fulfillment of the Requirements for the Degree of Master of Science (in Wildlife Management). May, 1976.

Deer (Odocoileus virginianus) responses to snowmobiles and selected natural factors were studied during the winters of 1972-73, 1973-74, and 1974-75. Field work was conducted in the 810-ha Hayden Brook deer wintering area, located in T3R4 and Pierce Ponds townships, Somerset County, Maine.

Deer use of a 17.1-km snowmobile trail was significantly correlated with deer density, and winter severity indices. Most deer movements on snowmobile trails were for short distances, and they commonly left the trail to browse. Deer used snowmobile trails most frequently and extensively near major bedding areas, where they incorporated the snowmobile trail into their own trail system. Disturbance of deer by snowmobiles did not cause them to abandon preferred bedding and feeding sites.

Deer sank 1/4-1/6 as deep on snowmobile trails as in undisturbed snow. Because of this, the snowmobile trail enhanced deer mobility, and probably reduced their energy expenditure.

Snowmobile trail hardness (during daylight hours) was inversely correlated with air temperature and time since sunrise. Deer sinking depth on snowmobile trails was inversely correlated with snowmobile trail hardness.

Attempts to re-locate deer within the wintering area were temporarily successful, but deer seemed to benefit more from the

felled cedar trees used to keep them in the new location than from improved mobility on the snowmobile trail.

Deer traveled and fed along snowmobile trails made in extensive openings adjacent to existing deer concentration areas, especially when deep, soft snow limited their off-trail mobility. Manpower and time limitations were obstacles to furnishing enough snowmobile trails to ensure uniform browse utilization.

Deer response to snowmobiles consisted of running out of sight or staying in place. The number of deer staying in sight increased, each winter, from December-April, and may have been caused by progressive weakening of deer, decreased activity in mid-winter, and habituation to snowmobile disturbance. Lateral concealment, lack of an easy escape route, deep snow, and large sinking depths may also have prompted some deer to avoid running away, when approached. Deer tended to panic when a fast-moving snowmobile was oriented directly toward them. At Hayden Brook, numerous areas, which were inaccessible to snowmobilers, served as refuges for deer from further disturbance, and enabled them to tolerate snowmobiles.

WINTER RESPONSE OF DEER TO SNOWMOBILES AND SELECTED NATURAL FACTORS

By

GERALD ROBERT LAVIGNE

A THESIS

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Science

(in Wildlife Management)

The Graduate School

University of Maine at Orono

May, 1976

ACKNOWLEDGMENTS

Dr. Voit B. Richens, Assistant Leader, Maine Cooperative Wildlife Research Unit, gave generously of his time and effort in various phases of the field work, and in the development of the manuscript. Dr. Michael D. Zagata, Assistant Professor of Wildlife Resources, and Dr. Marshall D. Ashley, Associate Professor of Forest Resources gave helpful advice on field and statistical procedures. The late Dr. James C. Whittaker, Associate Professor of Forest Resources and Dr. Chester F. Banasiak, Assistant Professor of Wildlife Resources reviewed the manuscript.

Research funds and equipment used in this project were furnished by the Maine Department of Inland Fisheries and Wildlife, the Maine Cooperative Wildlife Research Unit, and the University of Maine at Orono.

Mr. William B. Shoenthaler kindly provided the use of his property and my living quarters on the study area. Arthur and Yevette Haskell furnished valuable data on snowfall. The Scott Paper Company and Central Maine Power Company permitted use of their land for this study.

I am grateful to the many students, and to Roy D. Hugie, Assistant Big Game Project Leader, Maine Department of Inland Fisheries and Wildlife, for assistance with the dead deer searches, and other aspects of the field work.

Maxine Horne typed the final draft of the thesis.

TABLE OF CONTENTS

PAGE

INTRODUCTION 5

DESCRIPTION OF STUDY AREA 7

MATERIALS AND METHODS 12

Climatological Data 12

Population Estimates 13

Over-Winter Mortality 14

Deer Distribution 14

Deer Use of Snowmobile Trails 15

Deer Sinking Depth 17

Snowmobile Trail Hardness 18

Altering Deer Mobility 19

Re-locating Deer 19

Improving Local Mobility 19

Deer Response to Snowmobiles 20

Analysis of Data 20

RESULTS AND DISCUSSION 22

Climatological Data 22

Temperature 22

Solar Radiation 23

Wind 23

Snow and Deer Sinking Depths 24

Winter Severity Index 25

Deer Distribution 26

Winter Deer Population 28

PAGE

Population Estimates 28

Over-Winter Mortality 28

Deer Use of Snowmobile Trails 29

Relation to Winter Severity Index 32

Relation to Deer Distribution and Topography 34

Relation to Disturbances by Humans 38

Deer Sinking Depth 39

Snowmobile Trail Hardness 43

Altering Deer Mobility 47

Re-locating Deer 49

Improving Local Mobility 52

Deer Response to Snowmobiles 55

Encounters on Snowmobile Trails 55

Encounters off Snowmobile Trails 55

Encounters on Foot 60

Research Needs 61

SUMMARY AND CONCLUSIONS 62

LITERATURE CITED 65

BIOGRAPHY OF THE WRITER 68

INTRODUCTION

Since the commercial debut of the snowmobile in 19 snowmobiling has emerged as a popular form of winter recr the snowbelt of North America. The number of snowmobiles has increased from 259 in 1959, to over 2 million in 1972 Originally used as work vehicles by utility companies, sn today are used primarily for recreation (Baldwin and Stod The snowmobile has enabled many people to travel widely i areas which formerly were little disturbed by man in wint

Predictably, the rapid growth in popularity of sno and the mass invasion of remote woodlands by snowmobile e appears to have had considerable impact on wintering whit deer (Odocoileus virginianus). Some adverse effects of s on wintering deer include harassment and running of deer ion (Wettersten 1971, Heath 1974), disruption of normal h and activity patterns (Kopischke 1972, Dorrance et al. 19 depredations by feral dogs (Doherty 1971) and wolves (Mec traveling on snowmobile trails.

Some beneficial effects of snowmobiling on winteri have also been reported. Hugie (1973) found that deer re traveled and fed along snowmobile trails. Some snowmobil Minnesota and Ontario deliberately create trails in deer areas to improve deer mobility and feeding conditions (We 1971, Mech 1972, pers. comm.). Doan (1970) suggested tha maintenance of snowmobile trails in deer wintering areas

valuable management tool for reducing over-winter deer malnutr and mortality.

However, little is known about the extent of deer use c snowmobile trails, or of the environmental conditions which pr such use. No attempt has been made to determine the value of ing deer mobility by use of snowmobile trails, and deer behavi in the presence of snowmobilers has not been adequately docume

The objectives of this study were: (1) to relate deer snowmobile trails to snow characteristics and weather; (2) to determine the requisites for favorably altering deer mobility feeding patterns by use of snowmobile trails; and (3) to evalu deer reactions to snowmobiles.

DESCRIPTION OF STUDY AREA

Field work was conducted in the 810-ha Hayden Brook deer wintering area (Fig. 1) located in T3R4 and Pierce Ponds townships, Somerset County, west-central Maine. The wintering area encompasses the northern slope of Basin Mountain and the western slope of Hurricane Mountain to 430 m above mean sea level. Topography is gently rolling in the northwestern portion of the study area, while the remainder consists of gradual to steep mountain slopes and ridges of varying aspects. The schistose soils are rocky, generally shallow, and modified by glacial action (Rourke and Hardesty 1966); they are moderately well drained on the mountain slopes, but poorly drained elsewhere. The 20-yr mean annual snowfall for the area is 293 cm, and several successive days with temperatures below -17.6 C are common in winter.

The Hayden Brook and Spencer Stream deer wintering areas are arbitrarily separated by the Dead River. Deer readily cross the river at 4 or more locations by swimming or walking over the ice. Within the study area, this river contains several rapids, pools, and stretches of slow to swift water. Water levels, and hence river characteristics, vary considerably since much water is sometimes retained and/or released at the Dead River dam, 13 km upriver.

Numerous logging roads exist on the study area, ranging from roads suitable for automobile travel, to overgrown skidder trails. None of these roads were plowed during the 3 winters, and some were used during the study as a snowmobile trail route (Fig. 2, p. 16).

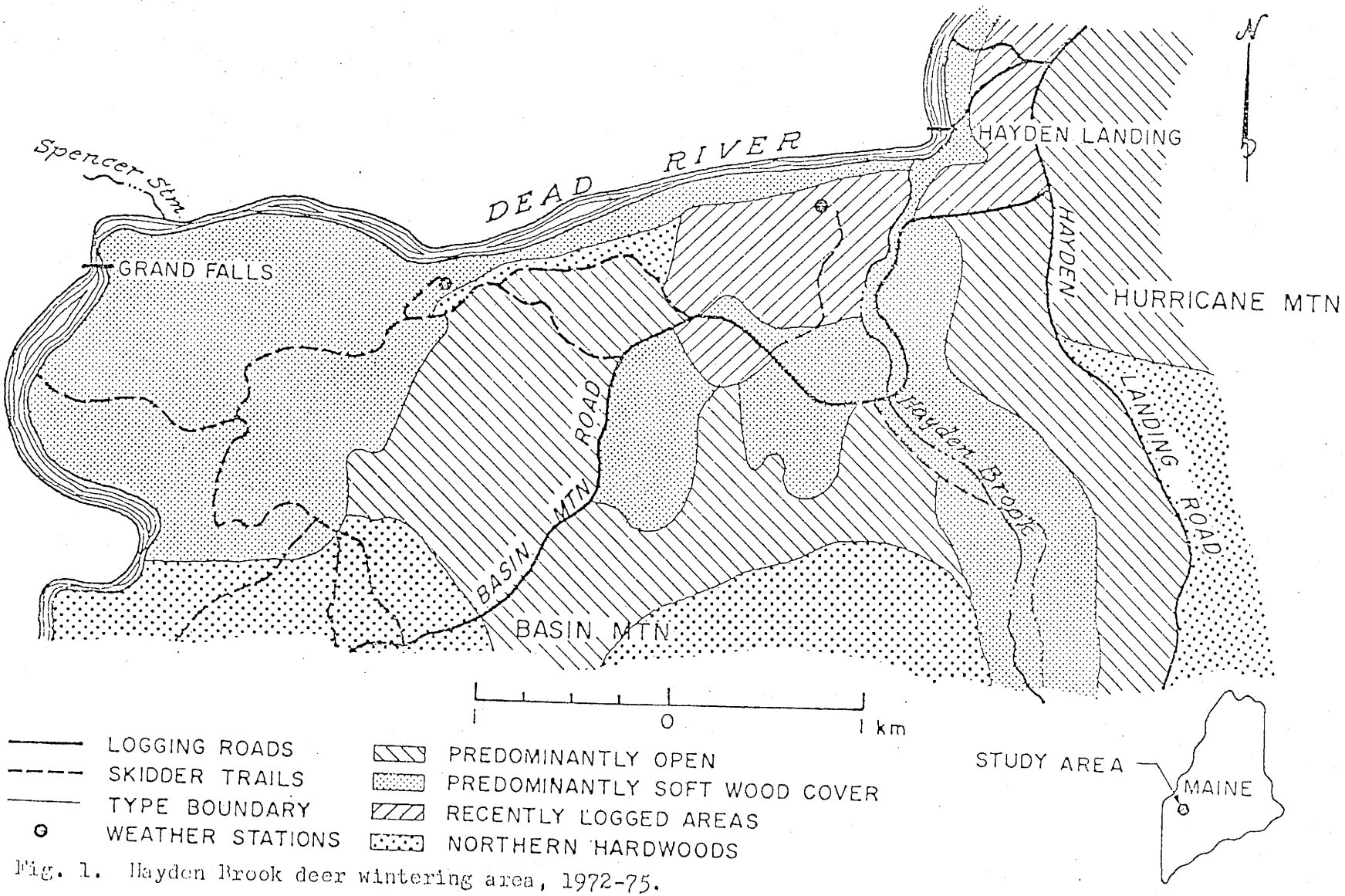

Fig. 1. Hayden Brook deer wintering area, 1972-75.

The study area received little use by snowmobilers, except on weekends, when a few groups of 5 or more were sometimes encountered, generally on the wider logging roads at the eastern end of the wintering area.

Numerous logging operations over the past several decades have resulted in a complex interspersion of cover types. The study area may be arbitrarily divided into 4 basic deer habitat types which have relevance to their mobility (Fig. 1). The western part of the wintering area, the river edge, and a few other localities support maturing spruce-fir forest interspersed by a few openings. These softwood stands are dominated by spruce (Picea rubens, P. glauca), balsam fir (Abies balsamea), and northern white-cedar (Thuja occidentalis) of various ages and densities. Because softwood canopies effectively reduce the depth of snow beneath them (Formozov 1946), this habitat type provided excellent shelter and mobility for deer, but little food. The few openings present were generally over-browsed.

The 2nd habitat type, predominantly open, consists of extensive brushy clear-cuts interspersed with many small residual softwood stands. Located mainly on the lower slopes of Basin and Hurricane mountains, this type furnished abundant browse, but its deep snow reduced deer mobility during parts of the winter. Logged areas (like these) characteristically undergo biotic succession from herbs to shrubs, to sprouts and seedlings, and finally to climax spruce-fir forest in most localities on the study area. Most of the open habitat on the study area is dominated by raspberry

(Rubus spp.), beaked hazelnut (Corylus cornuta), mountain maple (Acer spicatum), red maple (A. rubrum), striped maple (A. pennsylvanicum), sugar maple (A. saccharum), yellow birch (Betula allegheniensis), paper birch (B. papyrifera), American beech (Fagus grandifolia), pin cherry (Prunus pennsylvanicum), aspen (Populus tremuloides and P. grandidentata), willow (Salix spp.), balsam fir, red spruce, and northern white-cedar. Forest succession has been delayed in several openings by over-browsing by deer and moose (Alces alces).

Scattered maturing northern hardwood stands are the 3rd deer habitat type (Fig. 1), dominated by red and sugar maples, American beech, yellow birch, white ash (Fraxinus americanus), and eastern hemlock (Tsuga canadensis). Varying quantities of browse are present in the understory of these stands, but deep snow and lack of shelter often limit its use by deer.

The 4th habitat type, the recently-logged areas, provided a large quantity of browse from the felled tops when logged in late fall or winter. After the tops had dried, however, browse was scarce until sprout growth and seedlings dominated the sites. Several softwood and hardwood stands in the vicinity of Hayden Brook (Fig. 1) were logged in the fall of 1972. Deer utilization of the tops was extensive during that winter, but dropped off sharply during the following 2 winters.

Bobcats (Lynx rufus), which occasionally killed deer in winter, coyotes (Canis latrans), red foxes (Vulpes vulpes), fishers (Martes pennanti), ravens (Corvus corax), and bald eagles

(Haliaeetus leucocephalus) were common, and they frequently scavenged the remains of dead deer in winter. Black bears (Ursus americanus) were important scavengers of deer carcasses in late April and May. Beaver (Castor canadensis) occurred in the area in scattered locations; their cuttings provided deer with a limited amount of browse from the felled tops and from subsequent sprout growth. Snowshoe hare (Lepus americanus) abundance varied considerably on the study area, and their feeding coactions with deer are not known. Red squirrels (Tamiasciurus hudsonicus) provided some deer food by cutting cedar and hemlock branchlets attached to cones.

MATERIALS AND METHODS

Field work was conducted during the winters of 1972-73, 1973-74, and 1974-75 from 1 December-30 April. Generally, 3 wk were spent each month on the study area, and approximately 2,250 km/yr were traveled on snowmobiles. A klondike-type sled, equipped with a plywood box, was used to move equipment and white-cedar browse.

Climatological Data

Six weather stations, each equipped with a hygrothermograph, a maximum-minimum thermometer, a pyrheliograph, and a totalizing anemometer were operated in open, hardwood, and softwood habitats. Only data from weather stations placed in the open habitat are included herein. Weather stations were serviced weekly, from early December to late April of each year. Weekly weighted mean temperature, langleys of solar radiation, and kilometers of wind were calculated from the data following the method of Hugie (1973).

Snow depth was measured weekly to the nearest 1/2-inch (1.27 cm) at 5 sampling points in the open; it was then averaged, and converted to centimeters. Daily snowfall was recorded by Arthur and Yevette Haskell, attendants of the Long Falls Dam Climatological Station, 13 km south of the study area.

A method for quantifying winter severity for deer, as developed by Banasiak (1962) and modified by Hugie (1973) was used as a measure of the effect of snow conditions and weather on deer.

The Winter Severity Index (WSI) is calculated as follows:

$$WSI = (0.42)\frac{SF_s}{SF_m} + (0.22)\frac{SD_s}{SD_m} + (0.17)\frac{T_m-(T_s-T_m)}{T_m} + (0.19)\frac{W_s}{W_m} \times 100$$

where; s = seasonal value
m = long term mean
SF = total annual snowfall
SD = mean deer sinking depth in open habitat
T = weighted mean temperature
W = total kilometers of wind

Each parameter in the above equation was weighted according to its approximate effect on deer mobility (coefficients in parentheses) as previously determined by Hugie (1973) on this study area. A WSI-value of 100 was considered equivalent to a normal winter, above 100 to a more severe one, and below 100 to a less severe winter for deer. In this study, the WSI was calculated weekly, from December-April, as well as for the whole winter. Weekly weighted mean temperature, wind, snowfall, and deer sinking depth measured in the Hayden Brook wintering area for the years 1970-71, 1971-72 (Hugie 1973), and 1972-75 were averaged, constituting 5-yr long-term means for the study area. These long-term means were then used in the calculation of winter severity indices.

Population Estimates

The deer population was estimated at the end of each winter, using a formula based on pellet-group counts (Ryel 1971). Deer pellet groups were counted and tabulated by cover type and location on mil-acre (0.0025-ha) circular plots, located at 40-m intervals along randomly-located transects oriented north and south. Each

transect originated at the Dead River, and extended southward to a point 200 m beyond Basin Mountain Road.

In May 1973, 861 plots were used to determine mean density of deer pellet groups per plot on an exploratory basis. An analysis of the data revealed that at least 450 plots were necessary to estimate the wintering deer population with the desired degree of accuracy ($p<.05$). Four hundred and sixty-six "permanent" mil-acre plots were then established, as above, and subsequently used. All pellet groups were removed from the permanent plots in late fall to ensure that only deer pellets of the current winter were counted.

An estimate of the number of hectares occupied by deer during the winter, and of the number of days that deer occupied the wintering area was derived from field observations. The deer defecation rate given by Ryel (1971) was used for calculations. Ninty-five percent confidence intervals were calculated for each deer population estimate.

Over-winter Mortality

Estimates of over-winter deer mortality were derived at the end of each winter from dead-deer searches as conducted by Hugie (1973). Approximately 20, 22, and 19% of the Hayden Brook deer wintering area was searched by 15-25 people in the spring of 1973, 1974, and 1975, respectively.

Deer Distribution

Spacial distribution of deer in the Hayden Brook wintering

area, determined from observation of tracks, trails, bedding sites, and sightings, was plotted on a map of the study area each week. Factors influencing deer distribution, such as major snow or wind storms, development of snow crusts, and changes in food availability were also recorded.

Deer Use of Snowmobile Trails

Deer use of snowmobile trails was evaluated on a 17.1-km snowmobile trail system (Fig. 2) maintained all winter. Intensity of snowmobile trail use by deer was arbitrarily divided into light use (1-3 deer tracks), and heavy use (>3 tracks). A deer track was defined as a series of hoof-prints made by a single deer, whereas a deer trail was defined as the path created when deer repeatedly followed the same route through the snow.

The distance traveled by each group of deer on the snowmobile trail was measured to the nearest 0.01 mile (0.016 km) with the snowmobile odometer, and the distances of the various groups was summed. Deer trails crossing the snowmobile trail were counted and classified as "crossing trails", or "incorporated trails" (deer trails which followed 6 m or more of the snowmobile trail before crossing). All deer tracks extending 3 m beyond the snowmobile trail were counted, and a track/trail ratio was computed from the data.

Deer use of snowmobile trails was tabulated from late December to early April, each winter, only when the following conditions were met: (1) the deer were in a "normal" pattern of

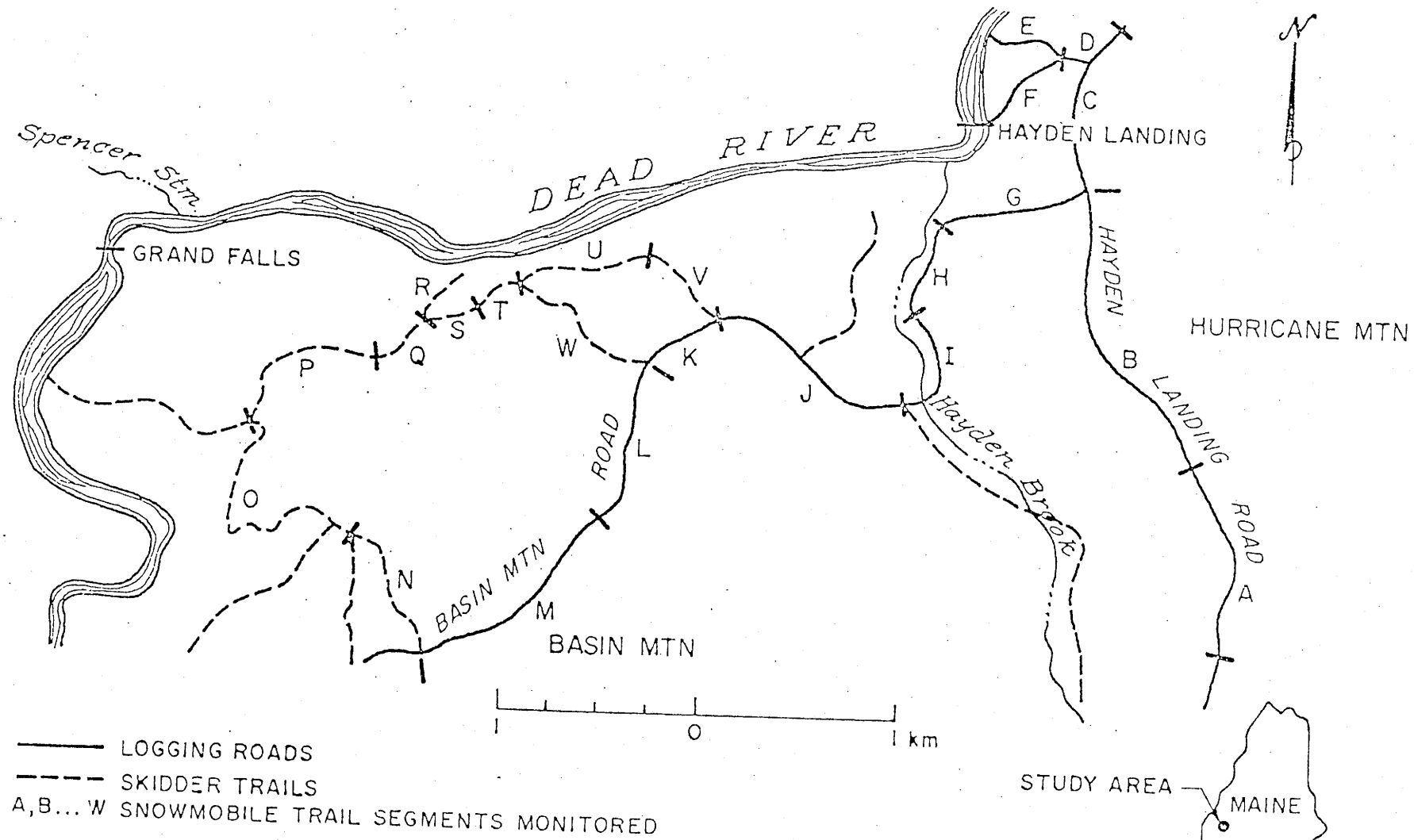

Fig. 2. Distribution of snowmobile trail segments used in UI evaluations in the Hayden Brook deer wintering area, 1972-75.

activity; (2) deer tracks were less than 24 h old, and (3) the weather preceding the evaluation was fairly representative of the weather pattern for that week. An evaluation conducted on 20 February 1975 was not included in the data analysis because the deer had not resumed normal activity following a major snowfall.

An index was devised to monitor differences in the intensity of snowmobile trail use by deer on various segments of the trail system. The trail was divided into 23 segments of unequal length based on differences in topography, cover type, and logging road width (Fig. 2). Each segment was usually classified weekly as heavily used, lightly used, or unused by deer, and assigned a value of 2, 1, or 0, respectively.

At the end of each winter, a use index (UI) was calculated for each segment as follows:

$$UI = \text{no. of times heavy use was recorded} \times 2 + \text{no. of times light use was recorded} \times 1 + \text{no. of times no use was recorded} \times 0$$

The UI was then adjusted to a scale of 100 by dividing 100 by the number of times the segment was evaluated, and multiplying the UI by that dividend. A UI of 100 represents consistently heavy use by deer, 50 represents consistently light use, and a value of 0 indicates no use. Intermediate values indicate intermediate intensities of use by deer.

Deer Sinking Depth

Sinking depths of 10-15 deer were periodically measured, each winter, on and off snowmobile trails, in open, hardwood,

mixedwood, and softwood cover types. Each measurement consisted of the mean sinking depth to the nearest centimeter of 3 hoof-prints per track. Deer sinking depths were not measured on wide logging roads because they did not adequately reflect the surrounding cover types.

Snowmobile Trail Hardness

Snowmobile trail hardness was measured during the winters of 1973-74 and 1974-75 with a modified Swiss Rammsonde penetrometer. This Rammsonde, modified from one developed by Testlab Inc. (Anon. 1970), consisted of a hollow aluminum shaft fitted with a 60° stainless steel cone, a nylon guide rod, and a drop hammer. In operation, the hammer was raised by hand to a certain height on the guide rod, and then dropped freely, driving the cone into the trail. The resistance to penetration in kilograms (hardness) was determined by observing the number of hammer drops necessary to obtain a certain penetration. The Rammsonde hardness number (R) was computed as follows:

$$R = \frac{Whn}{x} + W + Q$$

where; W = weight of drop hammer (kg)
h = height of drop (cm)
n = number of hammer drops
x = penetration after "n" hammer drops (cm)
Q = weight of penetrometer (kg)

Snowmobile trail hardness was measured at 7 locations on the snowmobile trail route; 5 measurements, spaced 1 m apart, were taken at each location. Air temperature, time of day, and deer sinking

depth on the snowmobile trail were concurrently recorded.

Altering Deer Mobility

Re-locating Deer

Field experiments were conducted to determine if snowmobile trails could be used to improve deer mobility in brushy feeding areas. During the winter of 1972-73, 10 attempts were made to move groups of deer from areas of high deer concentration to areas of low or no deer use, by using snowmobile trails and other inducements. In each attempt, a snowmobile trail was created, extending from the concentration area to the new location. Ten cedar trees were felled at the end of the trail, using either an axe or a chain saw. One of the following was then used to induce deer to the new location: (1) the snowmobile trail alone; (2) the snowmobile trail and cedar foliage, placed along it; or (3) the snowmobile trail, cedar foliage, and chain saw noise from felling the 10 trees. Each attempt was evaluated for deer use as often as possible, usually daily.

Improving Local Mobility

In the winter of 1974-75, 10 new snowmobile trails, totaling 9.1 km, were created in the wintering area in addition to the 17.1-km trail already established. These new trails, ranging from 0.2-1.9 km in length, originated in deer concentration areas, and led into brushy deer feeding areas in the form of loops, grids, dead-ends, and open-ends (trails which joined 2 main snowmobile trails).

The extent of deer use, deer feeding patterns, snow conditions, and prevailing weather conditions were evaluated for each trail at 1- or 2-day intervals.

Deer Response to Snowmobiles

Escape behavior of all deer encountered during winter was recorded. Deer encounters were classified as: (1) deer seen while I was on foot; (2) deer seen on the snowmobile trail while I was snowmobiling; or (3) deer seen away from a snowmobile trail while I was snowmobiling. Deer reactions, estimated initial encounter distance, location, cover type, date, time, and temperature were recorded for each deer encountered. Snow depth, deer sinking depth in the open, and the position of the deer in relation to the deer trail when first encountered were also recorded.

Analysis of Data

All quantitative data were put on IBM cards and computer-processed. An ANOVA table was made for deer sinking depths on and off snowmobile trails, by date of measurement, with cover types as treatments. Analysis of variance was also performed for snowmobile trail hardness, by date of measurement, with locations as treatments. Where F-values were significant, differences among ranked means were tested using Duncan's Multiple Range Test (Zar 1974).

Simple correlations were computed for the following: parameters of snowmobile trail use by deer with weekly WSI; seasonal mean deer use of snowmobile trails with seasonal WSI; deer density, as

determined by pellet group counts, with seasonal WSI; estimated deer mortality with seasonal WSI; and deer sinking depth on snowmobile trails, by cover type, with snowmobile trail hardness. Multiple correlation of snowmobile trail hardness with air temperature and time since sunrise was also computed.

Differences between means for deer sinking depth on snowmobile trails and similar means off snowmobile trails were tested, by cover type, using Student's t-test (Zar 1974).

Values for Chi-square were computed to determine if deer escape behavior was affected by the environmental conditions recorded.

RESULTS AND DISCUSSION

Detailed tabular data on weather, snow, winter severity indices, deer mortality, snowmobile trails, and deer encounters have been placed in a Thesis Supplement. Copies of the Supplement are filed in the Fogler Library, University of Maine at Orono; with the Maine Cooperative Wildlife Research Unit, University of Maine at Orono (Nutting Hall), and with the Maine Department of Inland Fisheries and Wildlife, also at Nutting Hall.

Climatological Data

Temperature

Weighted mean temperature for the 1972-73 (-5.2 C) and 1973-74 (-4.3 C) winters averaged 1.3-2.2 C higher than the 5-yr mean for the study area, while that for the winter of 1974-75 (-7.5 C) averaged 1 C lower. Weighted mean temperature during December was highest during 1973-74 (-3.9 C), followed by 1974-75 (-7.5 C), and 1972-73 (-9.2 C). January and February were the coldest months each winter, when minimum temperatures of -25 to -38 C were recorded during several successive weeks. Weighted mean temperatures in January were highest during 1973-74 (-7.5 C), followed by 1972-73 (-9.5 C), and 1974-75 (-11.4 C). Weighted mean temperatures during February averaged -8.3, -9.4, and -11.1 C during the winters of 1973-74, 1972-73, and 1974-75, respectively.

Temperatures tended to moderate during March and April of each year and readings exceeding 0 C were frequently recorded during

the day. Weighted mean temperature in March was highest during 1972-73 (-0.5 C). March 1973-74 (-3.2 C) and 1974-75 (-7.0 C) were considerably colder, by comparison. Weighted mean temperature in April was below 0 C only during the 1974-75 winter (-2.2 C), while that during 1972-73 was 2.2 C and for 1973-74, 2.1 C.

Solar Radiation

Trends in solar radiation in the open were similar each winter. Minimum weekly solar radiation occurred in December (160-560 ly/wk), and increased throughout the winter. Solar radiation in the open ranged from 1,600-3,000 ly/wk in April. Mean weekly solar radiation in the open was 1,059, 1,054, and 1,319 ly during the winters of 1972-73, 1973-74, and 1974-75, respectively.

Hugie (1973) found that mean weekly measurements of solar radiation were not suitable for analysis of deer mobility because of the extreme daily variation in solar radiation. For this reason, I made no attempt to correlate deer use of snowmobile trails with solar radiation during this study.

Wind

Wind was quite variable each winter, although December and January was less windy than February, March, and April. Occasional wind storms occurred each winter, resulting in wind-thrown cedar, balsam fir and some hardwood trees and branches; the twigs and foliage were readily eaten by deer. Hugie (1973), and Day (1963) also reported deer feeding on wind-thrown forage. Mean weekly

measurements of wind averaged 424, 428, and 375 km during the 3 successive winters. However, weekly wind ranged from 148-874 km during the study.

Snow and Deer Sinking Depths

Total snowfall for the winter of 1972-73 was 305 cm, 45% of which fell in December. Snow depth in the open averaged 76 cm for the winter, reaching a maximum depth of 102 cm in late February. Mean deer sinking depth in the open exceeded 40 cm from mid-December to early January, when snow was deep and powdery. A non-supporting crust, formed in early January following warm temperatures and rainfall, increased deer sinking depth to more than 60 cm in the open. The crust became fully supporting for deer in late January, and remained so until early March, although it was covered by subsequent light snowfall in February. During this period, deer sinking depths in the open ranged from 0-25 cm. The snowpack began to settle and melt in March and April, when temperatures commonly exceeded 0 C during the day. At this time, the snowpack was supporting for deer at night, but non-supporting during the day.

Total snowfall during the winter of 1973-74 was 227 cm, 46% of which fell in March and April. Mean snow depth in the open was 30 cm for the winter, but only 4 cm during December, when most of the precipitation occurred as rain and when there was a layer of ice on the ground surface later in the month. Frequent rainfall and warmth compacted the snow, resulting in excellent deer supportability throughout the 1973-74 winter. Rarely did deer

sinking depths exceed 26 cm in the open, and they averaged 10 cm for the winter.

Total snowfall for the winter of 1974-75 was 312 cm, slightly greater than the 5-yr mean. Mean snow depth in the open was 74 cm for the winter, and a maximum of 107 cm in early April. Mean deer sinking depth for the winter was 28 cm in the open, and a maximum of 76 cm in late February. The snowpack remained powdery from early December to late February, at which time a non-supporting crust formed, severely restricting deer mobility. Deer supportability improved in mid-March and April, as the snowpack settled during warm periods.

Winter Severity Index

The WSI for 1972-73 was 88, indicating a winter less severe than normal for deer in this region. However, weekly WSI's in December and early January were 117-153, mainly because deer sank deeply. After the supporting crust formed, weekly WSI's generally remained below 100.

The low WSI for the 1973-74 winter (68) reflects the mild weather that prevailed. Weekly WSI's were generally 31-80, reaching a maximum of 90 in mid-April. Limited snowfall, low deer sinking depths, and above-average temperatures account for the low WSI's observed during this winter.

By comparison, the winter of 1974-75 was the most severe for deer. The WSI for that winter was 97, indicating average severity for deer in this region. However, weekly WSI's exceeded 100 for

3 wk following major accumulations of snow in February and April. Prolonged periods of low temperatures, and high deer sinking depths account for these higher WSI's.

Deer Distribution

During the winter of 1972-73, deer began occupying the Hayden Brook wintering area in late November, but were widely distributed until late December, when snow depth exceeded 76 cm. Deer mobility was severely restricted in early January 1973 by a non-supporting crust. This resulted in a gradual deer movement downslope into the softwood forest (Fig. 1, p. 8) where less browse was available. When the crust became fully supporting for deer in late January, they again traveled widely in more open habitats, where there was more food. Deer stayed widely distributed for the remainder of the winter. By 30 April, most of the snow had melted, and the deer had dispersed.

Deer density as estimated by pellet group counts, was greatest during the 1972-73 winter, in the recently-logged portion of the wintering area (mean = 0.92 groups per mil-acre plot), less in softwood habitat (0.70 groups per mil-acre plot), and least in open habitat (0.34 groups per mil-acre plot). Deer density in hardwood habitat could not be assessed due to insufficient plots. Deer occupied the recently-logged habitat in large numbers only until mid-February 1973, when the browse supply was depleted; they then moved to other areas for the remainder of the winter. Day (1963) also noted movements of deer in response to food availability in winter.

During the winter of 1973-74, deer did not begin occupying the wintering area until late December. Subsequent limited snowfall and excellent deer mobility allowed them to range widely at a relatively low density all winter. They occurred higher on Basin and Hurricane mountains in 1973-74 than during the other winters studied. In addition, some deer wintered outside of their "normal" wintering range. Most deer had dispersed by mid-April 1974.

Deer density in open habitat, as determined by pellet group counts, was greater (mean = 0.32 groups per mil-acre plot) than in softwood (mean = 0.18 groups per mil-acre plot), and recently-logged habitats (mean = 0.26 groups per mil-acre plot). Deer were able to move into large openings with minimal use of trails.

In the winter of 1974-75, deer began occupying the wintering area in late November, coinciding with a 36-cm snowfall which persisted. Nonetheless, they remained widely distributed in the wintering area, and their mobility was relatively unrestricted in powdery snow until late January, following a 69-cm snowfall. At this time, some deer wintering at higher elevations moved into softwood habitat along Dead River (Fig. 1, p.8). A non-supporting crust that formed in late February, 1975 further restricted deer movement, and they abandoned most openings. When the snowpack settled and began to melt in March and April, some deer again moved upslope to more open habitats. Most deer had dispersed from the wintering area by late April.

Mean density of deer pellet groups per mil-acre plot during the 1974-75 winter was 0.48, 0.30, and 0.42 in the recent logging

sites, softwood forest, and open habitats, respectively. Increased deer use of the recently-logged habitat reflected the growth of hardwood sprouts and seedlings. The softwood habitat was heavily used by deer only in February, when their mobility was severely restricted elsewhere.

Winter Deer Population

Population Estimates

The estimated over-wintering deer population, as determined by pellet group counts was 478 ± 60 deer in 1972-73, 305 ± 64 deer in 1973-74, and 389 ± 69 deer in 1974-75. The differences in these estimates do not represent absolute changes in deer numbers, as they are estimates of the number of deer occupying 810 ha of wintering area. The high over-wintering deer population during 1972-73 probably resulted from attraction of deer to the logging operation from small nearby wintering areas, as well as deer from the Spencer Stream deer wintering area. Because the winter of 1973-74 was mild, fewer deer wintered at Hayden Brook.

Over-winter Mortality

Deer mortality in the Hayden Brook wintering area appeared to be directly proportional to winter severity, as determined by calculations of the WSI ($r = 0.95$; $n = 3$). However, statistical significance of the correlation could not be determined because of the small sample. Estimated over-winter mortality, as determined by dead deer searches was 9.8% in 1972-73, 3.0% in 1973-74, and

7.2% in 1974-75. Thus, the estimated over-winter mortality rates in this study were not high, but the winters were rather mild. During the severe winters of 1970-71 and 1971-72, Hugie (1973) estimated that 32-43%, and 20-25%, respectively, of the deer population died, the former winter being the most severe. An increase in the deer mortality with increasing winter severity was also reported by Severinghaus (1947) in New York, and Verme and Ozoga (1971) in Michigan.

During the winter of 1972-73, 5 deer were killed by bobcats, 1 died from severe malnutrition, 1 from a broken neck, and 10 died from unknown causes. Forty-six percent of the deer died prior to 1 February, when mobility was severely restricted and food was scarce.

Two dead deer were found during the 1973-74 search, but cause of death could not be determined.

During the winter of 1974-75, 1 deer died from malnutrition, 1 from a neck wound, and 7 died from unknown causes.

Deer Use of Snowmobile Trails

Deer use of a 17.1-km snowmobile trail (Fig. 2, p. 16) was evaluated on 6, 6, and 9 occasions during the 3 successive winters. To date, no other studies of deer-snowmobile relationships have documented the extent deer use snowmobile trails. Doan (1970), Mech (1971), Schmid (1971), and Hugie (1973) stated that deer travel and feed along snowmobile trails.

Considerable variation was noted in deer use of snowmobile trails during and between winters (Table 1). Total distance traveled by all deer tended to be greatest early in the winter, lowest in mid-winter, and greater again in late winter. This coincides with the general pattern of activity which deer exhibit in winter. Silver et al. (1969) and Kropp (1974) showed that penned deer voluntarily reduced their activity in mid-winter, even when fed ad libitum.

Snowmobile trails were used by deer for an average of 7.1 km during 1972-73, 2.8 km the following winter, and 4.0 km during 1974-75. This between-year variation in deer use was due, in part, to yearly differences in deer density in the wintering area. The mean total distance traveled by all deer using snowmobile trails was significantly ($p<.10$) correlated ($r = 0.98$) with mean density of deer pellet groups per mil-acre plot in the Hayden Brook wintering area during the 3 winters.

Most deer used snowmobile trails for short distances (Table 1). Deer seldom traveled farther than 0.2 km on any snowmobile trail in their daily movements. They often left the trail to feed, and returned to it at another location.

Deer commonly used snowmobile trails as a travel route connecting deer trails. The number of deer trails entering or crossing snowmobile trails tended to increase with winter severity, although the correlation was not significant at the 0.10 level.

Deer wintering near snowmobile trails did not always follow them, even under adverse snow conditions; they frequently crossed

Table 1. Deer use of a 17.1-km snowmobile trail in the Hayden Brook wintering area during the winters of 1972-73, 1973-74, and 1974-75.

Date	Km snowmobile trails used			Km traveled/deer		Number of deer trails			No. of deer tracks	Track/trail ratio
	Heavy use (>3)	Light use (1-3)	Total use	Heavy use (>3)	Light use (1-3)	Crossing[1]	Incorporated[2]	Total		
1-13-73	10.4	2.6	13.0	0.740	0.241	34	92	126	26	0.20
1-28-73	5.3	4.2	9.5	0.354	0.193	19	55	74	184	2.49
2-14-73	2.3	2.2	4.5	0.241	0.097	12	9	17	199	11.71
2-26-73	4.0	2.1	6.1	0.193	0.097	18	16	34	192	5.65
3-17-73	3.4	3.1	6.5	0.177	0.193	50	61	111	ND	ND
3-27-73	1.3	1.7	3.0	0.113	0.097	17	16	33	ND	ND
1- 7-74	2.8	2.6	5.4	0.225	0.081	17	14	31	247	7.96
1-14-74	0.7	3.0	3.7	0.129	0.161	5	6	11	166	15.09
1-24-74	0.3	1.7	2.0	0.081	0.097	12	3	15	67	4.46
2- 8-74	1.3	0.3	1.6	0.161	0.048	17	6	23	129	5.60
3- 6-74	0.7	1.1	1.8	0.113	0.081	31	15	46	98	2.13
4- 1-74	0.4	1.9	2.3	0.081	0.081	28	7	35	210	6.00
12-31-74	1.0	2.7	3.7	0.113	0.064	34	11	45	322	7.16
1-11-75	0.5	3.3	3.8	0.097	0.129	34	15	49	143	2.92
1-14-75	0.3	1.2	1.5	0.081	0.064	32	11	43	82	1.91
1-22-75	0.5	1.7	2.2	0.113	0.064	38	11	49	145	2.96
2- 4-75	1.5	2.5	4.0	0.257	0.097	46	16	62	119	1.92
2-20-75	0.4	1.5	1.9	0.064	0.081	34	11	45	59	1.31
3- 5-75	4.9	1.5	6.4	0.418	0.129	22	13	35	153	4.37
3-14-75	2.1	3.1	5.2	0.354	0.193	26	16	42	113	2.62
3-19-75	1.2	6.3	7.5	0.209	0.257	25	10	35	135	3.85
Winter Means										
1972-73	4.4	2.7	7.1	0.290	0.145	25	42	67	150	2.24
1973-74	1.0	1.8	2.8	0.113	0.097	18	9	27	153	6.87
1974-75	1.4	2.6	4.0	0.190	0.120	32	13	45	141	3.13

[1] A deer trail that merely crosses the snowmobile trail.

[2] A deer trail that incorporates 6 m or more of the snowmobile trail before crossing it.

the trail instead of following it. It was evident that some snowmobile trails were oriented at 90 degrees to the direction deer generally traveled. In one instance, they traveled on a snow-covered deer trail instead of on a well-packed snowmobile trail 2 m away. At sharp turns in snowmobile trails, deer occasionally made their own trail through undisturbed snow.

Deer infrequently used snowmobile trails as bedding sites; only those trails which were not disturbed by humans for 3 days or more were used, however. Deer beds were found on snowmobile trails both in open feeding areas, and in softwood cover types.

Relation to Winter Severity Index

Deer reliance upon snowmobile trails for travel was directly correlated with winter severity (Table 2). The total distance traveled by all deer on snowmobile trails was significantly correlated with weekly WSI's during 1972-73 ($p<.05$) and 1973-74 ($p<.10$). Total distance of snowmobile trails lightly used by deer was significantly correlated ($p<.05$) with weekly WSI's during the winter of 1973-74, when deer were distributed widely at a low density. Total and mean distance of snowmobile trails heavily used by deer was significantly correlated with weekly WSI's during 1972-73 ($p<.05$) and 1974-75 ($p<.10$) when deer were more confined. All other parameters of snowmobile trail use by deer were not consistently significant at the 0.10 level, when correlated with weekly WSI-values.

Deer remained inactive during snow storms, and for as long

Table 2. Simple linear correlation of various parameters of snowmobile trail use by deer with weekly indices of winter severity in the Hayden Brook wintering area, 1972-73, 1973-74, and 1974-75.

Parameters of snowmobile trail use	1972-73 (6)[1]	1973-74 (6)	1974-75 (8)
Total km traveled by all deer	0.73**	0.66*	0.45
Total km traveled by 1-3 deer (light use)	0.01	0.77**	0.06
Total km traveled by >3 deer (heavy use)	0.82**	0.18	0.54*
Mean km traveled by 1-3 deer	0.45	0.36	0.28
Mean km traveled by >3 deer	0.71**	0.05	0.74**
Total number of deer trails	0.47	0.24	0.18
Number of deer trails which crossed the snowmobile trail	0.24	0.16	0.09
Number of deer trails which followed 6 m of the snowmobile trail before crossing	0.52	0.33	0.35
Number of deer tracks crossing the snowmobile trail	-0.73**	0.74**	-0.25
Track/trail ratio	-0.63*	0.32	-0.22

[1]Sample size.

*Significant at the 0.10 level.

**Significant at the 0.05 level.

as 48 h after, when snowfall exceeded about 15 cm. When they resumed activity following a major storm, deer often followed snow-covered snowmobile trails in preference to traversing adjacent trailless areas. Hugie (1973) reported similar deer response.

In most instances of long-distance use of snowmobile trails, deer moved to more sheltered areas following a major storm, or moved in response to a new food source. The longest movement recorded during this study was 2.4 km, when 3 deer traveled on the snowmobile trail system from upper Basin Mountain Road to the Dead River (Fig. 2, p. 16), following a 69-cm snowfall in early February, 1975. During the winter of 1971-72, 1 deer walked approximately 4.8 km on a snowmobile trail between its bedding site and food near Hayden Brook, during several successive days (Richens 1972, pers comm).

Relation to Deer Distribution and Topography

Deer distribution in the wintering area influenced the length of snowmobile trails available for deer use. Sometimes deer did not inhabit parts of the wintering area through which the snowmobile trails passed. For example, snowmobile trails higher on the western half of Basin Mountain Road (Fig. 2, p. 16) were unused for long periods during the winters of 1972-73 and 1974-75 because most deer were at lower elevations. Changes in deer distribution and density, relative to snowmobile trail locations, may have biased my correlations of snowmobile trail use with winter severity.

The intensity of deer use of 23 segments of the snowmobile

trail route (Fig. 2, p.16) was evaluated on 12, 10, and 19 days from December to early April during the successive winters of study. The use indices (UI) computed from these evaluations (Table 3) reflect the relative intensity of snowmobile trail use by deer on each trail segment.

During each winter, the most intensively-used snowmobile trails were those located in major bedding areas (segments H,Q,R,S, T,U; Fig. 2, p.16). Mean UI's for these trail segments was 69 during 1972-73, and 61 in 1974-75, which is considerably higher than the mean UI values for all segments during those winters. The relatively low UI's for trail segments near bedding areas in 1973-74 (mean UI = 46) may be attributed to the excellent off-trail deer mobility and their low density along these segments. Deer generally used snowmobile trails in bedding areas daily, all winter, as a travel route from bedding sites to open feeding sites. These heavily-used snowmobile trail segments, therefore, functioned as an extension of the deer trail system. Deer trails entering the snowmobile trail in these segments tended to be numerous, and palatable browse along the snowmobile trail was usually exhausted by mid-winter.

Snowmobile trails on wide logging roads, such as Basin Mountain and Hayden Landing roads (Fig. 2, p. 16) were used rather sporadically by deer. Mean UI's for segments A through M were 40, 46, and 22 during the 3 successive winters, suggesting light to very light use of wide logging roads (Table 3). Deer tended to avoid traveling on these trail segments because browse was absent, deer

Table 3. Use index by snowmobile trail section and year in the Hayden Brook deer wintering area.

Snowmobile trail segment	Use Index[1]		
	1972-73	1973-74	1974-75
A	12	25	5
B	16	45	8
C	54	50	18
D	38	45	21
E	67	25	21
F	67	30	21
G	29	45	31
H	88	55	44
I	33	50	13
J	20	45	13
K	41	50	39
L	41	70	29
M	16	70	23
N	0	60	44
O	38	40	36
P	50	20	34
Q	54	50	65
R	63	40	52
S	75	35	70
T	62	25	75
U	71	70	60
V	50	50	52
W	58	65	42
Winter means	45	46	34

[1]See page 17 for explanation of Use Index.

were exposed to wind, snowmobile trails were repeatedly drifted in by wind-blown snow, and major parallel deer trails provided more sheltered traveling conditions for deer in areas of softwood cover. Gill (1957) and Banasiak (1964) pointed out that deer prefer to travel in areas which provide shelter from the wind in winter.

During the 3 winters of study, the intensity of deer use of snowmobile trails declined on segments C-G, which surround the recently-logged portion of the wintering area (Figs. 1, 2). Mean UI's for these trail segments declined from 51-39-22 for the 3 winters, a result of a decrease in the number of deer wintering in the logged areas. The mean number of deer pellet groups per mil-acre plot in the recently-logged area declined from 0.94-0.26-0.48 from 1972-73 to 1974-75, indicating a decline in deer density after the first winter.

Another area affected by a shift in deer distribution was snowmobile trail sections L and M on upper Basin Mountain Road (Fig. 2, p. 16). This area consisted of open, mixedwood, and hardwood habitats with much deer food usually covered by snow. Deep soft snow and a lack of shelter had prevented deer from using the food during parts of the 1972-73 and 1974-75 winters. However, deer were able to utilize these higher, open areas throughout the winter of 1973-74. Mean UI's on segments L and M were 19 and 32 during the first and last winters, but 67 during the mild winter of 1973-74.

Snowmobile trail segments A and B were located on the periphery of the wintering area (Fig. 2, p. 16). Deer used them mainly in dispersal from the wintering area in the spring, or

whenever snow conditions allowed them to travel widely. Deer use of these trail segments was characteristically sporadic and light; mean UI's were 14.0, 35.0 and 6.5 during the 3 winters of study (Table 3).

Gill (1957) stated that deer often habitually follow trails from bedding to feeding areas, even in summer. I suspect that each winter, deer used some snowmobile trails more out of habituation than necessity. Certain snowmobile trails passing through bedding areas were heavily used daily by deer, even when supporting crusts afforded them excellent off-trail mobility. That deer traveled on snowmobile trails at all during the mild winter of 1973-74, may be explained, in part, by their habituation to using snowmobile trails as a part of their own trail system.

Relation to Disturbances by Humans

Deer were subjected to a limited amount of disturbance by snowmobilers during this study, but the effects on deer activity patterns appeared to be minimal. Abrupt changes in areas occupied by deer could be accounted for by changes in snow supportability, and did not appear to be related to snowmobile disturbances. Deer consistently bedded near and fed along snowmobile trails, even when those trails were used by me daily. In addition, fresh deer tracks were repeatedly observed on snowmobile trails less than an hour after they were cleared, indicating that, in this study, deer were not driven from the vicinity of snowmobile trails.

In Minnesota, Dorrance et al. (1975) determined (using

telemetry) that deer home range size, daily movement, and distance from snowmobile trails increased with increasing snowmobile activity. They also found that deer responded negatively to very low intensities of intrusion by man and vehicles. Gilbert et al. (1970) reported that mule deer (Odocoileus hemionus) wintering in relatively open habitats were driven from preferred areas by snowmobile disturbance. Kopischke (1972) found that deer in Minnesota avoided places which were heavily used by snowmobilers, and that they can and do drive deer from otherwise desirable habitats. In Wisconsin, Bollinger et al. (1973), however, found that deer home range size and activity patterns did not differ significantly between a wintering area with heavy snowmobile use and one receiving no use. Results of my study appear to support the findings of Bollinger et al. (1973).

Deer Sinking Depth

A sample of 10-15 deer sinking depths was measured on and off snowmobile trails in open, hardwood, mixedwood, and softwood cover types on 4, 6, and 11 days during the 3 winters of study, respectively (Table 4). Analysis of variance, by cover type, was performed on each daily set of sinking depths, to examine the effects of various snow conditions (Table 5).

Deer sinking depth off the snowmobile trail was usually greatest in openings, and decreased from hardwood-mixedwood-softwood cover types (Table 4). Mean sinking depths off snowmobile trails in open, hardwood, and mixedwood habitats were each significantly

Table 4. Mean sinking depth of deer on and off snowmobile trails, by cover type, in the Hayden Brook deer wintering area.

Date measured	Off snowmobile trails				On snowmobile trails			
	O[1]	H[2]	M[3]	S[4]	O	H	M	S
2-27-73	20.9	20.9	21.9	12.3	5.9	3.9	5.1	3.5
3-13-73	22.2	22.3	11.2	9.2	7.2	7.9	5.9	5.5
3-29-73	8.1	8.0	10.2	4.4	3.9	3.3	4.0	3.4
4-8-73	19.8	18.8	17.1	9.9	11.6	7.8	8.3	5.2
1-14-74	5.0	4.1	3.4	2.9	2.5	2.5	2.1	1.7
1-18-74	20.9	20.5	16.4	11.8	3.6	3.4	4.2	2.7
1-22-74	22.6	20.2	18.9	12.9	9.7	8.5	8.8	6.2
2-5-74	2.2	1.6	1.1	1.0	0.9	1.2	0.9	0.9
3-7-74	11.8	12.5	11.2	6.9	3.8	3.2	2.9	2.5
4-1-74	17.9	15.3	13.2	11.8	5.1	5.1	3.9	3.4
12-7-74	13.0	8.9	12.9	13.3	4.1	3.1	4.4	4.7
12-29-74	24.7	22.8	18.5	11.9	4.0	3.6	4.6	4.4
1-12-75	26.1	23.0	22.0	16.4	9.2	8.8	7.4	6.6
1-15-75	16.9	12.2	11.7	7.6	0.7	0.6	0.5	0.5
1-22-75	26.7	21.8	16.5	8.0	3.2	3.0	2.1	2.0
2-5-75	50.3	40.7	28.5	23.6	4.2	3.8	3.9	3.1
2-13-75	53.6	45.3	34.0	25.6	3.8	3.9	3.2	2.9
2-21-75	47.1	38.4	30.8	23.1	6.8	6.0	5.4	4.7
3-4-75	35.1	28.3	23.4	19.3	4.9	4.5	4.1	3.8
3-13-75	30.0	26.5	22.5	19.6	4.7	4.2	3.7	3.0
3-19-75	31.8	27.8	22.1	17.0	4.9	3.5	2.9	2.7

1 = open

2 = hardwood

3 = mixedwood

4 = softwood cover types

Table 5. Summary of 21 ANOVA and Duncan's Multiple Range tests of mean off-snowmobile trail deer sinking depths by cover types (A), and of mean on-snowmobile trail deer sinking depths by cover type (B), for each day sinking depths were measured.

Percent of 21 ANOVA tests on which deer sinking depth in the cover type in Column X differed significantly ($P<.05$) from deer sinking depth in the cover type indicated in the adjacent columns.

A. Off-snowmobile trail deer sinking depths

Column X	Open	Hardwood	Mixedwood	Softwood
Open sig. >	--	28.6	56.7	90.5
Hardwood sig. >	0	--	28.6	85.7
Mixedwood sig. >	0	0	--	61.9
Softwood sig. >	0	0	0	--

B. On-snowmobile trail deer sinking depths

Open sig. >	--	4.8	4.8	23.8
Hardwood sig. >	0	--	4.8	19.5
Mixedwood sig. >	0	4.8	--	19.5
Softwood sig. >	0	0	0	--

greater ($p<.05$) than in softwood habitat in 90, 86, and 62% of the ANOVA tests performed (Table 5). Mean deer sinking depths off snowmobile trails in the open were significantly greater ($p<.05$) than similar means in hardwoods in 29% of the ANOVA tests, and in 57% of the tests in mixedwoods. Mean sinking depths of deer off snowmobile trails did not differ significantly by cover type on a day with a fully-supporting surface crust in all types.

Deer sinking depths on snowmobile trails tended to be similar in all cover types except softwood, where deer generally sank less due to lesser snowmobile trail depth, and hence, less potential sinking depth (Table 4). Mean sinking depths of deer on snowmobile trails did not differ significantly by cover type in 16 of the 21 ANOVA tests performed. Of the remaining ANOVA tests, deer sinking depths on snowmobile trails in openings were significantly greater ($p<.05$) than similar measurements in softwoods in 24% of the ANOVA tests. Similar measurements in hardwood and mixedwood types were each significantly greater ($p<.05$) than deer sinking depths on snowmobile trails in softwoods in 20% of the ANOVA tests.

Mean sinking depth of deer off snowmobile trails were significantly greater ($p<.05$) than comparable measurements on snowmobile trails in all cover types, as determined by the Student t-test. Deer sinking depths off snowmobile trails averaged 6.6 times greater than on snowmobile trails in openings, 4.5 times greater in hardwoods, 4.8 times greater in mixedwoods, and 4.4 times greater in softwoods.

Deer rarely sank more than 10 cm into a well-packed snowmobile

trail in any cover type (range of means = 0.4-11.6 cm). Deer sinking depths were more variable off than on snowmobile trails; sinking depth depends on snow depth, density, presence or absence of crusts and crust characteristics. Mean sinking depths of deer off snowmobile trails ranged from 1 cm when there were supporting surface crusts, to 54 cm, following a 69-cm accumulation of powdery snow.

Mattfeld (1974) determined that the energy expended by tame deer walking in snow increased logarithmically with increasing sinking depth, and that non-supporting crusts further increased the energy deer expended in traveling. Because of its continuous, packed surface and excellent deer supportability, the snowmobile trail probably enabled deer to reduce the energy they expended in traveling during this study. Doan (1970) believed the presence of a strategically-located snowmobile trail system in a deer wintering area could improve over-winter deer survival. This situation would only be true, however, if deer did not expend more energy in avoiding snowmobilers than they saved by traveling on snowmobile trails.

Snowmobile Trail Hardness

Snowmobile trail hardness, as determined with the Rammsonde, was measured on 5 days each, during the winters of 1973-74, and 1974-75, in 7 locations in the wintering area (Table 6). Locations included heavily-used, moderately-used, and lightly-used trails on wide logging roads, as well as moderately-used snowmobile trails

Table 6. Mean Rammsonde hardness (resistance to penetration in kg) of selected snowmobile trails by location, Hayden Brook wintering area.

Date measured	Wide logging roads Degree of snowmobile use			Skidder trails Cover type			
	Heavy	Moderate	Light	Softwood	Mixedwood	Hardwood	Open
1-21-74	15.3	16.3	15.4	21.4	18.0	16.9	20.8
1-22-74	10.2	2.0	3.9	4.9	2.4	3.6	2.5
1-24-74	141.1	199.8	146.6	162.5	161.1	166.0	113.3
3- 7-74	150.4	87.7	61.0	57.0	44.8	65.7	57.9
4- 1-74	86.2	93.4	129.8	44.6	46.0	54.6	88.7
12-29-74	28.7	33.0	25.9	34.6	16.7	19.3	21.7
1-12-75	97.1	76.6	52.8	18.3	14.0	17.2	17.3
1-23-75	35.7	30.2	33.3	46.1	42.6	35.7	25.6
2-21-75	14.8	12.7	14.2	18.5	19.3	17.6	22.1
3-13-75	18.2	20.7	17.9	30.1	24.8	24.7	23.2

in open, hardwood, mixedwood, and softwood cover types.

Mean hardness varied considerably by day of measurement, and ranged from a high of 199 kg when the trail was icy, to a low of 2 kg when it was slushy. The snowmobile trail appeared to be somewhat slushy below a hardness of 35, becoming increasingly harder above that value. Analyses of variance of mean Rammsonde hardness by location, for each day of measurement, revealed that no one snowmobile trail was consistently significantly harder ($p<.05$) than any other (Table 7).

The snowmobile trail softened as air temperature increased, particularly in the afternoon. The most dramatic softening of the trail occurred when air temperature exceeded 0 C. A snowmobile run over a slushy trail greatly compacted it, and resulted in a very hard, icy trail when it froze again.

Multiple correlation of air temperature and time since sunrise with snowmobile trail hardness ($r = 0.36$) revealed that these factors alone did not adequately account for the wide variance in trail hardness observed during this study. Other possible factors which could not be measured include: degree of compaction of the snowmobile trail, and recent freezing and thawing of the trail prior to each measurement. In addition, a more direct measurement of the heat energy absorbed by the snowmobile trail from sunrise to the time of measurement may have explained more of the variability in the data.

Snowmobile trail hardness was measured in the open over a 24-h period at 2-h intervals starting at 0600 on 16 April 1975, and

Table 7. Summary of 10 ANOVA and Duncan's Multiple Range tests for differences in snowmobile trail hardness by location, as measured with the Rammsonde penetrometer.

	Percent of 10 ANOVA tests in which the snowmobile trail in the location in column A was significantly harder (P>.01) than trails in the location indicated in the adjacent columns.						
Column A	WA[1]	WB[2]	WC[3]	C[4]	M[5]	H[6]	O[7]
WA sig. >	--	30	30	30	40	40	30
WB sig. >	10	--	20	40	40	30	40
WC sig. >	10	0	--	20	30	20	10
C sig. >	20	30	20	--	10	20	30
M sig. >	20	10	20	0	--	10	10
H sig. >	10	0	10	0	0	--	0
O sig. >	10	10	10	10	0	10	--

1,2,3 = Snowmobile trails located in wide logging roads receiving relatively heavy, moderate, and light snowmobile use, respectively.

4,5,6,7 = Snowmobile trails located in softwood, mixedwood, hardwood, and open cover types, respectively, and receiving moderate snowmobile use.

ending at 0600 on 17 April (Fig. 3). The day was sunny and warm (maximum temperature = 12.2 C), and the night was clear and cold (minimum temperature = -7.2 C). At sunrise, the trail was hard and icy, but it quickly weakened as air temperature increased. It became noticeably slushy by noon, reaching a minimum hardness at 1600. After sunset, the air cooled, and the trail slowly hardened again. The rate at which the snowmobile trail hardened increased greatly when air temperature dropped below 0 C.

Assuming that undisturbed snow behaved similarly, this daily cycling of snow hardness during spring indicates that deer would sink considerably deeper in snow in early evening than in early morning. Observations of deer sinking depths in March and April by Hugie (1973) and me support the above assumption. Deer sinking depths on snowmobile trails also differed between day and night. Sinking depths on snowmobile trails (Table 4, p. 40) in open, hardwood, mixedwood, and softwood cover types were significantly inversely correlated ($p<.05$) with snowmobile trail hardness ($r = -0.58$, -0.59, -0.78, and -0.62, respectively) during this study.

Altering Deer Mobility

During each winter, deer concentrated in several localities in the wintering area where food and shelter were available; they appeared to avoid other locations. These little-used locations were generally extensive openings where a considerable amount of browse existed, but was unavailable to deer when there was deep, soft snow. Deer fed along the edges of the openings, and developed

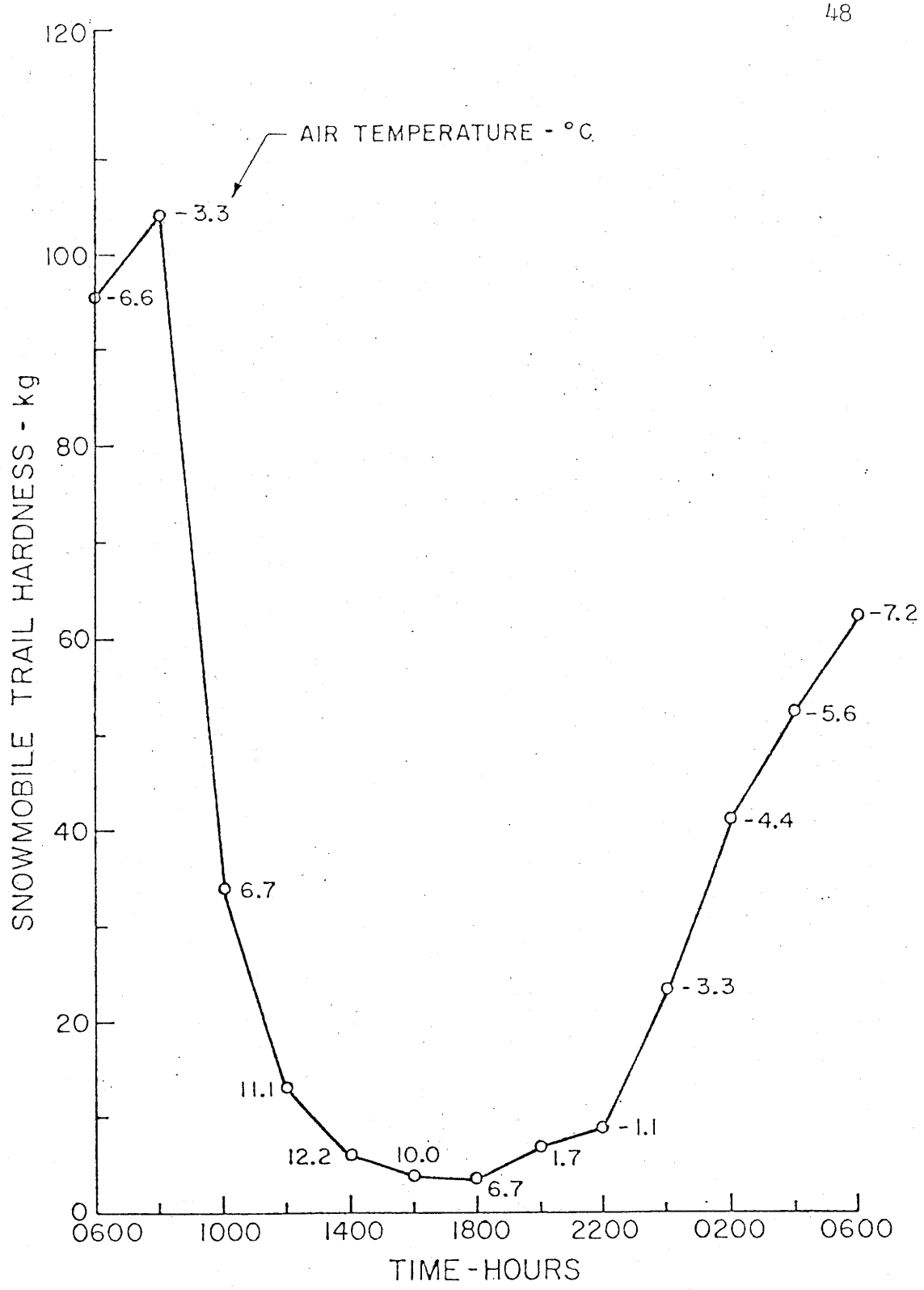

Fig. 3. Snowmobile trail hardness over a 24-h period, 16-17 April 1975.

an extensive trail system, but they did not fully exploit the interiors.

Re-locating Deer

The feasibility of using snowmobile trails to enhance deer mobility in open feeding areas was investigated during the first and last winters of study. During the former winter, 10 attempts were made to re-locate groups of deer; this involved inducing them to move from traditional to less exploited localities within the wintering area (Table 8).

Of the 3 inducements tested, the snowmobile trail alone was the least effective, in terms of the longer time required for deer to become established in the new location (Table 8). Deer appeared to be reluctant to travel on a snowmobile trail for long distances without the added inducements of food, or noise associated with food.

The snowmobile trail with cedar foliage placed along it was an effective inducement, but the distance of deer displacement was limited to the length of the snowmobile trail treated with cedar foliage.

A combination of snowmobile trails, cedar foliage placed along the trail, and chain saw noise was the most effective inducement for re-location of deer. Deer were induced to travel on snowmobile trails to a new location within 24 h, and the maximum known displacement recorded was 1.9 km, apparently in response to chain saw noise alone. The effectiveness of chain saw noise in

Table 8. Deer response to snowmobile trails and cedar cuts (used to re-locate them) within the Hayden Brook wintering area during the winter of 1972-73.

Cut no.	Date cut	Treatment	Re-location distance (km)	Prevailing snow conditions	Cut first used by deer (days)	Days cedar foliage fully used	Abandonment time (days)	Max. deer displacement (km)
1	12-10-72	A[1]	0.3	45 cm powdery snow	2	15	21	0.6
2	12-25-72	A	0.2	75 cm powdery snow	2	12	33	0.3
3	1- 6-73	A	1.0	85 cm non-supporting crust	26	37	50	1.1
4	1- 7-73	B[2]	0.2	85 cm non-supporting crust	1	17	27	0.8
5	1- 8-73	B	0.3	85 cm non-supporting crust	1	20	33	0.5
6	1-21-73	A	0.8	70 cm supporting crust	3	22	34	0.6
7	2- 8-73	C[3]	0.5	80 cm 10 cm powder on supporting crust	1	7	19	1.1
8	2-10-73	C	1.3	80 cm 10 cm powder on supporting crust	1	15	26	1.9
9	2-25-73	C	0.7	100 cm 30 cm on supporting crust	1	6	11	1.8
10	3- 7-73	B	0.6	95 cm 25 cm granular snow on crust	6	cedar not browsed out	23	0.6

1 = snowmobile trail alone; 2 = snowmobile trail with cedar foliage on it; 3 = snowmobile trail, cedar foliage and chain saw noise.

attracting deer was demonstrated on 2 occasions during the winter of 1972-73, when a chain saw was operated along a little-used snowmobile trail for 30 min without felling trees. On both occasions, deer heavily-used the snowmobile trail for distances of 0.8-1.4 km within 24 h, presumably in search of food associated with the noise.

Nine of the 10 re-location attempts were successful in at least temporarily re-locating groups of deer. Deer that moved in response to the above inducements did so in 3 phases. In the 1st, or discovery phase, a few deer traveled daily between the new location and their customary cover. This stimulated other deer to also move to and from the new food source. In the 2nd, or colonization phase, these deer remained near the new food source throughout the day, and they bedded nearby. At this time, the deer made their own trail system from the felled trees to nearby cover (sometimes marginal in quality) rather than returning to their former cover. As the supply of cedar foliage dwindled, deer began to feed heavily on hardwood regrowth in the vicinity. In the 3rd, or dispersal phase, some deer returned to the original location, while some stayed near the cedar cut and fed on the remaining foliage and other browse. Eventually, the re-location site was usually abandoned by all deer, unless additional trees were felled.

Since most deer remained in the new location only as long as the felled cedar trees provided browse, it seemed that they benefited more from artificial feeding than from improved mobility

on the new snowmobile trail. The snowmobile trail enabled them to travel into the interior of large openings under adverse snow conditions, but the concentrated supply of nutritious cedar foliage (about 110 kg/tree) was the inducement which kept them there. I doubt if deer would have stayed in the new location if the cedar had not been cut.

Improving Local Mobility

During the winter of 1974-75, greater emphasis was placed on improving deer feeding mobility adjacent to localities already used by deer, rather than re-locating them to new areas. Ten snowmobile trails, totaling 9.1 km, were made in the wintering area (Table 9), in addition to the 17.1 km of trails already established.

Deer made light-moderate use of these new trails; in most instances, 4 or fewer of them walked at any given place on the trail. Those deer that used a snowmobile trail, fed along it and left it for varying distances to browse. In time, several new deer trails were made along all 10 snowmobile trails. The new snowmobile trails were then used both for feeding and for travel within unexploited openings.

Deer use of most of the new snowmobile trails was inversely proportional to off-trail deer mobility. For example, deer use of these trails was particularly heavy and extensive in late February, 1975, when a non-supporting crust resulted in deer sinking depths of 76 cm in openings.

Length of the snowmobile trail, and its proximity to major

Table 9. Deer use of snowmobile trails in deer feeding areas, 1974-75.

Trail no.	Date made	Date terminated	Trail pattern	Trail length (km)	No. of days evaluated	Prevailing intensity of deer use	Mean % trail used by deer/day evaluated	Comments
1	12-30-74	3-19-75	open-ended[1]	1.9	19	light to no use	3.2	deer moved from area
2	1-10-75	3-19-75	loop	0.6	21	light to heavy	64.9	trail entered deer bedding area
3	1-19-75	3-19-75	open-ended	1.3	12	light to moderate	40.6	deer bedding area on each end of trail
4	2- 2-75	3-19-75	grid	1.6	12	light to moderate	57.4	snowmobile trail originated at major deer trail
5	2-10-75	3-19-75	grid	0.7	11	light to moderate	45.5	deer bedding area at one side of grid
6	2-11-75	3-19-75	open-ended	1.2	9	light to moderate	41.5	deer bedding area at one end of trail
7	3- 8-75	3-19-75	loop	0.2	4	light to no use	1.3	no bedding area nearby
8	3- 8-75	3-19-75	loop	0.3	4	moderate to heavy	83.8	trail entered deer bedding area
9	3- 8-75	3-19-75	dead-end	0.3	4	light to moderate	68.8	much travel to main snowmobile trail
10	3-13-75	3-19-75	open-ended	1.0	4	light to no use	37.5	very little browse available along trail

[1]An open-ended trail connected two other snowmobile trails which were part of the "permanent" trail system.

deer bedding areas also affected its use by deer (Table 9). The shorter snowmobile trails located within, and adjacent to bedding areas (trails 2, 8, and 9) were more frequently and intensively used by deer than were other trails.

Snowmobile trails arranged in a grid pattern allowed more uniform use of available browse than did other patterns. Deer trails made between grid lines further enhanced browse utilization. Those portions of the open-ended snowmobile trails farthest from the deer concentration area were generally little-used by deer.

In an extensive wintering area, such as at Hayden Brook, the 9.1 km of snowmobile trails made to increase deer use of food in openings were inadequate to allow deer to fully utilize the available food. Several more kilometers of snowmobile trails would have been desirable, but manpower and time limitations prevented me from making them. When snow was deep and soft, it was necessary to cut brush and pack the route with snowshoes before the snowmobile could pass through. Under the worst conditions, only 0.2 km of snowmobile trails were created per hour in brushy areas. Perhaps large numbers of snowmobilers working together can make trails in openings more efficiently. Doan (1970) and Wettersten (1971) reported that some snowmobile clubs in Manitoba and Minnesota make an outing of providing trails for deer use. However, no study of the efficiency and cost of providing snowmobile trails for deer use on a large scale has been conducted.

Deer Response to Snowmobiles

The behavior of deer encountered while I was snowmobiling was recorded and compared to that of deer encountered while I was on foot. A total of 214 deer encounters were recorded during the winter of 1972-73; 36 were on-snowmobile trail encounters, 136 off-snowmobile trail encounters, and 78 on-foot encounters. Corresponding figures for 1973-74 were 1, 13, and 18, for a total of 32. One hundred forty-one deer encounters were recorded during the winter of 1974-75, of which 32, 108, and 33 of these were on-snowmobile, off-snowmobile, and on-foot encounters.

Encounters on Snowmobile Trails

Deer met on snowmobile trails usually fled immediately after seeing me. Six deer, each encountered singly on a snowmobile trail, were chased with a snowmobile during January, 1973, when off-trail mobility was severely restricted. When chased, each deer ran down the snowmobile trail for 43-200 m before leaving it. Four of these deer remained in sight, and showed signs of exhaustion after the chase. Thereafter, deer encountered on the snowmobile trail were given ample time to move away without being chased. Deer met very near a snowmobile trail sometimes ran toward me in order to gain access to the snowmobile trail for escape.

Encounters off Snowmobile Trails

The escape behavior of deer seen away from the snowmobile trail consisted of 2 responses: (1) running out of sight, or

(2) staying within sight. Date, time, cover type, encounter distance, number of deer seen (group size), deer position in relation to a deer trail, snow depth and deer sinking depth in the open, and air temperature were recorded for each deer seen. Data on deer encounters for the 3 winters were pooled to increase sample size, and Chi-square tests were performed to determine if deer escape behavior was significantly ($p<.05$) affected by any of the above factors.

Deer response to snowmobiles differed markedly each winter. When met by me, significantly more deer ran out of sight than stayed during the first 2 winters, but not during 1974-75, when significantly more deer stayed in sight as I passed them.

The number of deer staying in sight increased as the winter progressed, during all the winters. Most deer ran from sight in December and January (Table 10) but they tended to stay within sight during February, March and April. These monthly differences in deer escape behavior may have been associated with a progressive weakening of the animals' physical condition over the course of the winter, as was noted by Severinghaus (1947) for deer in New York. Silver et al. (1969) and Bateman (1972) reported that deer voluntarily reduce their activity in mid-winter; this inactivity may have influenced the deer's tendency to run from sight in the present study. To some extent, I believe that deer became conditioned to snowmobile activity as the winter progressed. The daily disturbance of deer by a small snowmobile traveling slowly along the same route without purposeful harassment may have conditioned some deer to

Table 10. Percent of total deer encountered off snowmobile trails while snowmobiling, that stayed in place as I passed, by month, in the Hayden Brook wintering area during the winters of 1972-73, 1973-74, and 1974-75.

Month	1972-73	1973-74	1974-75	All years
Dec	N.D.[1]	N.D.	0.0 (7)[2]	0.0 (7)
Jan	16.3 (43)	20.0 (10)	33.3 (10)	17.9 (56)
Feb	25.4 (63)	N.D.	79.2 (3)	40.2 (87)
Mar	46.7 (30)	66.7 (3)	57.3 (61)	54.3 (94)
Apr	N.D.	N.D.	84.6 (13)	84.6 (13)
All winter	44.3 (136)	30.8 (13)	61.1 (108)	41.6 (257)

[1]No deer encountered while snowmobiling.

[2]Total number of deer encountered while snowmobiling.

accept this disturbance as part of their daily routine. For example, a doe with twin fawns (all in good condition) allowed me to snowmobile within 20 m of them in their bedding site during 5 successive days in February, 1975. They merely watched as I passed, and made no attempt to run as long as I kept moving, and avoided direct eye contact. Young and Boyce (1971) stated that artificially-fed deer in a Michigan deer wintering area learned to live with snowmobiles, and were conditioned to appear at the sound of a snowmobile in anticipation of food.

Significantly more deer encountered while snowmobiling ran than stayed between 0800 and 1359 h; whereas significantly more deer stayed in place from mid-afternoon to sunset. Deer response to snowmobiles was not studied during the night. Forty-seven percent of all deer encountered while snowmobiling were observed between 1000 and 1400 h, when most deer were bedded.

Cover type was an important factor influencing deer response to snowmobiles. Significantly more deer ran when met by me (on a snowmobile) in open and hardwood cover types. However, deer met in mixedwood and softwood cover ran or stayed in approximately equal numbers. Fifty-four percent of all deer seen while snowmobiling were observed in softwood stands.

Since deer showed a decided tendency to run when approached by a snowmobile in the open, and an increased tendency to stay when approached in softwoods, the deer's response seemed to depend on its apparent security. Softwood cover allowed deer to observe me without obviously exposing themselves, and with considerable lateral

concealment, they stayed rather than ran. However, deer could not easily hide in open or hardwood cover types, so they tended to run.

In the Hayden Brook wintering area, deer had access to numerous localities which were inaccessable to snowmobilers because of topography, cover type, or lack of roads. Because of this, a deer had to travel only a short distance to escape from a snowmobiler. These inaccessable localities served as refuges from further disturbance and permitted them to tolerate snowmobiles. Kopischke (1972) also reported that deer in Minnesota sought places which were inaccessable to snowmobilers during high-use periods.

The number of deer seen per encounter did not significantly affect their escape tendency; they ran or stayed about equally regardless of the number of deer encountered. Forty-one percent of these encounters were with single deer, 27% with 2 deer, 18% with 3 deer, and 14% with 4 or more deer.

Proximity of deer to a deer trail, when encountered, enabled them to escape with a minimum of effort; significantly more ran than stayed in place. Deer encountered away from deer trails while snowmobiling stayed or ran in about equal numbers. Fifty-nine percent of all deer encountered while snowmobiling were observed on or near deer trails.

Significantly more deer observed within 15 m of the snowmobile trail stayed than ran as the snowmobile passed. Beyond that distance, significantly more ran than stayed. Since snowmobiles can be heard for quite a distance, it is likely that deer near the trail that were prone to run away did so before I saw them. On

the other hand, deer that felt secure allowed me to pass within 15 m of them without running away. It is also likely that I observed moving deer more readily beyond 15 m than stationary ones.

No relationship was detected between air temperature and deer response to snowmobiles.

When snow depth exceeded 76 cm, significantly more deer stayed in place when encountered off snowmobile trails. At lesser snow depths, however, the opposite response was noted. Sixty-four percent of all deer seen while snowmobiling were observed when snow depths exceeded 76 cm in the open.

An increasing number of deer tended to remain in place as deer sinking depth in the open increased. Significantly more deer ran out of sight when they sank less than 20 cm, but they stayed as often as they ran at greater sinking depths.

Some differences in the behavior of deer encountered seemed to be due to snowmobiling habits. Snowmobiling at high speeds frightened deer more easily than at low speeds (16 km/h or less). Stopping to view deer invariably resulted in their running away. More deer, however, stayed in place if the snowmobile was kept moving slowly. More deer ran when approached directly than when approached obliquely with a snowmobile. Similarly, deer were more easily frightened when I maintained direct eye contact with them, than when I avoided doing so.

Encounters on Foot

The behavior of deer seen while walking in the wintering

area differed markedly from their behavior in the presence of snowmobiles. Of 114 deer encountered on foot, 15 of them stayed within sight as I passed. A significantly greater number of them ran than stayed under all snow, weather, habitat, and temporal conditions recorded during the study. This decided tendency of deer to run with the approach of a human on foot, in contrast to their tendency, under certain conditions, to stay in sight when approached by a snowmobiler seems to indicate that deer responded to the machine in the latter case, and not to the person riding it.

Research Needs

Research should focus on the following:

1. The documenting of various intensities of snowmobile disturbance on deer home range size, and activity patterns in a wide variety of deer wintering areas.

2. The energy expended by deer in avoiding contact with snowmobilers.

3. The further investigation of deer escape behavior in relation to snowmobilers.

4. A cost/benefit study of the creation of snowmobile trails for deer use in wintering areas on a large scale.

5. More intensive investigation of the feasibility of re-locating deer within and between wintering areas.

SUMMARY AND CONCLUSIONS

Deer response to snowmobiles and selected natural factors was studied during the winters of 1972-73, 1973-74, and 1974-75. Study objectives were: (1) to relate deer use of snowmobile trails to snow characteristics and weather; (2) to determine the requisites for favorably altering deer mobility and feeding patterns by use of snowmobile trails; and (3) to evaluate deer reactions to snowmobiles.

Field work was conducted in the 810-ha Hayden Brook deer wintering area, located in T3R4 and Pierce Ponds townships, Somerset County, Maine. The wintering area lies in the valley of the Dead River, and encompasses the lower slopes of Basin and Hurricane mountains to 430 m above mean sea level. Important deer habitat types found on the study area include: mature softwood, extensive openings, northern hardwoods, and recently-logged areas. Most snowmobile trails were located on logging roads and skidder trails. The study area was remote, and received little use by snowmobilers during the study.

The winters of 1972-73 and 1974-75 were slightly below average in severity for deer in this region, but during both winters, deer mobility was severely restricted by deep snow cover and non-supporting crusts for several weeks. At such times, deer were restricted to mature softwoods where food was scarce. The winter of 1973-74 was very mild for deer at all times, and they remained widely distributed throughout the winter. Estimated wintering deer

populations were 478 ± 60 in 1972-73, 305 ± 64 in 1973-74, and 389 ± 69 deer in 1974-75. Over-winter mortality estimates were 9.8, 3.0, and 7.2% of the wintering population during the 3 winters.

Deer use of a 17.1-km snowmobile trail was significantly correlated with deer density in the wintering area, and with winter severity, as determined by a winter severity index. They commonly fed along snowmobile trails and used them most frequently and extensively near major bedding areas. Most deer traveled for short distances on snowmobile trails, although deer movements exceeding 1 km were occasionally noted. Changes in deer distribution resulted in similar changes in their use of snowmobile trails. In some localities, deer incorporated the snowmobile trail into their own trail system. Snowmobile disturbance did not cause deer to abandon their preferred bedding or feeding sites.

Deer sank 1/4-1/6 as much on snowmobile trails as in undisturbed snow. They rarely sank more than 10 cm into a snowmobile trail. Because of its excellent supportability for deer, the snowmobile trail enhanced deer mobility, and probably reduced the energy they expended while traveling and obtaining food.

Snowmobile trail hardness (during daylight hours) was inversely correlated with air temperature and time since sunrise. Deer sinking depth on snowmobile trails was inversely correlated with snowmobile trail hardness.

Nine of 10 attempts to re-locate groups of deer from concentration areas to less exploited localities were temporarily successful. A combination of snowmobile trails, cedar foliage (placed along it), and chain saw noise was the most effective

inducement used, in terms of response time, and deer displacement. However, re-located deer probably benefited more by the felled cedar trees at the end of the trail than by improved mobility on snowmobile trails.

Deer responded favorably to snowmobile trails made in extensive openings adjacent to existing concentration areas, especially when deep, soft snow limited their off-trail mobility. Manpower and time limitations were considered obstacles to furnishing deer with enough snowmobile trails to ensure uniform utilization of browse in large openings.

Deer response to snowmobiles consisted of running out of sight or staying in place when observed. The number of deer staying within sight increased each winter, from December-April. Progressive weakening of deer, reduced activity in mid-winter, and habituation to snowmobile disturbance may have prompted some deer to avoid running away when confronted by a snowmobiler. Lateral concealment, lack of an easy escape route (e.g., a deer trail), deep snow, and large deer sinking depths also seemed to prompt some deer to stay in sight rather than run. Deer tended to panic when confronted by a fast-moving snowmobile oriented directly toward them. At Hayden Brook, numerous localities which were inaccessable to snowmobilers served as refuges for deer from further disturbance, and permitted them to tolerate snowmobilers.

LITERATURE CITED

Anomymous. 1970. The Swiss Rammsonde. Spec. Tech. Pap. No. 1, Testlab Div. of G.D.I., Chicago, Illinois. 15pp.

Baldwin, M. F., and D. H. Stoddard. 1973. Snowmobile profile. Pages 1-4 in Baldwin, M.F., Ed. Off the road vehicle and environmental quality. 2nd ed. The Conserv. Found., Washington, D. C.

Banasiak, C. F. 1962. Deer yard evaluation. Maine Dept. Inland Fish. and Game. Pittman-Robertson Proj. W-37-R-12, Job B-3. 7pp.

_____. 1964. Deer in Maine. Maine Dept. Inland Fish. and Game. Game Div. Bull. 6. 163pp.

Bateman, M. C. 1972. Winter shelter: some effects on the behavior and physiology of penned white-tailed deer. M.S. Thesis, Univ. Maine, Orono. 108pp.

Bollinger, J. G., O. J. Rongstad, A. Soom, and R. G. Eckstein. 1973. Snowmobile noise effects on wildlife. Rep. 1972-73, Univ. Wisconsin, Madison. 14pp.

Day, B. W. 1963. Winter behavior of white-tailed deer in north-central Maine. M.S. Thesis, Univ. Maine, Orono. 151pp.

Doan, K. H. 1970. Effects of snowmobiles on fish and wildlife resources. 16th Convention Int. Assoc. Game, Fish, and Conserv. Comm. pp. 97-103.

Doherty, P. 1971. Effects on fish and game management. Pages E-28-E-30 in Butler, R. W., P. S. Elder, H. N. Janish, B. M. Petrie, Eds. Conference on snowmobiles and all-terrain vehicles. Univ. Ontario, London, Ontario, Canada.

Dorrance, M. J., P. J. Savage, and D. E. Huff. 1975. Effects of snowmobiles on white-tailed deer. J. Wildl. Manage. 39(3): 563-569.

Formozov, A. N. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. (Trans. from Russian). Publ. 1, Boreal Institute, Univ. Alberta, Edmonton, Alberta, Canada. 176pp.

Gilbert, P. F., O. C. Wallmo, and R. B. Gill. 1970. Effect of snow depth on mule deer in Middle Park, Colorado. J. Wildl. Manage. 34(1):15-23.

Gill, J. D. 1957. Review of deer yard management. Maine Dept. Inland Fish and Game. Game Div. Bull. 5. 61pp.

Heath, R. 1974. A look at snowmobile damage. The ORV Monitor, Environmental Defense Fund, Berkeley, California. 8pp.

Hugie, R. D. 1973. A winter study of deer mobility in west-central Maine. M.S. Thesis, Univ. Maine, Orono. 78pp.

Kopischke, E. B. 1972. Effects of snowmobile activity on the distribution of white-tailed deer in south-central Minnesota. Minn. Dept. Nat. Resour., Game Res. Proj. Quar. Prog. Rep. 32(3):139-142.

Kropp, J. R. 1974. A study of the winter activity and behavior of penned white-tailed deer. M.S. Thesis, Univ. Maine, Orono. 57pp.

Mattfeld, G. F. 1973. The effect of snow on the energy expenditure of walking white-tailed deer. Trans. N.E. Fish Wildl. Conf., Dover, Vermont. 30:327-343.

Mech, L. D., L. D. Frenzel, Jr., and P. D. Karns. 1971. The effect of snow conditions on the vulnerability of white-tailed deer to wolf predation. Pages 51-59 in Mech, L. D., and L. D. Frenzel, Jr., Eds. Ecological studies of the timber wolf in northeastern Minnesota. USDA For. Serv., Res. Pap. NC-52.

Rourke, R. V., and J. S. Hardesty. 1966. The soils of Maine. Maine Agric. Exp. Stn., Misc. Publ. 676. 34pp.

Ryel, L. A. 1971. Evaluation of pellet group survey for estimating deer populations in Michigan. Ph.D. Thesis, Michigan State Univ., Ann Arbor. 237pp.

Schmid, W. 1971. Modification of the subnivean microclimate by snowmobiles. Proc. 1971 Snow and Ice Symposium, Iowa State Univ., Ames. pp. 251-255.

Severinghaus, C. W. 1947. Relationship of weather to winter mortality and population levels among deer in the Adirondack region of New York. Trans. N. Am. Wildl. Conf. 12:212-223.

Silver, H., N. F. Colovos, H. B. Holter, and H. H. Hayes. 1969. Fasting metabolism of white-tailed deer. J. Wildl. Manage. 33(3):490-498.

Verme, L. J., and J. J. Ozoga. 1971. Influence of winter weather on white-tailed deer in upper Michigan. Proc. 1971 Snow and Ice Symposium, Iowa State Univ., Ames. pp. 16-28.

Wettersten, R. 1971. Environmental impact of snowmobiling. Pages E-10-E-13 in Butler, R. W., P. S. Elder, H. N. Janish, B. M. Petrie, Eds. Conference on snowmobiles and all-terrain vehicles. Univ. Ontario, London, Ontario, Canada.

Young, J., and A. Boyce. 1971. Recreational uses of snow and ice in Michigan and some of its effects on wildlife and people. Proc. 1971 Snow and Ice Symposium, Iowa State Univ., Ames. pp. 193-196.

Zar, J. H. 1974. Biostatistical analysis. Prentiss-Hall Inc., Englewood Cliffs, N.J. 620pp.

BIOGRAPHY OF THE WRITER

Gerald Robert Lavigne was born in Troy, New York on 22 February 1951, and graduated from St. Bernard's Academy, Cohoes, New York in 1968. He received a Bachelor of Science degree in Forest Zoology from the State University of New York, College of Environmental Science and Forestry, at Syracuse University in 1972.

Lavigne entered the University of Maine in September 1972 as a Graduate Research Assistant of the Maine Cooperative Wildlife Research Unit, and is a candidate for the Master of Science degree in Wildlife Management in May 1976.

Mr. Lavigne married the former Jeannine C. Oakes in 1975. He is a member of The Wildlife Society.