ASPECTS OF THE WINTER ECOLOGY OF BLACK-TAILED DEER (*Odocoileus hemionus columbianus* Richardson) ON NORTHERN VANCOUVER ISLAND

by

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ABSTRACT

Black-tailed deer (*Odocoileus hemionus columbianus* Richardson) were studied in the Nimpkish Valley on northern Vancouver Island to determine the effects of clearcut logging upon the ecology of the deer in winter. Because Provincial government biologists suspected that logging was decreasing the amount of winter range, and therefore the number of deer, on Vancouver Island, most emphasis was placed upon the interrelationships between logging, snow depth, habitat selection by deer, and nutritional condition of deer.

The study was done during during the winters of 1971-72 and 1972-73. The first winter was severe and had heavy snowfall, and the second winter was mild and had light snowfall.

If deer sink deeper in snow than their chest height, they have a hard time moving. In the Nimpkish Valley, fawns had chest heights of about 17 inches, and adults about 22 to 23 inches.

During the first winter, snow in the logged habitats averaged 4 ft deep, but snow in the mature timber habitats averaged less than 2 ft deep. There was more snow at high elevations than at low elevations. Snow was less deep than deer chest height only in mature timber habitats at low elevations. Snow was also shallowest in mature timber habitats having a high crown closure. During the severe winter, only mature timber habitats at low elevations with crown closures greater than 65% were used heavily by deer.

The most important aspect of snow is not simple snow depth, but how deeply deer sink in it. When a hard crust formed on deep snow in the regenerated logging slashes, deer were able to move freely on top of the crust, and made heavy use of these areas for feeding.

Deer also used mature timber habitats heavily during the mild winter. Deer made more use of timber habitats having a shrub understory than those having a conifer understory, probably because there was more food available in the timber having a shrub understory. Many deer remained as high up the mountains as snow conditions and food availability permitted.

Generally, deer made light use of the logged habitats during both winters, but they used these habitats heavily in the spring.

Deer were collected to measure their food habits and physical condition. Deer were not able to eat as many plant species in the severe winter as in the mild winter, and were in worse physical condition in the severe winter than in the mild winter.

In the Nimpkish Valley, deer made heavy use of mature timber habitats during winter. In many other areas of western North America, black-tailed deer usè logged habitats for winter range. However, the Nimpkish Valley is much more mountainous and has more snowfall than many other areas in which deer ecology has been studied. The habitat selection patterns of deer in the Nimpkish Valley probably occur only in areas having similar topography, vegetation, and climate.

Most other studies of black-tailed deer have concluded that logging is beneficial to deer. However, continued clearcut logging in the regions of Vancouver Island having high snowfall will eliminate deer winter range and reduce deer populations. It is recommended that logging companies leave strips of mature timber, going from the subalpine to the valley bottom, and including winter range habitats, in all those areas where deer populations are desired.

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The study was proposed by Ian Smith and supervised by Fred Bunnell, both of whom provided much assistance in planning the field work. Byron Mason and Charles Veasey of Nanaimo provided detailed knowledge of deer winter range and without their assistance much of the feel for the winter range problem would have been lost.

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1. INTRODUCTION

1.1 Definition of the problem

In many areas, black-tailed deer (*Odocoileus hemionus columbianus* Richardson) prefer early seral types as winter range. There is more food available in the early seral types, and the plants in the early seral types are often more nutritious (Brown, 1961; Einarsen, 1946; Gates, 1968).

Until recently, many biologists felt that on Vancouver Island, deer use early seral types for winter range. However, some previous workers suggested that in those regions of Vancouver Island where winter is severe, deer require mature timber seral types as shelter from deep snow (Cowan, 1956; Edwards, 1956). Similarly, in high snow areas deer populations have decreased when all timber has been removed (Edwards, 1956; Smith, pers. comm.). If deer depend on mature forest for winter survival, then continued clearcut logging in the regions of Vancouver Island having high snowfall will result in lower deer populations. The purpose of this study is to investigate the winter ecology of black-tailed deer in the regions of Vancouver Island having high snowfall.

1.2 Objectives and scope

The study was designed to determine the relationships between clearcut logging and the winter ecology of deer. The hypothesis was that logging decreases winter range because mature timber is necessary for shelter from deep snow. I originally attempted to study the effects of logging on the winter ecology of deer by measuring deer-use of logged and unlogged habitats, within classes of aspect and elevation. However, this approach was too simple to produce meaningful results, and therefore I included some relationships between environmental conditions, habitat selection, and physical condition of deer, and also described some characteristics of deer winter range habitats. This study was intended to be useful in the management of deer, and in planning further research.

The study does not deal in depth with any single topic of deer winter ecology, but deals superficially with several related topics, and thus provides an overview of deer winter ecology. The specific topics examined include:

1) vegetation characteristics of various habitat types,
2) food habits of deer,
3) deer-use of habitat types,
4) effects of vegetation, snow, and season (winter versus spring) on deer-use of habitats,
5) movements of deer,
6) physical condition of deer,
7) chest heights of deer.

2. STUDY AREA AND STUDY PERIOD

2.1 Description of the study area

The study area is located in the Nimpkish Valley on northern Vancouver Island (Figure 1), and most field work was done near the Davie River. Since the Davie River is a major tributary of the Nimpkish River, the study area is referred to as the Nimpkish Valley. Willms (1971) described the major ecological characteristics of the Nimpkish Valley, and his description is summarized below.

The Nimpkish Valley was glaciated in the Pleistocene, and therefore the soils are deep only on the valley bottom, and outcroppings of bedrock are common on the sidehill areas. Most of the valley area below 2000 ft elevation has been burned by wildfire within the last 1000 years. Logging in parts of the valley outside the study area began in 1915, but logging in the study area itself began in 1947 and continues at present. The valley bottoms and some of the sidehill areas were progressively clearcut, but at present, most logging settings are separated by mature timber which is left unlogged for 3 or more years. The Nimpkish Valley is mountainous, with many peaks higher than 4000 ft, and there is often much snow during winter (Figure 2).

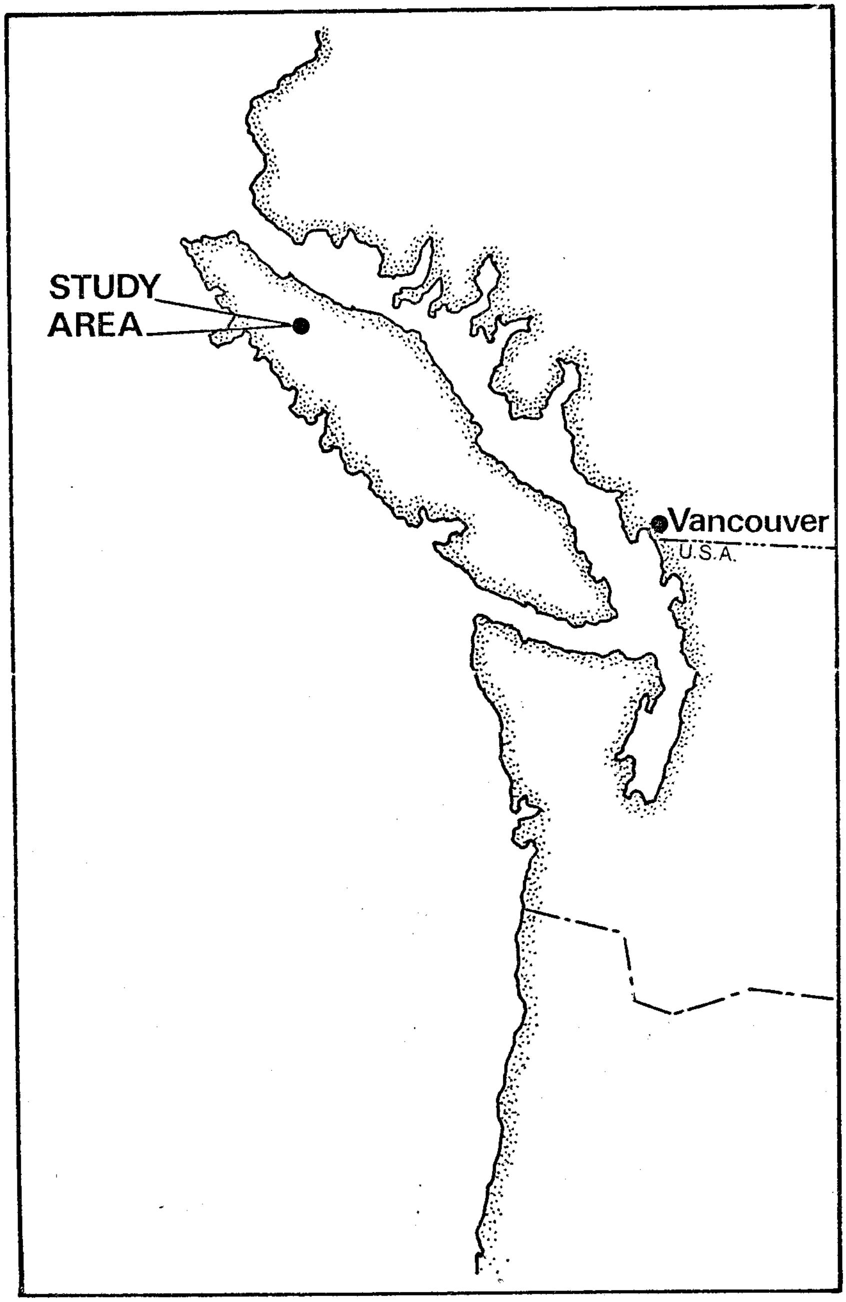
The following biogeoclimatic zones are present in the study area: Wet Douglas Fir, Dry Western Hemlock, Wet Western Hemlock, Mountain Hemlock (subalpine), and alpine (Packee, 1972). Most of the field work was done within the Dry Western Hemlock and the Wet Western Hemlock zones, although some work was done in the other zones.

2.2 Period of field work

Most of the field work was done in the consecutive winters

Figure 1

Location of the Nimpkish Valley study area
on northern Vancouver Island


STUDY
AREA
Vancouver
U.S.A.

of 1971-72 and 1972-73, with preliminary field work from September through November, and intense study from December through April. Some additional data on deer movements were collected from May of 1973 through February of 1974.

3. STUDY METHODS

3.1 Classification of habitat types

In order to measure deer-use of different habitats, measurable parameters must be used to classify habitat types. Initially, habitats were classified according to seral type, elevation, and aspect, because previous workers have considered these variables important to deer winter range (Gates, 1968; Loveless, 1967). Three classes of seral type and elevation, and two classes of aspect were used. The seral types distinguished are clear slash, second-growth slash, and mature timber. Clear slash refers to logged areas without obvious conifer regeneration, second-growth slash refers to logged areas having obvious conifer regeneration, and mature timber refers to unlogged habitats. Where appropriate, clear and second-growth slash habitats are called logged habitats. The elevation classes used were low (500-1500 ft.), medium (1500-2500 ft.) and high (2500-4000 ft.).

The aspects used were south-facing and north-facing slopes. South aspects include all aspects from west through south to southeast, and north aspects include all other aspects.

3.2 Kinds of data collected

I collected data describing all of the study topics listed in section 1.2, and have organized the methods according to the type of data collected.

3.2.1 Deer-use data

Three methods were used to measure deer-use:

1) deer track counts in the snow,
2) daytime deer counts,
3) nighttime deer counts.

3.2.1.1 track count plots

I counted deer tracks in the snow to obtain instantaneous indices of deer-use,and attempted to count only tracks that were less than one-day old, but varying weather conditions often made tracks difficult to age. A different design of track count plot was used during the second winter than the first, and the method used during the second winter is described later.

During the first winter, a radial plot design was used to measure deer-use (Appendix 1). The plots were temporary and unmarked, and the centre of each plot was a fresh deer track. All plot centres were at least 100 feet apart, and each plot consisted of four 50-foot long compass lines radiating in the cardinal directions.

The instantaneous deer-use index is the total number of tracks crossed by the four compass lines. It was difficult to count tracks accurately when there were more than four or five tracks on each 50-foot line, and the centre track was counted only if it crossed a 50-foot line. If a track crossed a 50-foot line twice or more, it was counted only once. It was often impossible to determine if a track crossed more than one 50-foot line.

I walked through the area under study and took track-count data as deer tracks were encountered. I walked through the area in one direction, such as uphill, downhill, or sidehill.

Eighteen snow depth measurements were taken in some areas sampled with track count plots (Appendix 1). The snow depth for the area is the mean of the eighteen measures.

3.2.1.2 daytime deer counts

I counted deer in daylight to measure deer-use of both logged and unlogged habitat types, and used ordinary hunting techniques to see deer. The deer-use index is deer seen per unit searching time.

3.2.1.3 nightime deer counts

I counted deer at night to measure deer-use of clear slash habitats. My assistant and I each had a spotlight, and we counted deer as I drove the truck at 5 to 15 mph. The measure of deer-use is deer seen per mile of road.

I counted deer on twelve transects, totalling 20.5 miles of road, at intervals of approximately two weeks, but occasionally missed some transects because of bad weather. It was not normally possible to count all the transects in one night, so the counts were taken over several nights. There were 9 sampling periods, and for data analysis it was assumed that all counts were done on the middle date of the sampling periods.

3.2.1.4 permanent track count plots

The results of the first year of field work suggested that deer-use of habitats was influenced by more than elevation, aspect, or seral type. Consequently, I designed a permanent plot from which the following data were collected:

1) deer-use, measured by track counts,
2) percent cover of some plant species,
3) deer track depth in the snow,
4) snow depth,
5) estimate of the abundance of lichen litterfall.

I also recorded the elevation, aspect, seral type, and percent crown closure of each plot.

Most of the permanent plots were located in areas visited during the winter of 1971-72. Each permanent plot consisted of 20 subplots, and the design of the plots is shown in Appendix 2.

The number of fresh deer tracks in the snow between each pair of subplots was counted, and the deer-use index for the plot is the mean of the 15 individual track count samples. The snow depth at the centre of each subplot was measured, and the snow depth for the plot is the mean of the snow depths on each subplot. I measured deer track depth from 5 clear footprints of a representative track that crossed the track count line, but did not measure track depths from all track count lines. The individual track depth is the mean of the measures taken from a single track, and the track depth for the plot is the mean of the individual track depths.

The abundance of lichen litterfall (Alectoria sp only) was estimated on a four point scale: 0, 1, 2, 3. A value of '0' indicates that no lichen was available, '1' indicates that lichen litterfall was "light", '2' indicates that lichen litterfall was "medium", and '3' indicates that lichen litterfall was "heavy". The lichen index for the plot is the mean of the indices from the 20 subplots.

The percent cover of vegetation on each subplot was measured, excluding plant species which are commonly less than 1 ft high, and considering only plants with living parts above ground during winter. I measured the maximum length and width of each species-specific clump of vegetation, and rounded all measures to the nearest one-quarter foot. The horizontal coverage was then calculated as the area of an ellipse. If there were a large number of small clumps, the percent cover was estimated. High overhanging branches were excluded from the vegetation data.

I measured the percent crown closure of the mature timber plots by using a 35-mm single lens reflex camera to photograph the canopy directly above the centre of each subplot. A wide-angle lens (focal length = 35 mm) was used on the camera. I took the percent cover by delineating canopy and non-canopy on a 3.5 by 5 inch print, and using a dot grid (64 dots per square inch) to measure percent cover from a 2 inch by 2 inch square at the centre of the print. The crown closure measure was rounded to the nearest 5%, and the crown closure measure for the plot is the mean of the measures from the 20 subplots.

It was impossible to collect many data from the low elevation plots because of the unusually light snowfall during the winter of 1972-73, and 16 of the 19 permanent plots were in low elevation habitats. Therefore, 5 unmarked temporary plots, identical to the permanent plots, were measured in various high elevation habitats where there was a significant snowpack. All temporary plots were placed in mature timber habitats 3400 ft or more in elevation.

3.2.2 Deer collection data

I collected deer in late January and late March of each year and took the following data from each deer collected:

1) whole weight and eviserated weight,
2) total weight of kidney fat,
3) chest height (sternum to tip of nail),

4) a rumen sample.

I modified the method of Anderson, Medin, and Bowden (1972) to calculate an index of deer condition:

$$Ic = F/W \times 100$$

Ic = deer condition index

F = mean kidney fat weight of the two kidneys

W = whole weight of the deer.

Anderson, Medin, and Bowden (1972) trimmed the kidney fat square with the kidney, but I did not do this because I felt that their method introduces bias into the results. I assume that the deer condition index is directly proportional to "nutritional condition" or the "ability to survive winter stress".

A lab technician analyzed the rumen samples, using the standard method employed by the British Columbia Fish and Wildlife Branch (Appendix 3). The plants eaten were classified into 8 food types: conifers, shrubs, forbs, ferns, lichens, mosses, liverworts, and miscellaneous; and the percent volume and percent occurence of individual species and food types in the rumen samples was calculated. The species listed in Figures 7 and 8 include only the most common species found in the rumen samples.

I also sampled deer in November of 1972, but took only the data necessary to calculate the condition index from these samples.

3.2.3 Deer movement data

I used radio telemetry to study deer movements and tagged one deer in January of 1973 and six in April of 1973. I located the tagged deer from the ground and from fixed-winged aircraft.

4. RESULTS

4.1 Abiotic data

Snow data were taken because snow has a great effect upon the ecology of deer in winter. An understanding of the factors that influence snow depth is essential for an understanding of deer ecology.

4.1.1 Comparison of the winter of 1971-72 with the winter of 1972-73

Much more snow fell during the winter of 1971-72 than during the winter of 1972-73 (Figure 2). The total snowfall at 500 feet elevation was 125 inches over the winter of 1971-72, and only 10 inches over the winter of 1972-73. During both winters, the snowfall at elevations above 500 feet was greater than the snowfall recorded in Figure 2. The data show that the winter of 1971-72 was more severe than the average since 1954, and that the winter of 1972-73 was less severe. However, neither winter was the most severe, or the least severe, winter on record.

Figure 2

Monthly snowfall at Woss Camp

These data were provided by Canadian Forest Products Ltd. and were collected at 500 feet elevation.

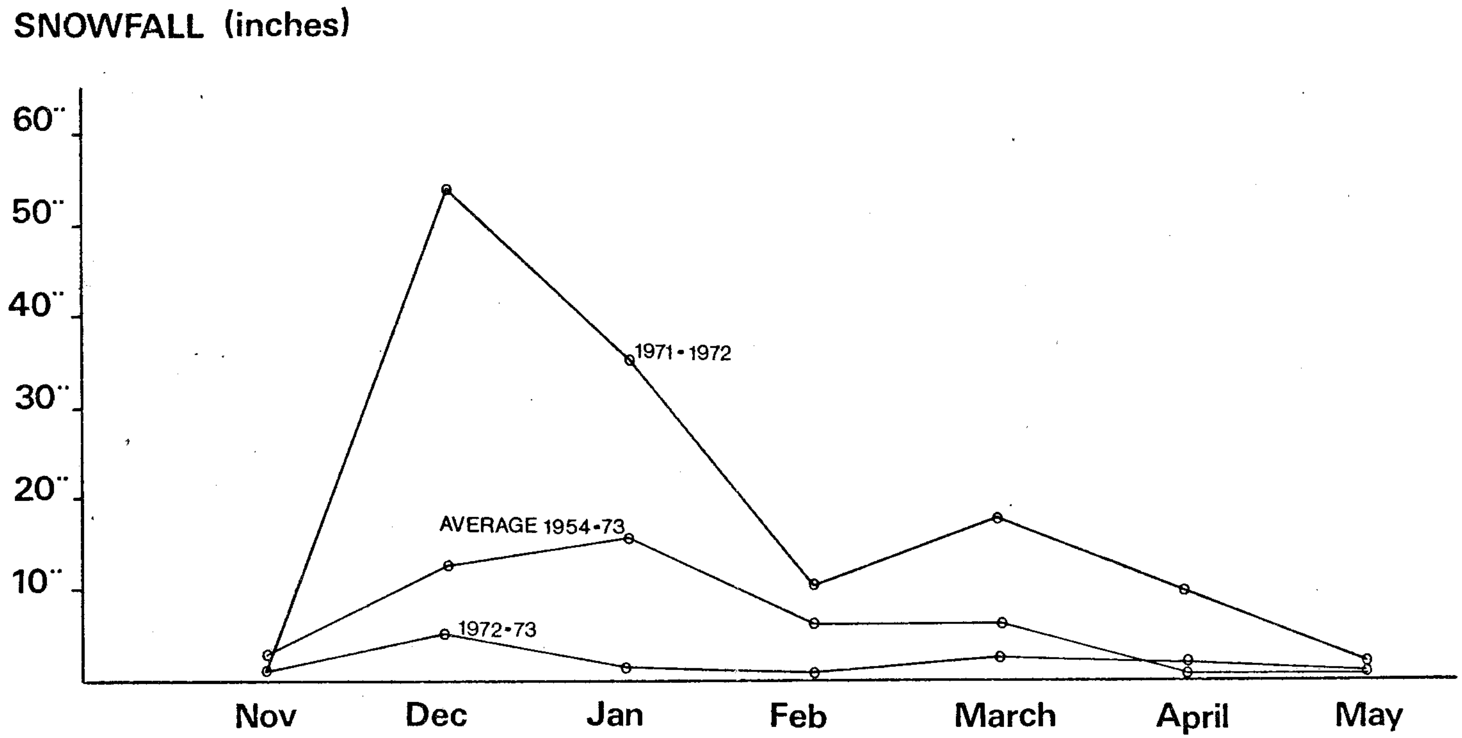

SNOWFALL (inches)
60"
50"
40"
30"
20"
10"
1971 - 1972
AVERAGE 1954-73
1972-73
Nov
Dec
Jan
Feb
March
April
May

Figure 3

Relationship between snow depth and elevation

These data were collected from
December of 1971 through March of 1972

Test of common equation: $F = 47.19$ $p < 0.001$

The slopes of the two equations are not
different at the 5% level of significance

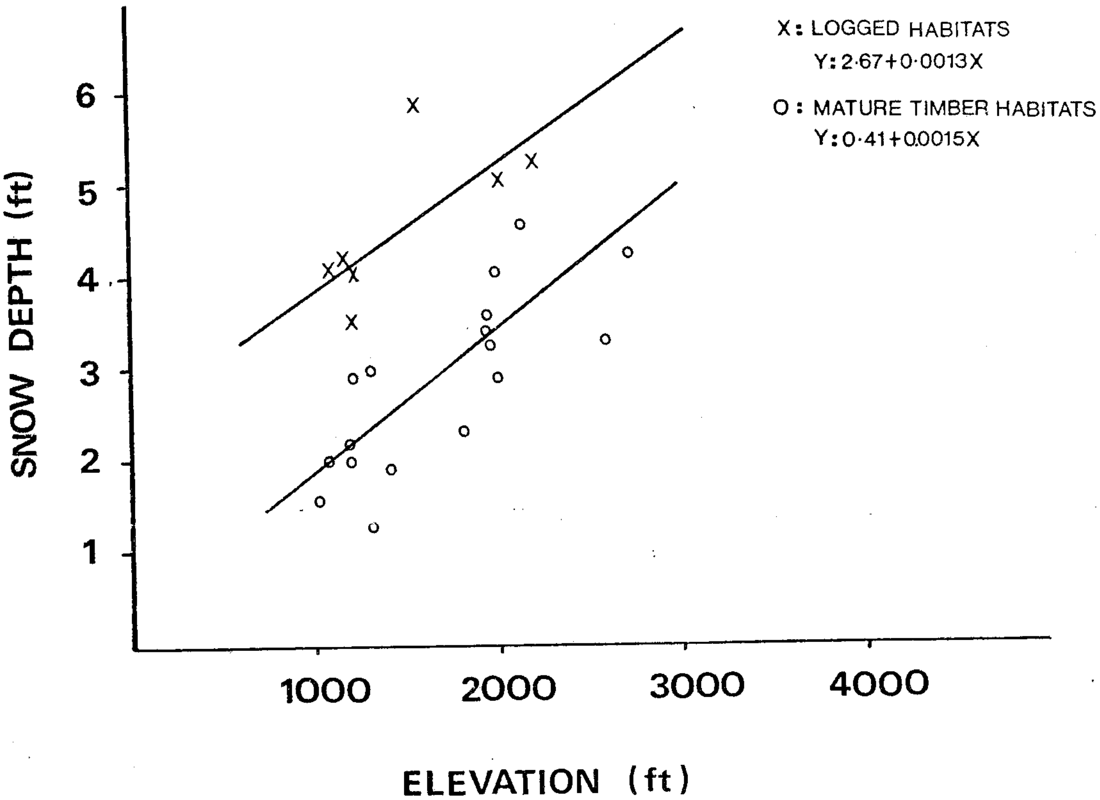
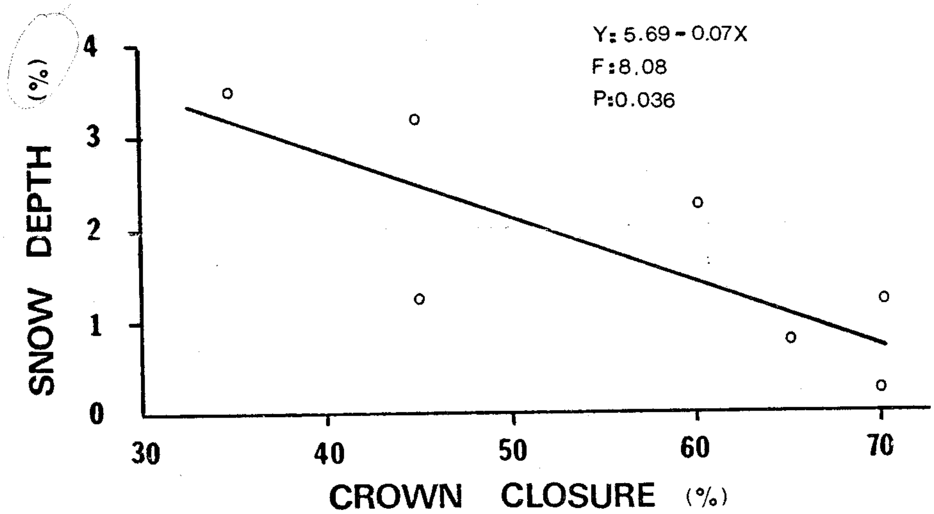

X: LOGGED HABITATS
Y: 2·67+0·0013X
O: MATURE TIMBER HABITATS
Y: 0·41+0.0015X
SNOW DEPTH (ft)
1
2
3
4
5
6
1000
2000
3000
4000
ELEVATION (ft)

Figure 4

Relationship between snow depth and crown closure

These data were collected from
January through March of 1973.

These data were collected in mature timber
habitats above 3000 feet elevation


Y: 5.69 - 0.07X
F: 8.08
P: 0.036
SNOW DEPTH (%)
0
1
2
3
4
30
40
50
60
70
CROWN CLOSURE (%)

4.1.2 Relationships between snow depth, elevation, and crown closure

Within the elevation range sampled during the winter of 1971-72, snow was deepest at high elevations and in the logged habitats (Figure 3). Snow is less deep in the timber because the dense crown closure reduces the amount of falling snow that reaches the ground surface (Meiman, 1968). In the Nimpkish study area, snow was about twice as deep in the logged habitats as in the mature timber habitats (Figure 3). A dense crown closure intercepts a greater proportion of a snowfall than an open crown closure, and therefore snow depths decrease with increasing crown closure (Figure 4).

Much of the variation shown in Figures 3 and 4 undoubtedly arose from sampling over time and from sampling in different areas.

4.2 Vegetation in the habitat types

I measured vegetation because deer-use of habitats is influenced by vegetation. The vegetation data presented were taken from the permanent plots during the autumn of 1972. I have presented only data describing several of the more common plant species found on the plots.

Visual inspection of the data suggests that vegetation cover varied a great deal within seral types (Table 1). For example, cover of *Vaccinium* sp in mature timber habitats on south aspects, and between 500 and 1500 ft elevation, varied

Habitat type	Winter range [1/]	Elevation	Crown closure	Years since burning	Vaccinium species	Salal	Cedar [2/]	Douglas fir	Western hemlock	True fir
Clear slash; south aspect	No	1000	0	9	2 ± 3	1 ± 3	0	1 ± 2	0	0
	No	1300	0	4	1 ± 2	13 ± 21	0	<1	1 ± 2	0
	No	1400	0	5	0	0	0	0	0	0
Second growth; south aspect	No	1000	0	20	7 ± 10	<1	9 ± 13	13 ± 19	15 ± 23	0
	No	1100	0	20	1 ± 2	9 ± 17	13 ± 12	16 ± 24	7 ± 13	0
	No	1300	0	19	<1	0	0	2 ± 8	11 ± 20	
Mature timber; south aspect	Yes	1100	75 ± 10		3 ± 6	0	0	0	54 ± 42	9 ± 22
	Yes	1400	80 ± 23		3 ± 4	76 ± 31	0	0	12 ± 23	0
	Yes	1800	75 ± 15		<1	0	0	0	8 ± 21	<1
	Unsure	1100	55 ± 11		30 ± 30	16 ± 26	0	0	20 ± 27	10 ± 15
	Yes	1000	70 ± 15		40 ± 24	0	0	0	4 ± 9	0
	Unsure	700	60 ± 20		35 ± 27	0	0	0	18 ± 25	0
	No	3600	45 ± 20		56 ± 26	0	6 ± 10	0	0	4 ± 8
	No	3000	50 ± 25		78 ± 32	0	2 ± 5	0	3 ± 8	9 ± 11
	No	2900	75 ± 19		52 ± 35	0	0	0	4 ± 8	9 ± 14
Mature timber; north aspect	No	1600	70 ± 13		31 ± 23	1	0	0	2 ± 5	18 ± 19
	Yes	1200	65 ± 13		1 ± 2	0	0	0	10 ± 17	0
	No	1500	60 ± 10		27 ± 27	0	0	0	34 ± 39	5 ± 11
	Yes	1500	10 ± 15		27 ± 16	0	1	0	23 ± 30	4 ± 7

Table 1 Percent plant cover on the permanent track count plots as measured in the autumn of 1972 (mean ± st. dev.).

1/ Indicates whether or not this area was used as a winter range during the severe winter of 1971-72.

2/ Red cedar and yellow cedar.

Each value is the mean of 20 subplot samples.

from 3 to 40%. Because of the high variation within types, broad seral types cannot be used to predict vegetation cover.

The habitat classification system used does not adequately explain the variation in the vegetation data. There is as much variation within habitat types defined by elevation, aspect, and seral type as there is between these habitat types (Table 1). Given that vegetation influences deer-use, it follows that deer-use of these habitat types will vary a great deal.

4.3 Winter and spring food habits

To understand deer ecology, one must know the factors influencing deer nutrition. In this study, severe winter weather had a definite effect upon the diet of the deer.

4.3.1 Food habits during the severe winter of 1971-72

During the severe winter deer ate mostly conifer and shrub material (Figure 5). The only food types occurring in more than 50% of the samples were conifers, shrubs, and lichens (Figure 6). Red cedar, salal, Douglas fir and western hemlock each contributed more than 10% to the total volume eaten; and more red cedar and salal was eaten than any other plant species (Figure 7). The only species occurring in more than 50% of the samples were red cedar, Douglas fir, western hemlock, salal, and *Vaccinium* species (Figure 8).

The food habits during early spring were different from the food habits during winter. Deer ate less conifer material and more forb, fern, and lichen material, but the amount of shrub material in the diet remained constant. All 8 food types occurred in more than 50% of the samples in early spring, but only 3 food types occurred in more than 50% of the samples from winter. The species showing the greatest increases in volume from winter to spring were deer fern, Alectoria species, bunchberry, and grasses. Red cedar, salal, and Alectoria species each contributed more than 10% to the total volume eaten in spring. The species occurring in more than one half of the samples in early spring were red cedar, salal, deer fern, Douglas fir, western hemlock, Vaccinium species, bunchberry, grasses, Alectoria species, and Lobaria species (a foliose lichen).

4.3.2 Food habits during the mild winter of 1972-73

During the mild winter, deer ate mostly conifers, shrubs, and ferns. A greater volume of forbs and lichens was eaten during the mild winter than during the severe winter. The food types occurring in more than 50% of the samples were conifers, shrubs, forbs, ferns, and lichens. Deer fern and red cedar each contributed more than 10% to the total volume eaten. Hemlock and Douglas fir were less heavily used during the mild winter than during the severe winter, suggesting that they were utilized when more palatable species were difficult to obtain. The following species occurred in more than 50% of the samples: red cedar, western hemlock, salal, deer fern, Vaccinium species, bunchberry, twinflower, Rubus species, and Polystichum species (a fern).

Figure 5

Percent volume of the food types in the rumen samples

1	Conifer	p = 0.003
2	Shrubs	p = 0.911
3	Forbs	p = 0.036
4	Ferns	p = 0.001
5	Lichens	p = 0.028
6	Mosses	-----
7	Liverworts	-----
8	Misc	-----

The proportion of each browse type in each rumen samples was calculated and the statistics are calculated with each rumen used as one sample. The statistics are calculated with the Kruskal-Wallis H test.

The probability value given is the probability that the percent volume of a food type is equal in the 4 sample periods.

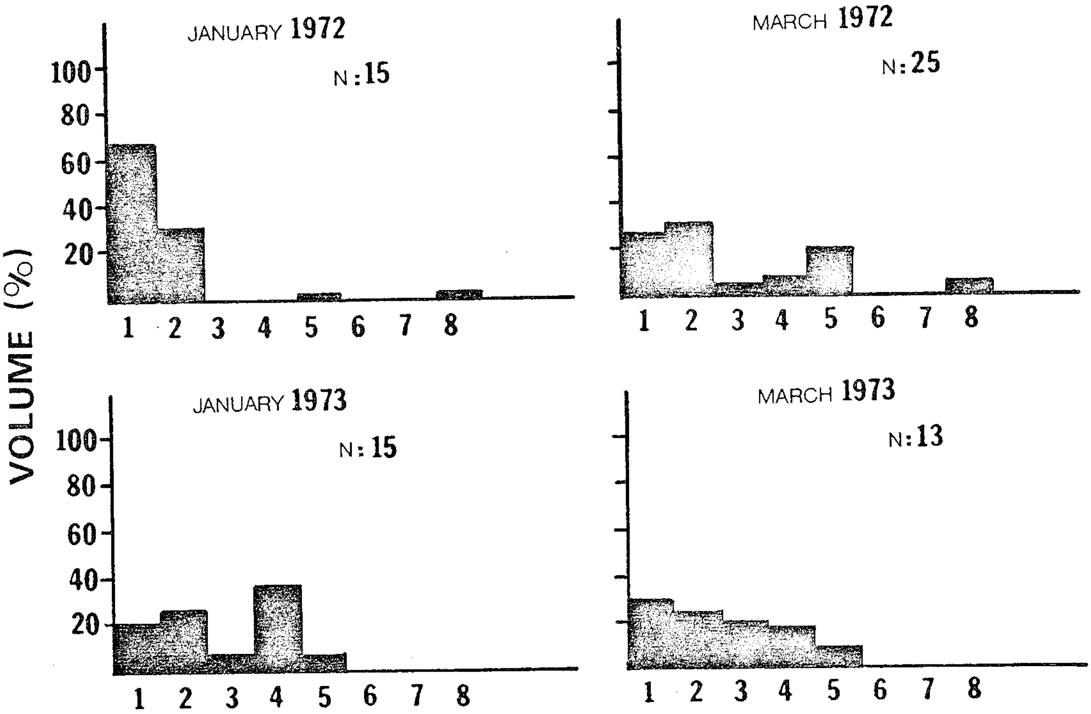

JANUARY 1972
N:15
MARCH 1972
N:25
JANUARY 1973
N:15
MARCH 1973
N:13
VOLUME (%)
100
80
60
40
20
1 2 3 4 5 6 7 8

Figure 6

Percent occurrence of the food types in the rumen samples

FOOD TYPE

1 Conifers
2 Shrubs
3 Forbs
4 Ferns
5 Lichens
6 Mosses
7 Liverworts
8 Misc

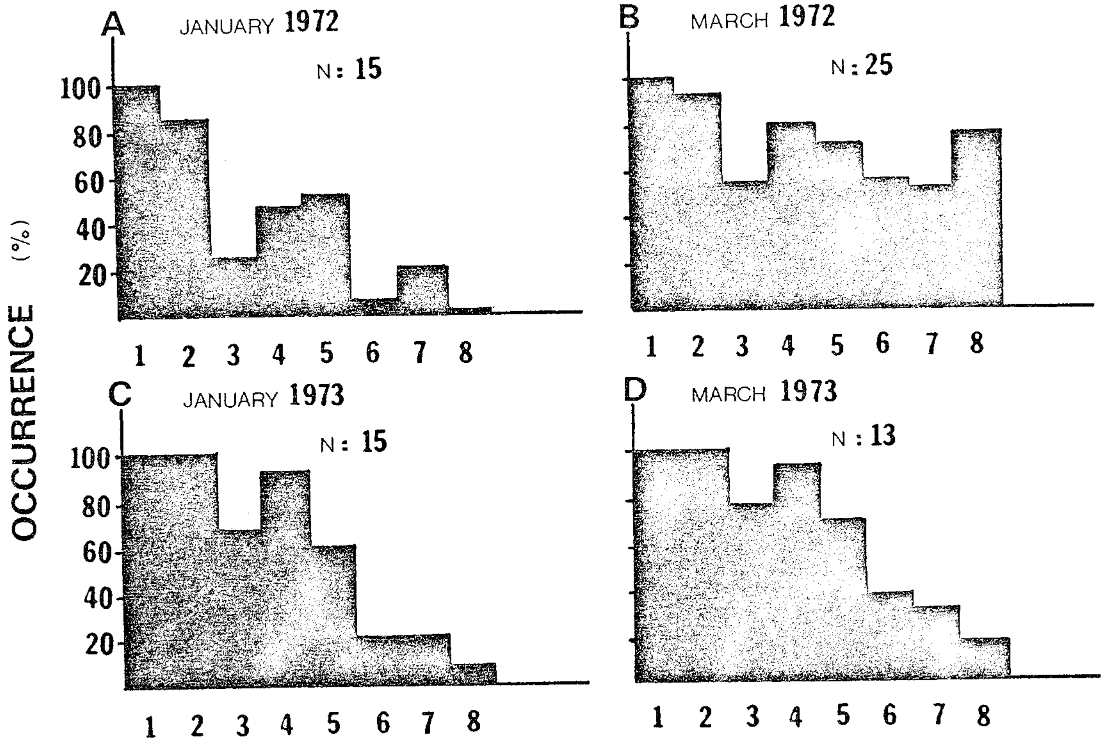

A
JANUARY 1972
N: 15
B
MARCH 1972
N: 25
C
JANUARY 1973
N: 15
D
MARCH 1973
N : 13
OCCURRENCE (%)
100
80
60
40
20
1 2 3 4 5 6 7 8

Figure 7

Percent volume of the species in the rumen samples

1	Red cedar	p = 0.047
2	Salal	p = 0.294
3	Deer fern	p = 0.001
4	Douglas-fir	p = 0.059
5	Twinflower	p = 0.003
6	Hemlock	p = 0.044
7	Alectoria sp	p = 0.348
8	Vaccinium	p = 0.524
9	Bunchberry	p = 0.075
10	Rubus sp	p = 0.056
11	Grasses	p = 0.041

The proportion of each species in each rumen sample was calculated and the statistics are calculated as explained in Figure 5.

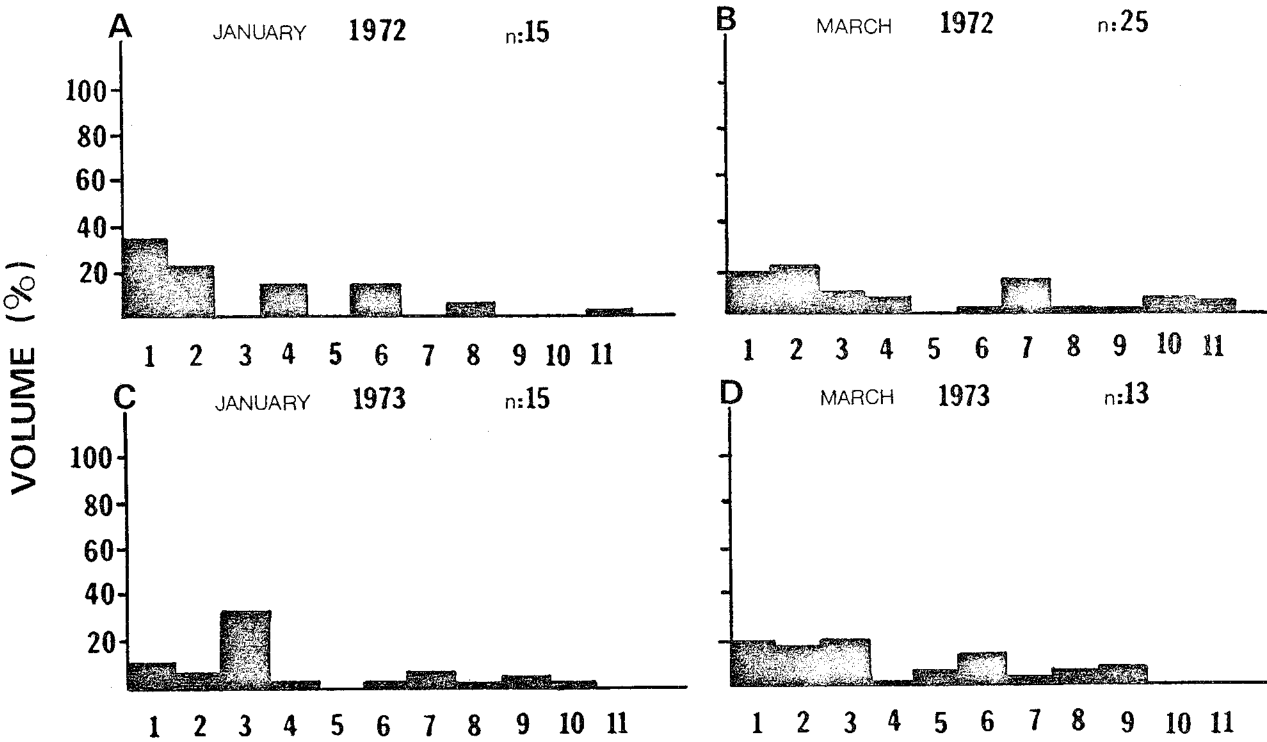
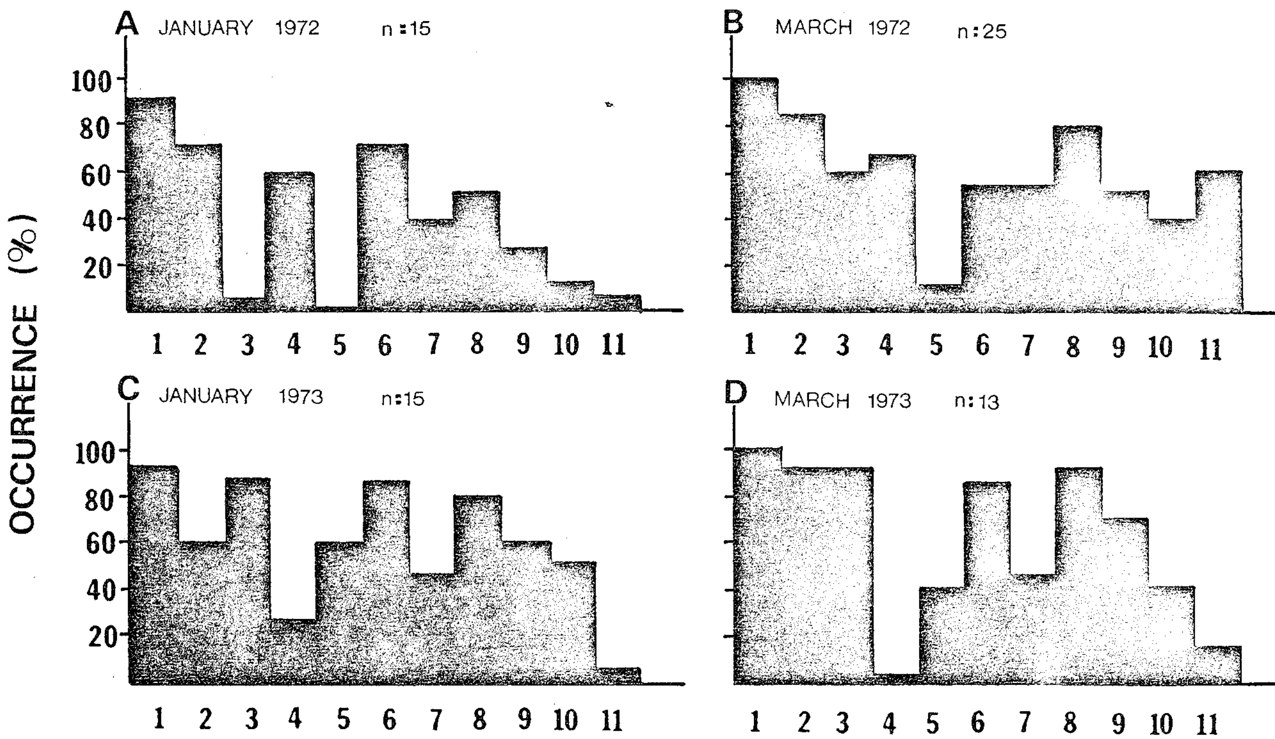

A
JANUARY 1972
n:15
B
MARCH 1972
n:25
C
JANUARY 1973
n:15
D
MARCH 1973
n:13
VOLUME (%)
100
80
60
40
20
1 2 3 4 5 6 7 8 9 10 11

Figure 8

Percent occurrence of the species in the rumen samples

1 Red cedar
2 Salal
3 Deer fern
4 Douglas-fir
5 Twin flower
6 Hemlock
7 Alectoria sp
8 Vaccinium
9 Bunchberry
10 Rubus sp
11 Grasses


A JANUARY 1972 n:15
B MARCH 1972 n:25
C JANUARY 1973 n:15
D MARCH 1973 n:13
OCCURRENCE (%)
100
80
60
40
20
1 2 3 4 5 6 7 8 9 10 11

Although the food habits during early spring were similar to the food habits during the mild winter, deer ate much less deer fern in spring than in winter. Of the species occurring in more than 50% of the winter samples, only twinflower and Rubus sp failed to occur in at least 50% of the samples from early spring.

4.3.3 Summary and discussion

The data indicate that severe winter conditions limit the availability of many plant species to deer. In the severe winter, most of the diet was conifers and shrubs, but in the mild winter, conifers, shrubs, forbs, ferns, and lichens were used. In the severe winter, 5 species occurred in more than 50% of the samples, whereas in the mild winter 9 species occurred in more than 50% of the samples. More species were utilized in winter than in spring, which again suggests that winter conditions restrict food availability to deer.

Some of the conclusions from the food habits data differ from those based upon subjective field observations of deer food habits. The most important difference is in utilization of lichens. Field observations suggest that arboreal lichens (principally Alectoria sarmentosa) are much more heavily utilized than shown in the data. One reason that Alectoria was not more common in the rumen samples is that most deer were collected in logged habitats, where Alectoria does not occur. However, because some deer taken from logged habitats had been eating Alectoria , these deer must have done some feeding in mature timber habitats. The data presented in the next section indicate that in winter, deer used mature timber habitats more heavily than logged habitats. In other areas on Vancouver Island, arboreal lichens made available as litterfall comprised 34% and 14% of the winter diet of deer (Cowan, 1945; Gates, 1968). Future studies will probably show that deer in the Nimpkish Valley eat more lichen than was suggested in this study.

4.4 Winter habitat selection by deer

4.4.1 Habitat selection during the severe winter of 1971-72

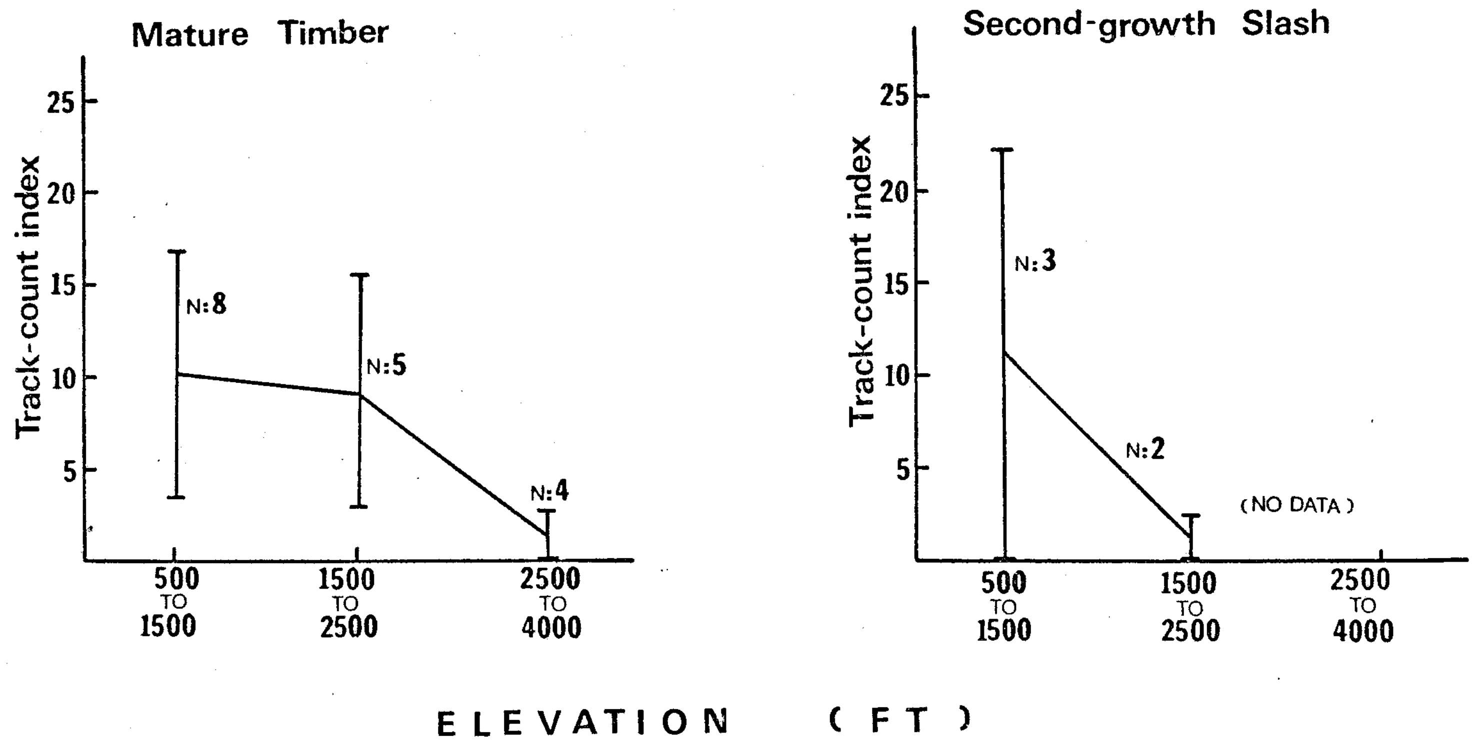
During the severe winter much snow fell from December through early March, and temporary track count plots were used to measure deer-use. The results show that deer-use of mature timber and second-growth habitats was highly variable (Figure 9), and deer-use indices taken from clear slash habitats (on south aspects at low elevations) ranged from 0 to 9.4 (Appendix 4). Deer generally used south aspects more than north aspects, and low elevations more than high elevations, but the differences were not consistent (Figure 9 and Appendix 4).

Much of the variation in deer-use of logged habitats was probably caused by differences in snow conditions. Few deer used logged habitats when the snow was deep and soft, but they used mature timber habitats where snow was less deep. However, many deer used logged habitats when the snow became hard crusted,

Figure 9

Range and median of the deer-use indices
taken during the winter of 1971-72

The data presented in this figure
were taken from south aspects



Mature Timber
Track-count index
25
20
15
10
5
N:8
N:5
N:4
500 TO 1500
1500 TO 2500
2500 TO 4000
Second-growth Slash
Track-count index
25
20
15
10
5
N:3
N:2
(NO DATA)
500 TO 1500
1500 TO 2500
2500 TO 4000
ELEVATION (FT)

especially the second-growth slash where the upper parts of shrubs and conifers were eaten. The deer-use indices from an area of second-growth were 0 and 2.3 when the snow was soft, but when the snow became hard crusted the deer-use index increased to 24.6. The crusted snow conditions occurred for about 10 days out of the three-and-one-half-month winter period.

During most of the severe winter, deer made more use of mature timber habitats than logged habitats, apparently because snow was shallowest in the timber habitats (Figure 3). The most heavily used mature timber habitats were those having a dense crown closure, probably because snow depth is inversely related to crown closure (Figure 4).

Of the 19 permanent plots, 6 were in areas that deer used extensively in the severe winter, and 11 were in areas that were used only slightly (Table 1). Five of the 6 plots used extensively during the first winter had 65% or greater crown closure, and 1 had 60% crown closure. Only 2 of the plots that were used slightly had 65% or greater crown closure, and 1 of these plots was at 2900 ft elevation where snow was too deep for deer. Also, 3 of the 5 temporary plots located during the mild winter (at elevations of 3400 ft or greater) had 65% or greater crown closure, and 2 of these were used extensively by deer. None of the plots having less than 65% crown closure were used extensively. From these data, I conclude that in general, only habitats having 65% or greater crown closure are suitable for winter range habitats when there is much snowfall.

The results indicate that habitat selection is variable, and depends upon more than elevation, aspect, and seral type. Field observations suggested that snow depth, snow hardness, crown closure, and food availability had more influence upon habitat selection than seral type, elevation, or aspect. The experimental design was modified before the second winter of study to determine if habitat selection was closely related to these variables.

4.4.2 Habitat selection during the mild winter of 1972-73

The habitat classification scheme was expanded in the second year of study to include the following habitat types:

1) mature timber having a shrub understory,
2) mature timber having a conifer understory.

The predominant understory species in the conifer understory timber types were western hemlock and *Abies* species, and the predominant understory species in the shrub understory types were salal and *Vaccinium* species. When snow was present, I used the permanent track count plots to measure deer-use, and when snow was absent, I counted deer to measure deer-use.

Because of the unusually light snow conditions little useful information was collected from the permanent track count plots, and several assumptions were made when the data were analyzed:

1) when there were no deer tracks on a plot, I estimated

the track depth from measured track depths taken from similar plots,

2) to take advantage of sporadic snowfall, I saved time by not measuring vegetation if the snow depth was similar to the snow depth at the previous sampling date. It was assumed that the vegetation cover on the plot was identical to the cover at the previous sampling date.

4.4.2.1 selection of logged versus unlogged habitats

In the mild winter, habitat selection by deer was apparently not correlated with elevation, crown closure, the estimate of lichen abundance, snow depth, or percent cover of food plant species (Table 2). The track count indices were also poorly correlated with seral type (Table 2), which suggests that deer made equal use of all seral types. This suggestion is incorrect, however, because many of the permanent plots in timber habitats were located in areas that were used heavily by deer during the severe winter of 1971-72. During the mild winter, deer made light use of these areas, and they made more use of neighbouring mature timber habitats at high elevations. The data taken by counting deer in the daytime show that in winter, deer made more use of mature timber habitats than of logged habitats (Table 3). The mean deer-use index from December through March was 2.1 in all timber habitats, and 1.5 in all logged habitats. During April, deer made more use of the logged habitats than of the mature timber habitats (Table 3).

	All habitats	Timber, above 3100 ft. only
	r =	r =
Elevation	0.17	-0.08
Seral type	0.13 [1/]	-
Crown closure	0.24	0.53
Lichen est.	0.22	0.36
Snow depth	-0.18	-0.51
Track depth	-	-0.10
2/ Percent cover food species	0.06	-0.29
	n = 30	n = 9

Table 2 Correlations of the deer-use indices with other habitat measures taken during the winter of 1972 - 73.

These data were taken from the permanent track count plots.

1/ Spearman rank correlation.

2/ Total cover of <u>Vaccincum</u> species, salal, deer fern, western hemlock, cedar, and Douglas fir.

These data were collected from the permanent track counts plots.

Period	Logged habitats	Mature timber habitats	Compare habitat types
December to March	1.5 ± 2.1 n = 24	2.1 ± 1.8 n = 38	H = 4.07 p = 0.044
April	23.5 ± 53.3 n = 9	1.3 ± 1.8 n = 13	H = 6.18 p = 0.013

Table 3 Deer-use of logged and mature timber habitats during the winter and spring of 1972-73 (mean ± st. dev.).

These indices are calculated from the daytime deer counts as deer seen per 100 minutes of searching time

Each day's count is considered as one index of deer-use, and all statistics are calculated with each daily index used as one sample. The statistics are calculated with the Kruskal-Wallis H test.

Period	Shrub understory	Conifer understory	Compare habitat types
December to March	2.8 ± 1.9 n = 24	1.1 ± 1.0 n = 14	H = 9.19 p = 0.002
April	0.9 ± 0.8 n = 8	2.0 ± 2.8 n = 5	H = 0.35 p = 0.553

Table 4 Deer-use of mature timber habitats having a shrub understory and a conifer understory, during the winter and spring of 1972-73 (mean ± st. dev.).

The deer-use indices and the statistics are calculated as explained in Table 3.

4.4.2.2 selection of mature timber habitats

During the mild winter, deer made more use of timber habitats having a shrub understory than those having a conifer understory (Table 4). The shrub understory habitats were probably preferred because they provided more browse than the habitats having a conifer understory.

The track count indices from mature timber habitats (3400 ft elevation or greater) were poorly correlated with elevation, track depth, and percent cover of food species (Table 2). Deer-use of the high elevation timber habitats was positively correlated with the estimate of lichen litterfall, although the correlation coefficient was low. Use of the high-elevation timber habitats was also positively correlated with crown closure and negatively correlated with snow-depth (Table 2).

Many deer wintered in mature timber habitats at high elevations where snow was present and browse scarce (Figures 10 and 11). I feel that these deer wintered as high in elevation as conditions permitted, and subjective observations suggest that Alectoria litterfall was a heavily used food item on the high elevation winter ranges. Most high elevation areas that were heavily used by deer had shallow snow and high crown closure (Figures 10 and 11).

4.4.2.3 selection of logged habitats

The data taken by counting deer at night show that deer made little use of clear slash habitats in January, and the

Figure 10

Location of the track count plots on Mt. Cain

	Plot number 1	2	3	4
Elevation (ft.)	3800	3600	3000	1500
Crown closure	70%	45%	50%	80%
Deer-use	0	0	0	0
Snow-depth (ft.)	1.2	3.2	1.8	0.5
% cover of Vaccinium sp	1%	<1%	19%	2%

Location 5 was a heavily used winter range during the mild winter of 1972-73. This area was not sampled with plots.

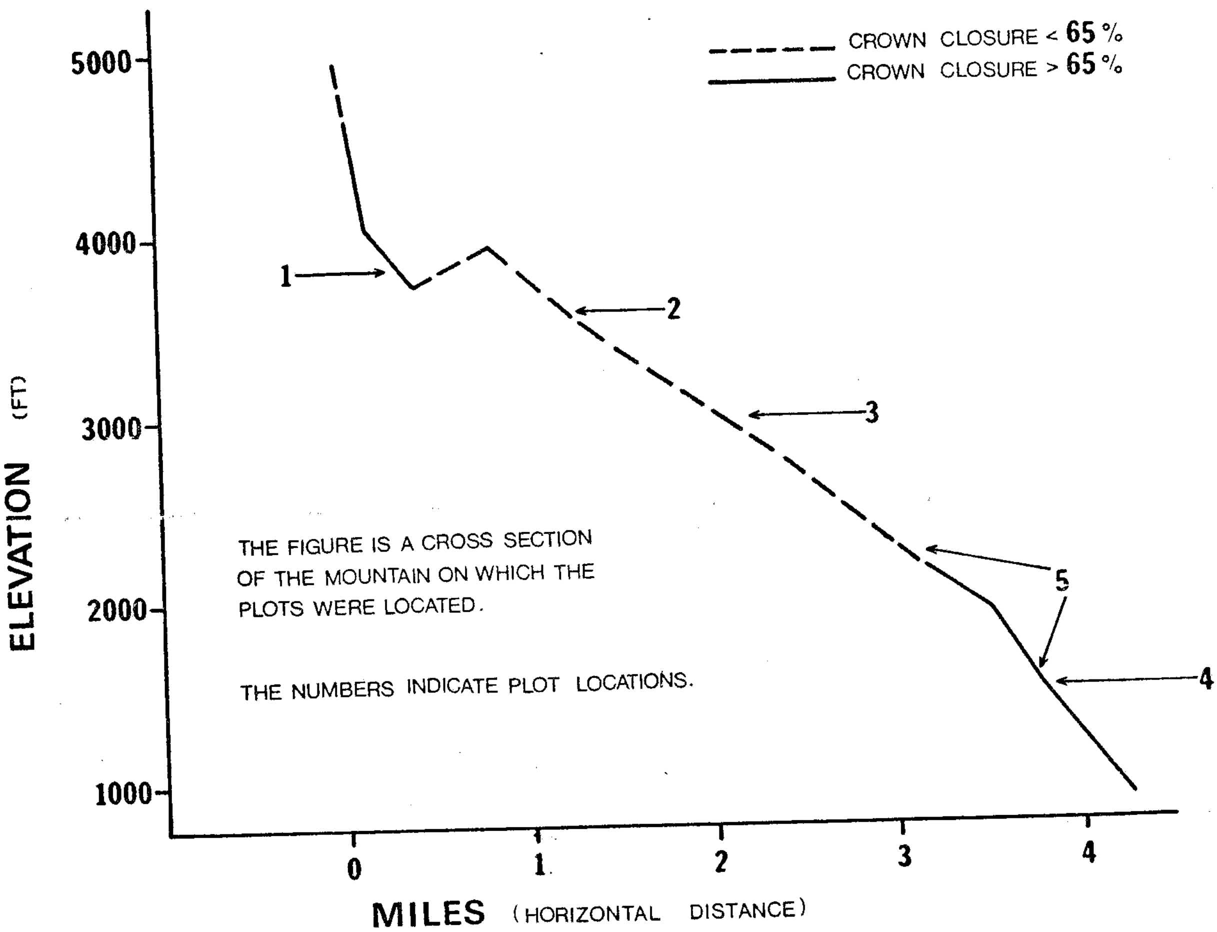
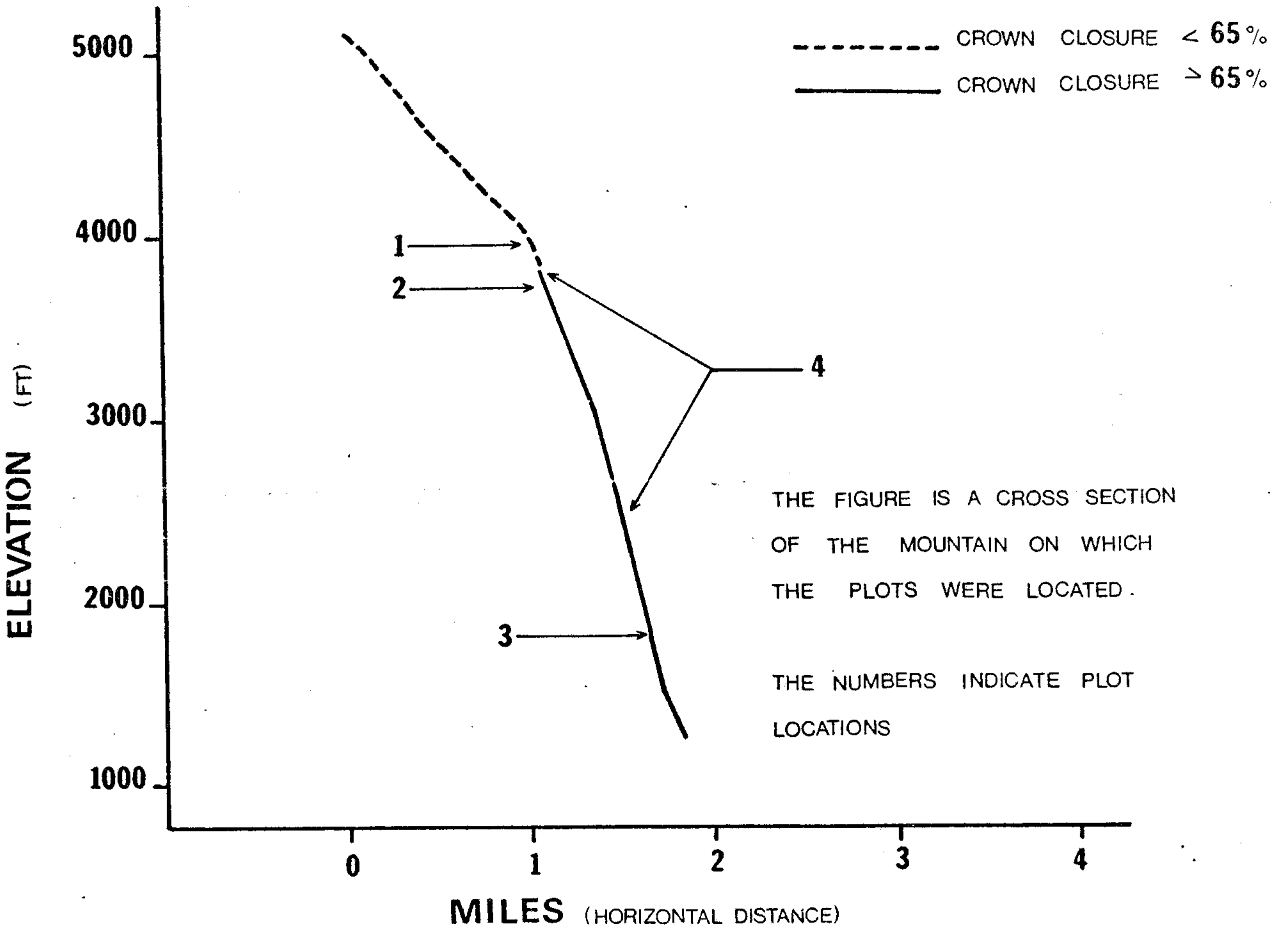

CROWN CLOSURE < 65 %
CROWN CLOSURE > 65 %
5000
4000
3000
2000
1000
ELEVATION (FT)
1
2
3
5
4
THE FIGURE IS A CROSS SECTION OF THE MOUNTAIN ON WHICH THE PLOTS WERE LOCATED.
THE NUMBERS INDICATE PLOT LOCATIONS.
0
1
2
3
4
MILES (HORIZONTAL DISTANCE)

Figure 11

Location of the track count plots on Abel Ridge

	Plot number		
	1	2	3
Elevation (ft.)	3900	3700	1800
Crown closure	35%	65%	75%
Deer-use	0.5	6.6	1.2
Snow-depth (ft.)	3.5	0.8	0.6
Track-depth (ft.)	0.4	0.4	-
% cover of Vaccinium sp	0	1%	<1%

Location 4 was a heavily used winter range during the mild winter of 1972-73. This area was not sampled with plots.


CROWN CLOSURE < 65 %
CROWN CLOSURE > 65 %
5000
4000
3000
2000
1000
ELEVATION (FT)
1
2
3
4
THE FIGURE IS A CROSS SECTION OF THE MOUNTAIN ON WHICH THE PLOTS WERE LOCATED.
THE NUMBERS INDICATE PLOT LOCATIONS
0
1
2
3
4
MILES (HORIZONTAL DISTANCE)

intensity of use increased linearly from January through mid-May (Figure 12). The data points shown are the mean values of the individual counts taken during each sampling period. Because deer did not make equal use of all clear slash areas, only 32% of the variation in individual deer-use indices was explained by the time variable.

In areas where large numbers of deer wintered in the mature timber habitats, use of neighbouring logged areas did not increase linearly from January through April. The rate of increase of deer-use was greater in March and April than in January and February (Figure 13). In early spring, heavily used deer trails led downhill from the high elevation winter ranges to the logged spring ranges. Deer-use of clear slashes did not continue to increase after mid-May of 1973 (Rochelle, pers. comm.).

4.4.2.4 effect of snow on deer-use of a logged habitat

In mid-March of 1973 there was a brief period when about 10 inches of snow fell at 1000 ft elevation. When the roads were passable near the end of the snow period, I counted deer at night. The results indicate that the snow caused deer to make less use of the clear slash habitats (Figure 14). In some areas most of the deer that were seen were on the border of the timber and the logged habitats.

4.4.3 Characteristics of winter range habitats

The data are not sufficient to describe winter range

Figure 12

Deer-use of clear slash habitats during the winter and spring of 1972-73

The deer use index is calculated as the number of deer seen at night per mile of road. The data points shown are the mean values of all counts done within each sampling period but the statistics are calculated with the individual deer-use indices (n=107)

The independent variable was 'day', with January 1 equal to '1' and May 17 equal to '137'

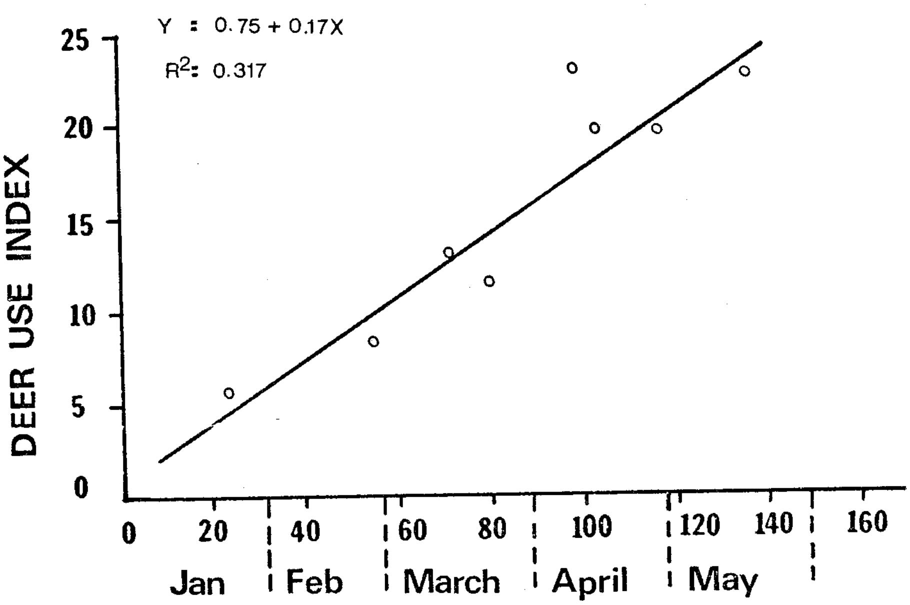

Y = 0.75 + 0.17X
R2: 0.317
DEER USE INDEX
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160
Jan
Feb
March
April
May

Figure 13

Deer-use of two clear slash areas during the winter and spring of 1972-73

Each data point represents the number of deer counted each night the transect was sampled

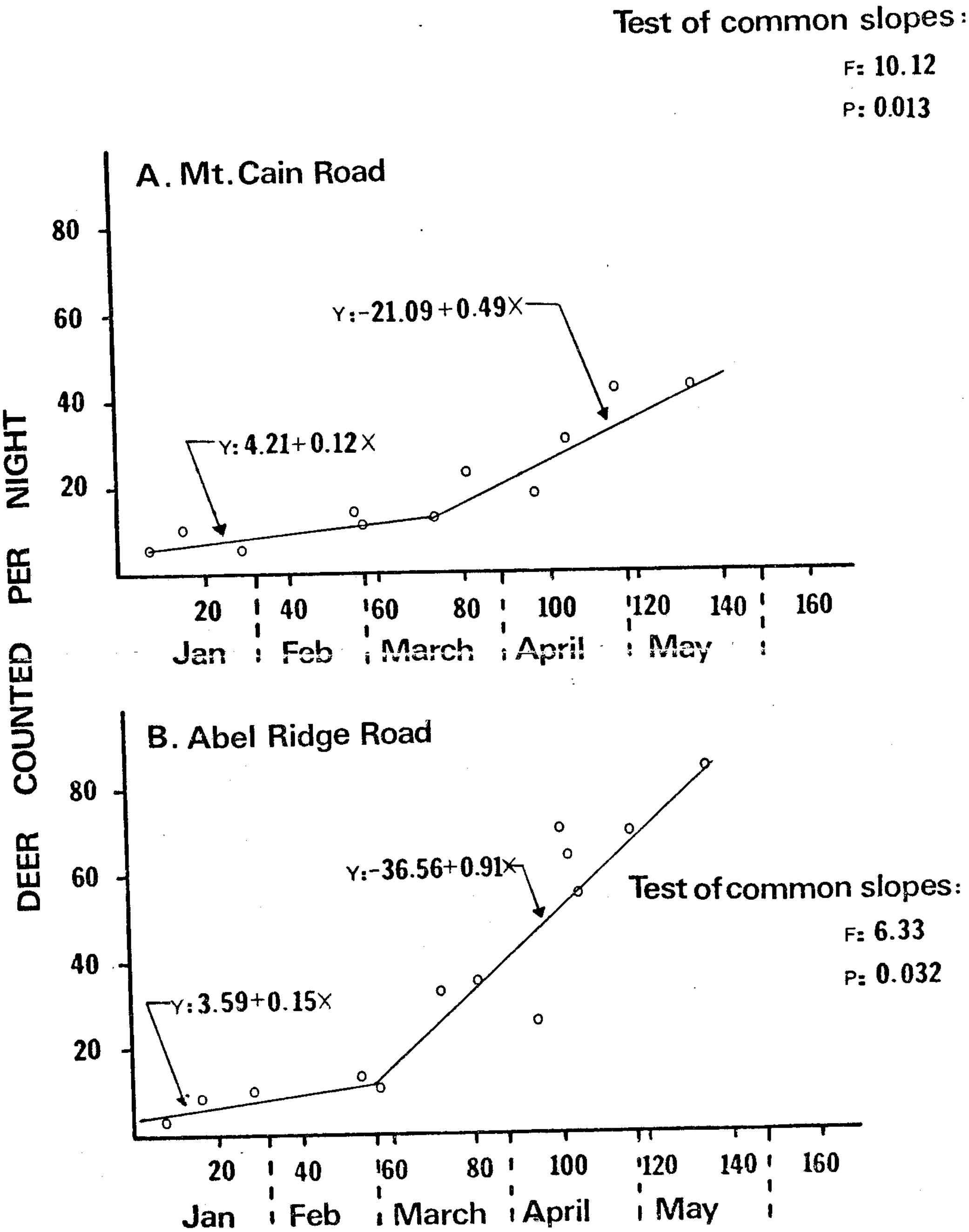

Test of common slopes:
F: 10.12
P: 0.013
A. Mt. Cain Road
Y: -21.09+0.49X
Y: 4.21+0.12X
80
60
40
20
20
40
60
80
100
120
140
160
Jan
Feb
March
April
May
DEER COUNTED PER NIGHT
B. Abel Ridge Road
Y: -36.56+0.91X
Y: 3.59+0.15X
Test of common slopes:
F: 6.33
P: 0.032
80
60
40
20
20
40
60
80
100
120
140
160
Jan
Feb
March
April
May

Figure 14

Effect of snow on deer-use of a clear slash area during the winter of 1972-73

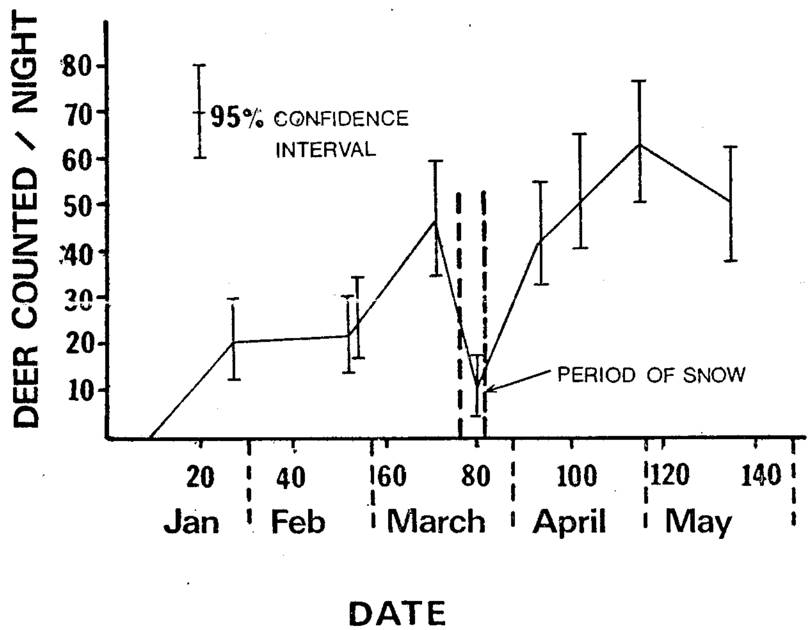
Each data point represents the number of deer counted each time the transect was sampled

The intervals shown are 95% confidence intervals of the proportion P, where

$P = Ni / Nt$

Ni = deer counted at each sampling

Nt = total deer counted over all samplings


DEER COUNTED / NIGHT
80
70
60
50
40
30
20
10
95% CONFIDENCE INTERVAL
PERIOD OF SNOW
20
40
60
80
100
120
140
Jan
Feb
March
April
May
DATE

4.4.3 Characteristics of winter range habitats

The data are not sufficient to describe winter range habitats quantitatively. However, subjective evaluations allow me to describe the characteristics typical of deer winter range in the Nimpkish study area. I realize that more detailed work is necessary to quantify the relationships expressed, and have presented these descriptions so that wildlife and forest managers can identify winter range habitats. Two types of winter range habitats are described:

1) habitats used during the severe winter, when snow was deep and soft,
2) habitats used during the mild winter, when snow was seldom present below 2500 ft elevation.

4.4.3.1 habitats used during the severe winter

During the severe winter, most deer used mature timber habitats at low elevations, and having shallow snow. Some characteristics of the winter ranges were:

1) Crown closure: The habitats used heavily by deer during the winter of 1971-72 had 65% (62.5%) or greater crown closure (Table 1). White-tailed deer normally require winter habitats having a crown closure of 70%, although in some habitat types 45% is sufficient (Gill, 1957). The most important effect of crown closure is the reduction of snow accumulation on the ground. In the Nimpkish, snow in the mature timber habitats was about one-half as deep as snow in the logged habitats. Some heavily used winter ranges in mature timber on the valley bottom had low

crown closure (40 to 50% est.). Such areas were small patches of timber surrounded by logged habitats. Subjective observations suggested that mortality was very high in such areas, and therefore such patches of timber are probably not good winter range.

2) Food: The most important food items in the mature timber habitats were red cedar, Douglas fir, salal, Vaccinium species, arboreal lichens, and western hemlock (Figures 7 and 8). Lichens, red cedar, and Douglas fir were made available as litterfall.

3) Seral type: All heavily used winter ranges were mature timber habitats. However, not all mature timber habitats were winter range. The most important characteristic of the winter range habitats was a high crown closure. Logged habitats were used when the snow was hard crusted.

4) Timber type: Most heavily used winter ranges had Douglas fir and western hemlock in the overstory. Timber habitats having cedar species or Abies species abundant in the overstory were normally not used. The importance of timber type was its effect on crown closure. Douglas fir and hemlock types usually had higher crown closure than did types having abundant Abies species or cedar species.

5) Rock bluffs: Some heavily used winter ranges had exposed rock bluffs under the forest canopy. Such bluffs were often free of snow, and often had food available. However, some heavily used winter ranges did not have

exposed rock bluffs. The crown closure was very low in some areas having exposed rock bluffs and therefore snow was deeper. Deer use was low in such areas. In general, areas having small bluffs were more heavily used than areas having large bluffs.

6) Slope: Many winter ranges were on slopes steeper than 50%, and snow was often shallower on steep slopes than on valley bottom or ridgetop areas. The relationship of snow depth with slope was not consistent in all areas visited.

7) Elevation: Most winter ranges were below 2500 feet elevation. However, elevation itself was not an important factor. The most important factor affecting habitat selection was snow depth, and elevation was only one of several variables affecting snow depth.

8) Aspect: Many winter ranges were on south aspects. North slope areas having a high crown closure and relatively high food abundance were used by deer. South slope areas having low crown closure were not used by deer. In an earlier study, 16% of white-tailed deer winter ranges were found on north, east, or northwest aspects, and it was uncertain whether aspect or vegetation type was the important factor influencing habitat selection (Webb, 1948).

4.4.3.2 habitats used during the mild winter

Deer were observed in all habitat types during the mild winter. However, deer did not make equal use of all habitat types. Some characteristics of the habitats that were heavily used are:

1) Crown closure: Most heavily used timber habitats had 65% or lower (estimate) crown closure. However, some high elevation winter ranges had crown closure greater than 65%. High crown closure was important at high elevations because of greater snowfall. In general, areas having low crown closure had greater food abundance. Because of low snowfall, a dense crown closure was not necessary at most elevations.
2) Food: The most important food items during the mild winter were red cedar, salal, _Vaccinium_ species, arboreal lichens, deer fern, bunchberry, and twinflower.
3) Seral type: Many deer wintered in timber habitats having high abundance of salal, _Vaccinium_ sp, and _Alectoria_ sp. Some deer wintered in second-growth slash habitats having high abundance of red cedar, _Vaccinium_ sp, and salal. In most areas, deer used logged habitats heavily only in the spring.
4) Timber type: Most timber habitats that deer used extensively had much Douglas fir and western hemlock, or mountain hemlock, in the overstory. In some areas, habitats having predominantly _Abies_ species and cedar species in the overstory were heavily used. The composition of the overstory probably had less effect on habitat selection than the composition of the understory.

5) Rock bluffs: Mature timber areas having exposed rock bluffs were often used heavily by deer. Such areas often had high abundance of salal, Vaccinium species and arboreal lichens. When soft snow was deeper than one foot on the areas having bluffs, deer moved to habitats having a dense crown closure where snow was less deep.

6) Slope: Many timber winter ranges were in areas having steep (greater than 50% est.) slopes. Such areas generally had more exposed rock bluffs than less steep areas. However, in many areas, deer made extensive use of flat-topped ridges. The relationship of deer-use with slope was inconsistent between different areas.

7) Elevation: Many winter ranges were at elevations greater than 2500 feet. High elevation winter ranges were usually on south slopes and had high crown closures, and food was scarcer in comparison with many low elevation habitats. Some deer moved to lower elevations when fresh snow was more than one foot deep and some remained high until the snow melted.

8) Aspect: Deer did not appear to consistently choose any single aspect, and food abundance, snow, and topography apparently had the greatest effect upon habitat selection.

4.5 Movements of deer

The radio-location data are insufficiently detailed to show accurately the home range size of the deer. However, I have specified the maximum amount of area that the deer used during the winter period. In both cases, the maximum area was approximately one-quarter square mile (160 acres).

One yearling female deer was tracked through the winter of 1972-73. During winter, this deer used a mature timber area of less than 160 acres, on a south-facing slope at about 2000 ft elevation. On February 13 the deer was in a second-growth slash area at 1100 ft, and from February 15 to February 20 it was back in the timbered winter range. In early March it moved to an adjacent clear slash area of less than 160 acres. The deer was found in that area until May 25 when the radio signal was lost.

A second yearling female deer, tagged in April of 1973, was tracked on its winter range from November 4 until February 8, 1974. During this period it used a 1200 ft elevation patch of timber of less than 160 acres as its winter range.

The limited data collected suggest that deer on their winter ranges move very little. Both of the tagged deer used less than 160 acres as their winter range.

Of the seven deer tracked later than May 1 of 1973, three moved from low elevation logged habitats to high elevation mature timber habitats. These movements occurred in June, July, and September. In May, one deer moved from a low elevation logged area into a low elevation area of mature timber. All of these movements were longer than 1 mile. These results suggest that about one-half (4/7) of the deer that use logged areas in spring move to unlogged areas in spring and summer. These observations agree with those of Cowan (1956), who reported that

	Fawn (inches)	Yearling (inches)	Adult (inches)	Test equality of ages (lumped sexes)
Male	17.8 ± 1.0 (14)	20.9 ± 1.0 (5)	23.4 ± 1.2 (8)	H = 43.045 $p < 0.001$
Female	17.5 ± 1.0 (9)	20.7 ± 1.0 (5)	20.9 ± 1.2 (25)	
test equality of sexes	H = 0.122 p = 0.73	H = 0.40 p = 0.53	H = 15.004 $p < 0.001$	

Table 5 Chest heights of deer (mean ± st. dev.).

The sample size is in brackets.

migrations from the spring ranges start in April or May.

4.6 Chest heights of deer

Old deer had greater chest heights than young deer, and male adult deer had greater chest heights than female adult deer (Table 5). There was no sex difference in chest heights of fawn and yearling deer.

The data suggest that deer will have a difficult time moving if they sink deeper than 17 to 23 inches in snow. Adult deer will be able to move freely in deeper snow than will fawns, and male adults will be able to move in deeper snow than will females.

4.7 Summary and discussion

Snow is an important factor limiting the winter distribution of black-tailed deer (Edwards, 1956), mule deer (*Odocioleus hemionus hemionus*) (Walmo and Gill, 1971), and white-tailed deer (Verme and Czaga, 1971). Where snowfall is heavy, all 3 deer species winter in habitats having the least snow.

The ability of an animal to survive in deep snow will depend on its ability to move freely, and the ability to move freely depends largely upon how deeply the animal sinks in the snow. The four most important factors governing how deeply an animal sinks in snow are chest height, snow depth, weight-loading on the hooves, and snow hardness. For example, moose

(*Alces alces*) have greater chest height than white-tailed deer, and are able to winter in deeper snow than are the deer (Kelsall, 1969).

It is obvious that if the sinking depth in snow exceeds chest height for a long period, deer will have difficulty moving in search of food. In the Nimpkish Valley, chest heights of deer averaged 17 to 23 inches, depending on sex and age (Table 5). In the severe winter of 1971-72, snow in the logged habitats at 1000 ft was about 4 ft deep for several months. This snow depth was much greater than the chest height of deer. Snow in the mature timber habitats was about one-half as deep as snow in the logged habitats (Figure 3). Snow was least deep in mature timber habitats having a high crown closure, but even in such habitats snow was often more than one foot deep. Snow in the timber was deep enough to cause hardship for deer, but snow in the logged habitats was deep enough to make deer-use impossible.

When the deep snow in the logged habitats formed a hard crust, deer made heavy use of these areas. The tops of shrubs and conifers projected above the snow and were utilized during the period when the snow was hard crusted. In the severe winter, the most important factor influencing use of logged habitats was not simple snow depth, but the combined effect of snow depth and snow hardness on deer sinking depth.

In the mild winter, many deer used mature timber habitats. Use of second-growth habitats was less intense than use of the timber winter ranges, and this observation contradicts those of Gates (1968). Gates found that because food was most abundant in

12 to 15 year-old logged habitats in mid-central Vancouver Island, deer preferred to winter in these logged habitats. The different habitat selection patterns in the different areas are probably related to the different environmental conditions. Gates's study area has a generally milder winter climate and less snowfall than my study area. The area studied by Gates is fairly level and has no steep mountains, whereas the Nimpkish area is flat only on the valley bottoms, and most of the area is mountainous. In the Nimpkish area, the timbered habitats that were used heavily by deer in the mild winter were usually on steep mountains.

It is uncertain whether deer chose winter ranges having the greatest food abundance. Many deer wintered in high elevation timber habitats where browse was not abundant. The high elevation habitats had less browse than the second-growth habitats, but the second-growth was not used heavily during winter. However, more deer used timber habitats having a shrub understory than used timber habitats having a conifer understory, probably because the shrub understory had more available food than the conifer understory. I feel that deer didn't always use habitats having the greatest food abundance, but they used those habitats having adequate food abundance. In Oregon, black-tailed deer often winter in habitats where total browse abundance is not the greatest available to the deer, and where the most palatable species are not abundant (Hines, 1973).

The areas that were used heavily by deer during the severe winter were lightly used during the mild winter. Subjective observations suggest that the habitats that were heavily used during the mild winter were the same as those used in autumn. The data on deer movements suggest that in summer, many deer move from the spring ranges at low elevations to high elevation areas. I feel that the deer that make this movement are the same deer that use high elevation areas in mild winters. These deer will move to low elevation areas only if forced down by deep snow. Black-tailed deer (Dasmann and Taber, 1956), mule deer (Dixon, 1934; Russell, 1932) and white-tailed deer (Cook and Hamilton, 1942; Severinghaus and Cheatum, 1956) often use high elevation areas or summer range areas during mild winters.

In the mild winter there were 2 major habitat types that were heavily used by deer:

1) mature timber habitats having exposed rock bluffs, high abundance of salal and *Vaccinium* species, and high abundance of *Alectoria* ,
2) mature timber habitats above 2500 feet elevation, having high crown closure, high abundance of *Alectoria* , and low abundance of *Vaccinium* species.

The pattern of deer-use of the logged habitats varied considerably between the two winters. In the severe winter, use of the logged habitats was low except when snow was hard-crusted. When the snow melted in April, many deer used the logged habitats. In the mild winter, use of the logged habitats was low in January and increased linearly through April. A brief period of snow in March temporarily caused many deer to stop using the logged habitats. Subjective observations suggest that deer made extensive use of the logged habitats before the new year's growth of forbs had begun. Subjective observations of deer behaviour suggest that deer made heavy use of the logged habitats in April because these areas were the warmest.

4.8 Condition of deer

In order to understand deer winter ecology, something should be known about the relationships between winter weather and the nutritional condition of deer.

The kidney fat method was used to estimate deer condition in late January of 1972 and 1973, late March - early April of 1972 and 1973, and November of 1972. The results are shown in Table 6. The Kruskall-Wallis H test was used to test for differences between the means of the different samples of deer condition. In all analyses discussed in section 4.8, fawns are deer less than 1 year old, and adults are deer more than 1 year old. More age classes would have been used had the sample sizes been larger. Probability values are given only when the results are significant at the 5% level. I feel that the differences discussed in the text are real, even though not all of the differences are statistically significant. It is probable that more of the differences would have been significant if larger samples had been obtained. I was not able to obtain complete data describing the condition of all age and sex classes of deer.

4.8.1 Deer condition over the winters of 1971-72 and 1972-73

Within all age and sex classes of deer for which comparable data are available (male fawns, female fawns, female adults ($p = 0.01$)), deer condition worsened during the severe winter of 1971-72. All age and sex classes from which samples were taken (male fawns, male adults ($p = 0.02$), female adults ($p = 0.03$) also lost condition during the mild winter. All age and sex classes for which samples are available were in worse condition during the severe winter than during the mild winter (Table 6).

The linear regressions of deer whole weight against deer eviserated weight are presented in Figure 15. The regression lines calculated for each winter of the study have significantly different slopes ($p = 0.024$, which means that the average whole body weight for a given eviserated weight was greater in the severe winter than in the mild winter . Therefore, a greater proportion of whole body weight was muscle and fat in the mild winter than in the severe winter. This result suggests that deer were in better condition in the mild winter than in the severe winter. The difference in condition was greater for large deer (adults) than for small deer (fawns).

4.8.2 Relationships between deer condition and the sex and age of deer

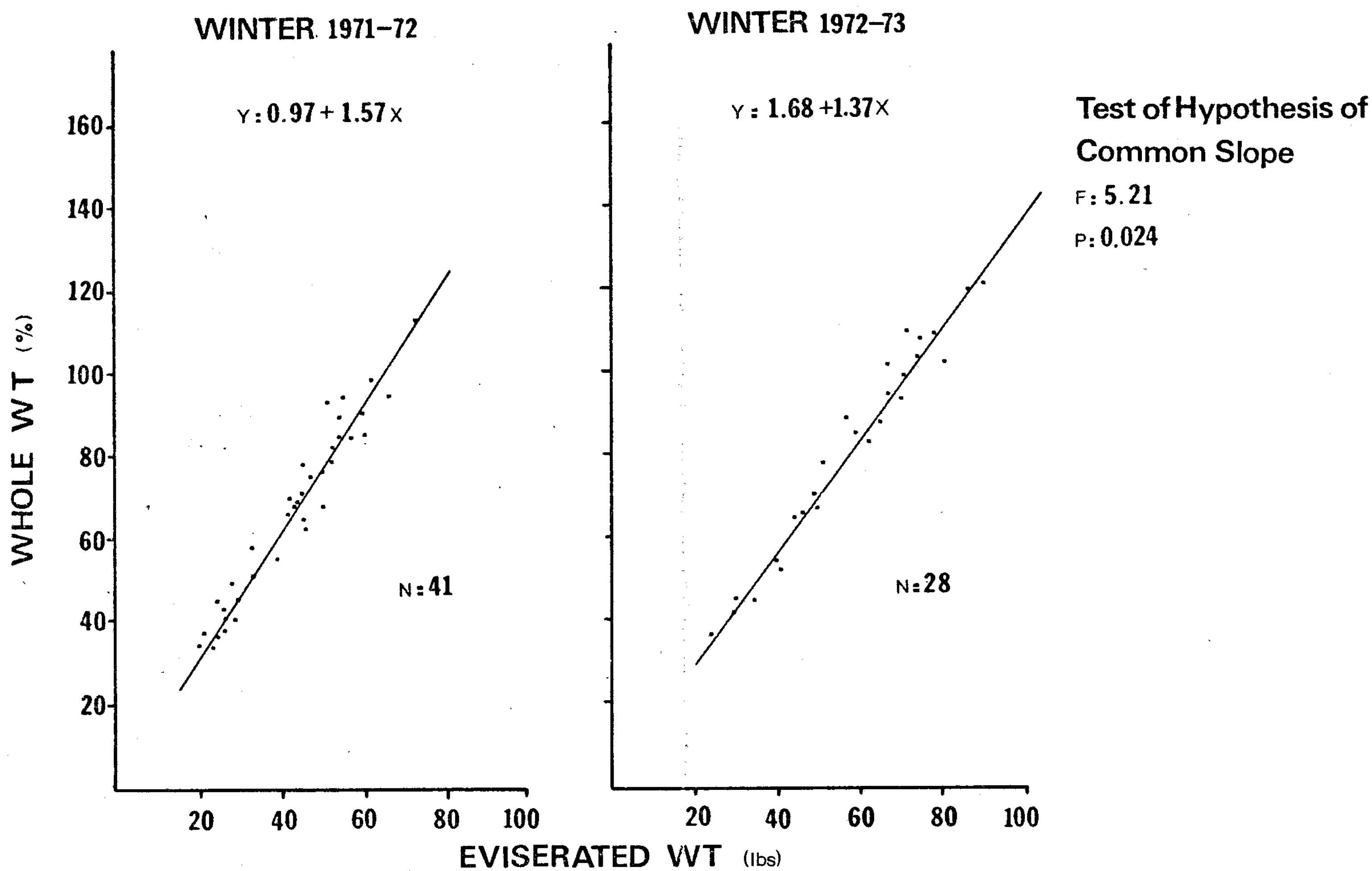
In all sample periods for which comparable data are available, female fawns were in better condition than male fawns (January of 1972, March of 1972, January of 1973); and female adults were in better condition than male adults (March of 1972,

Period	Male fawn	Female fawn	Male adult	Female adult
January 1972	6.9 ± 9.5 n = 5	11.5 ± 2.7 n = 3	-	43.1 ± 24.0 n = 7
March 1972	1.2 ± 3.3 n = 4	3.8 ± 6.0 n = 5	2.8 ± 5.0 n = 6	8.7 ± 9.0 n = 11
November 1972	61.6 ± 49.2 n = 3	-	113.2 ± 79.0 n = 3	113.9 ± 25.3 n = 2
January 1973	9.2 ± 3.7 n = 3	18.4 ± 9.0 n = 2	45.6 ± 27.1 n = 3	100.5 ± 55.8 n = 7
March 1973	8.2 ± 1.0 n = 2	-	11.0 ± 6.4 n = 6	41.2 ± 30.5 n = 6

Table 6 Deer condition indices (mean ± st. dev.).

Figure 15

Regression of whole weight against eviserated weight



WINTER 1971–72
WINTER 1972–73
Y: 0.97 + 1.57 X
Y: 1.68 + 1.37 X
Test of Hypothesis of
Common Slope
F: 5.21
P: 0.024
160
140
120
100
80
60
40
20
WHOLE WT (%)
N: 41
N: 28
20
40
60
80
100
20
40
60
80
100
EVISERATED WT (lbs)

January of 1973, March of 1973 ($p = 0.01$); (Table 6)).

In all sample periods, female fawns were in worse condtion than female adults (January of 1972 ($p = 0.02$), March of 1972, January of 1973 ($p = 0.04$)); and male fawns were in worse condition than male adults (March of 1972, November of 1972, January of 1973 ($p = 0.05$), March of 1973; (Table 6)).

4.8.3 Summary and discussion

Deer condition deteriorated markedly during the severe winter of 1971-72, probably because of the severe weather. Deer condition also deteriorated during the mild winter, but less than it did during the severe winter. Various authors have noted that even when food is abundant in a mild winter, deer voluntarily reduce their food intake and therefore lose up to 25% of their body weight (Bandy, 1965; Czoga and Verme, 1970).

In all sample periods, fawns were in worse condition than adults. Even in November of 1972, fawns had less body fat than adults. These results agree with all published studies of black-tailed, mule or white-tailed deer (Anderson, Medin, and Bowden, 1972; Bartlett, 1950; Bartlett, 1955; Brown, 1961; Einarsen, 1956; Erickson, Gunualson, Stenlund, Burcalow and Blankenship, 1961; Lassen, Ferrel and Leach, 1952; Robinette, Gashwiler, Low and Jones, 1957). Fawns are less able to withstand severe winter weather than are yearlings or adults. The relative mortality rates of fawns and adults vary with the severity of winter. In general, the proportion of adults in the mortality increases with increasing severity of winter (Bartlett, 1955) and with decreasing range condition (Klein and Olson, 1960).

The data suggest that male deer were always in worse condition than female deer. In most areas, male black-tailed deer (Taber and Dasmann, 1954), mule deer (Robinette, Gashwiler, Low and Jones, 1957), and white-tailed deer (Bartlett, 1955) die at higher rates than females. However, some authors have found that female fawns sometimes die at higher rates than male fawns. Robinette, Gashwiler, Low, and Jones (1957) found that although adult male mule deer had the highest mortality rates, female fawns died at higher rates than male fawns. The results of a previous study on Vancouver Island suggested that female fawns have higher mortality rates than male fawns (Smith, 1968).

The results of this study, and some previous studies, indicate that when winter weather is severe, deer condition decreases rapidly and many deer die. The amount of condition that the deer lose, and the number of deer that die, are directly related to the severity of the winter (Severinghaus, 1947). In Ontario, 46% of a herd of white-tailed deer died during a severe winter, but only 6% died during a mild winter (Cumming and Walden, 1970). Fawns usually die at higher rates that adults, and males usually die at higher rates than females.

5. DISCUSSION

The following discussion synthesizes the results of this study with those of earlier workers, and is divided into 3 sections:

1) Effects of winter weather on deer
2) Ecological mechanisms mitigating the effects of winter weather on deer
3) Management recommendations

5.1 Effects of winter weather on deer

Various authors have reported that the severity of winter weather, or the amount and quality of winter range, are important factors affecting population sizes of black-tailed, mule and white-tailed deer (Brown, 1961; DeNio, 1938; Edwards, 1956; Wallmo and Gill, 1971). The effect of severe weather is to cause malnutrition and mortality.

5.1.1 Relationships between deer condition, mortality rates, and winter weather

In deep snow, deer have a hard time finding food (Coblentz, 1970; Moen, 1973) and moving about (Verme and Czoga, 1971; Wallmo and Gill, 1971). The food plants available in winter are less nutritious than the herbaceous plants available in spring and summer (Gates, 1968). Movement through deep snow is difficult and requires much energy (Verme and Czoga, 1971), and cold winds or low temperatures cause additional energy losses (Moen, 1968a, 1968b).

Many authors have reported that deep snow in winter causes poor condition and heavy mortality of black-tailed, mule, and white-tailed deer. In western Washington, snow depths of 2 feet caused 25% to 30% of a black-tailed deer herd to die. Most of the carcasses were found in clear slash habitats (Brown, 1961). In California, a severe winter resulted in death of 35% of a mule deer herd and loss of 82% of fawns (Lassen, Ferrel, and Leach, 1952). In another area of California, 4-foot snow depths resulted in death of one-third of a mule deer herd and loss of almost all of the fawns (Leopold, Riney, McCain, and Tevis, 1951). In Utah, snow depths of 2.5 to 3 feet resulted in the death of 42%, 26%, and 9% of 3 mule deer herds, and the losses were inversely related to the amount of available browse (Robinette, Julander, Gashwiler, and Smith, 1952). A severe winter caused the death of 63% of fawns, 19% of adults, and 35% of a white-tailed deer herd (Bartlett, 1950). In other areas, severe winters caused mortality rates of 10 to 25% and 60% of 2 white-tailed deer herds (Erickson, Gunualson, Stenlund, Burcalow, and Blankenship, 1961; Bartlett, 1955). It is clear that severe winters can cause extensive mortality of deer.

Fawns and very old deer usually have higher mortality rates than prime age deer. Fawns probably die at high rates because they have less body fat in proportion to their weight than adults (Table 6). Fawns have less fat than adults because they have a fast rate of growth during their first summer of life (Bandy, 1965). Fawns also have more difficulty than adults in deep snow because they have lower chest heights than adults (Table 5). Males often die at higher rates than females, possibly because they lose more condition in late autumn. However, males have greater chest heights than females, indicating that they have less difficulty moving in deep snow (Table 5).

5.1.2 Relationships between winter weather and deer reproduction

I was not able to assess the effects of winter weather on deer reproduction. However, previous authors have found that severe winters affect reproduction of mule and white-tailed deer.

Verme (1969) found that if white-tailed females are in poor condition during winter, they give birth to weak or stillborn fawns. Mule deer fawns born after a severe winter weighed 12% less than those born after a mild winter (Robinette, Gashwiler, Low, and Jones, 1957). There are fewer fawns per female following a severe winter than following a mild winter (Robinette, Gashwiler, Low, and Jones, 1957; Verme, 1967). In California, the rates of reproduction were negatively correlated with the degree of utilization of winter food (Dasmann and Blaisdell, 1954). Apparently, severe winter weather causes greater prenatal and early mortality rates of males than females (Robinette, Gashwiler, Low, and Jones, 1957). Klein (1970) summarized the reasons why early mortality of newborn fawns increases after a severe winter:

1) the fawns are in poor condition,
2) the fawns are too small to reach the teats,
3) the female delays lactation,
4) the female will not allow the fawn to suckle.

The effects of severe winter weather on future reproduction depend partly upon the rate of early fawn mortality (Verme, 1969). If a female successfully raises fawns after a severe winter she must lactate all summer, but if her fawns die she will not lactate all summer. Those females that lactate during the summer may not be able to regain condition, and will have lower pregnancy rates the following autumn. However, those females that do not lactate quickly gain condition, and will probably have high productivity the following autumn. Poor condition of the summer range may also lower productivity the following autumn (Verme, 1969).

5.2 Ecological mechanisms mitigating the effects of winter weather on deer

The preceeding discussion showed that severe winter weather reduces deer survival and reproduction. The information discussed in the results indicated that deep snow is a major factor affecting deer. Severe cold also affects white-tailed (Moen, 1968a and 1968b) and presumably black-tailed and mule deer.

One adaptation to winter weather is a reduction of metabolic rate (Silver, Colovos, Holter, and Hayes, 1969). Deer probably require less food in winter than at other times of the year, and black-tailed and white-tailed deer voluntarily reduce their food intake in winter (Bandy, 1965; Ozoga and Verme, 1970). The reduction in food intake is coincidental with the onset of mating acitivity (Bandy, 1965). The net effect of reduced food intake and reduced metabolic rate is weight loss and reduction of body fat reserves. Severe winter weather increases the loss of weight and fat, as demonstrated in this study.

In areas where winter is severe, deer alter habitat selection and activity patterns to reduce the effects of severe weather. In cold weather, white-tailed deer feed less (Ozoga and Verme, 1970), but increase movements to sheltered habitats (Ozoga and Gysel, 1972). Deer confined to cold habitats seek out the warmest micro-climates (Robinson, 1960). Deer in poor condition feed more than deer in good condition (Ozoga and Verme, 1970).

Many authors have demonstrated that deep snow makes movement difficult for deer, although snow hardness is also important. Snow depths of 18 inches (Gilbert, Wallmo, and Gill, 1970), 20 inches (Cumming and Walden, 1970; Telfer, 1970a; Severinghaus, 1947), 15 inches (Kelsall, 1969), 20 to 24 inches (Loveless, 1967), and 24 inches (Miller, 1968) caused black-tailed, mule, and white-tailed deer to concentrate. Snow depths of 24 to 36 inches (Russell, 1932), 4 to 6 feet (Spiker, 1933), and 4 feet (Leopold, Riney, McCain, and Tevis, 1951) were disastrous for mule and white-tailed deer.

In all studies where snow depths greater than 20 inches were reported, deer moved to areas where snow was less deep. In some areas, mule and black-tailed deer move to lower elevations where snow is very shallow or non-existent (Wallmo and Gill, 1971; Dasmann and Taber, 1956). In regions where snow is deep at all elevations, deer move to mature coniferous timber habitats where the dense canopy reduces snow depth on the ground

(Cumming and Walden, 1970; Edwards, 1956; Kelsall and Prescott, 1971; Ozoga, 1968; Telfer, 1970a and 1970b; Verme, 1965). In Alaska, deer often winter on beaches at sea-level, where snow is least deep (Klein and Olson, 1960). In Yellowstone Park, mule deer have been known to winter near hot springs at high elevations. Even though snowfall is heavy the heat from the hot springs keeps the ground bare (Russell, 1932).

White-tailed deer in many areas have a behavioural pattern known as "yarding" (Spiker, 1933; Webb, 1948). A "yard" is typically an area where heavy cover is interspersed with open areas. The heavy cover provides shelter while the open areas provide food. Although snow is deep in the open areas, the deer maintain a network of packed trails through the snow. Movement is difficult except on the packed trails (Verme and Ozoga, 1971). A white-tailed deer winter concentration area is only a true "yard" if it is a clearly defined area having a network of packed trails (Webb, 1948). Cover is the most important factor of a deer yard. Deer will not use an open area if coniferous timber cover is absent, but they will use an area where timber cover is present but food scarce (Hamerstrom and Blake, 1939; Hosley, 1956; Webb, 1948). Gill (1957) suggested that winter shelter and food should be a maximum of 100 yards apart.

The studies reviewed suggest that white-tailed deer and black-tailed deer in northern areas are subjected to severe winter snow conditions. Food and cover are separated in many areas used by white-tailed deer during winter, but the mature timber habitats used by black-tailed deer in the Nimpkish Valley provide both food and shelter. My observations suggest that salal, *Vaccinium* species, and litterfall (red cedar, Douglas fir and arboreal lichens) are the most important foods in the mature timber. Litterfall and windfall material is sometimes a significant source of winter food for black-tailed, mule and white-tailed deer (Cowan, 1945 and 1956; Dixon, 1934; Gates, 1968; Ozoga and Gysel, 1972; Spiker, 1933). In South Dakota, the amount of litterfall lichen (*Usnea* species) eaten by mule and white-tailed deer increases with increasing snow depth (Schneewis, Seversen, Petersen, Schenck, Linden, and Richardson, 1972).

In all areas where winter is severe and black-tailed, mule, or white-tailed deer cannot move to areas where snowfall is light, mature coniferous timber is necessary for winter shelter. However, deer in different areas choose different seral types for use during mild winters. Gates (1968) reported that on Vancouver Island, deer used 12 to 15-year old seral types in mild winters. In other areas, early seral types are the best winter ranges during mild winters (Brown, 1961; Taber, 1961). However, recently burned areas are poor winter range because the shrub communities are destroyed and there are few plants alive during winter (Interstate Deer Herd Committee, 1954). Use of very early seral types is low in winter and increases in spring (Spiker, 1933). In the Nimpkish Valley, many deer used high elevation mature timber habitats in the mild winter, and use of logged habitats was low in January and increased through April (Figure 12). It appeared as if most deer remained as high in elevation as snow conditions permitted. In other areas, deer use summer or autumn ranges during mild winters (Cumming and Walden, 1970; Dasmann and Taber, 1956) and deer in the Nimpkish Valley behave similarly.

Deer-use of winter concentration areas is heavy only during severe snow or temperature conditions. This behaviour pattern results in the food plants on the critical winter ranges being heavily utilized only when necessary.

5.3 Management recommendations

This study was intended to provide information useful in the management of deer in the mountainous, high snow regions of Vancouver Island. The following recommendations should not be generalized to regions having climate or topography different from those of the Nimpkish Valley study area.

The results and discussion show that deer depend upon mature timber during severe winters. Logging removes mature timber and therefore reduces winter range and deer populations. In the Nimpkish Valley, continuation of previous logging methods will create extensive areas of early seral types with no mature timber available for deer winter range. Therefore, the most important recommendation is that heavily used winter ranges be excluded from future logging plans.

The results of the radio-tagging project suggest that at least one-half of the deer using low elevation logged habitats in spring move to high elevation mature timber habitats in summer and fall. In winter, the deer remain in high elevation mature timber habitats until forced to low elevations by snow, and possibly by cold weather. In the Nimpkish Valley there is little logging above 3000 ft elevation, and when snow is shallow many deer winter in timber at this elevation. However, when snowfall is heavy the deer move to low elevation timber habitats. Observations suggest that deer move through mature timber habitats to the low elevation winter ranges. If mature timber is not available for downhill movement, and if snow is deep in the logged habitats, many deer are forced to remain at the lower edge of the high elevation timber. Therefore, I recommend that strips of mature timber be left extending from sub-alpine to the low elevation winter ranges. Such strips would be used as winter range during mild winters and as downhill movement routes during severe winters. Subjective observations suggest that such corridors should be a minimum one-half mile in width.

Not all low elevation mature timber habitats are suitable for deer winter range. The most important characteristic of timber winter range is a dense crown closure. The data taken from the permanent plots suggest that crown closure should be 65% or greater. White-tailed deer require timber having a minimum crown closure of 45 to 70% (Gill, 1957) or 50% (Verme, 1965), depending on forest type. When snowfall is heavy, the amount of shelter provided by a habitat type determines which habitats are available for use by deer. Within the habitats available for their use, they will make most use of those having the best food supply. I recommend that only those habitats having crown closures greater than 65% be left for deer winter range. A more detailed list of the characteristics of winter range was presented in section 4.4.3.

It is uncertain how much area is required for winter range, and much will depend on how many deer are desired in an area, on the frequency of severe winters, and on the number of deer that a habitat can support. My subjective observations suggest that good winter habitats may support up to 400 deer per square mile over a 3 to 4 month winter period, a figure consistent with some previous studies of white-tailed deer (Davenport, Shapton, and Gower, 1944). Previous authors have stated that winter range occupies 10% (Cowan, 1950), 13% (DeNio, 1938), 7 to 8%, 10 to 13% (Severinghaus and Cheatum, 1956), and 5 to 15% (Telfer, 1970a) of a given region. If these figures are relevant to the Nimpkish Valley, then approximately 10% of the area should be left as winter range.

The guidelines given are general because any given valley is a separate case, and should be studied individually to determine a management plan. The guidelines relate to the current situation and state of knowledge, and will undoutedly be altered in the future. The necessity for old-growth timber as winter range will decrease as new growth on logged areas matures.

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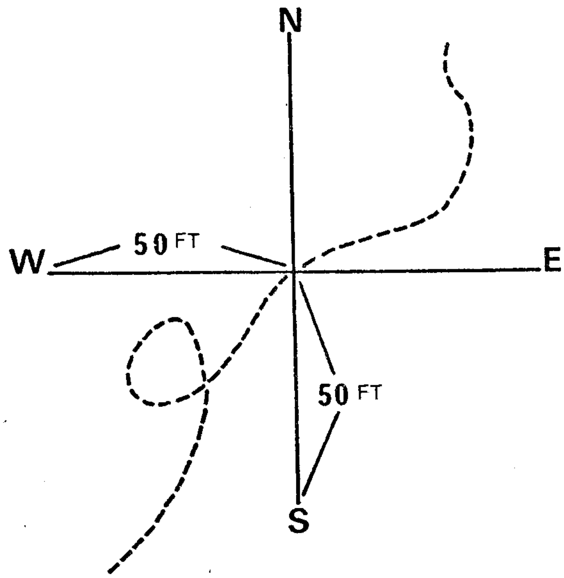
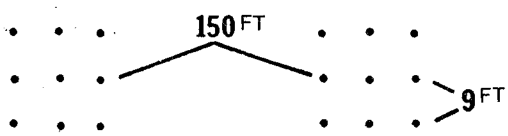


A) Method of measuring deer use

The area under study was sampled with 1 to 20 temporary track count plots.

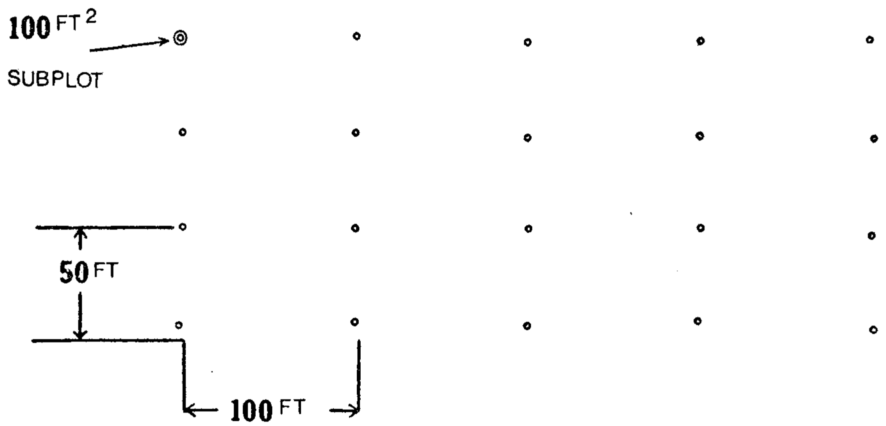
The deer use index is the total number of tracks crossed by all 4 fifty foot lines.



B) Method of measuring snow depth

The snow depth measure is the mean of the 18 samples

Appendix 1 Methods used to count deer tracks and measure snow depths during the winter of 1971-72.



Appendix 2 Design of the permanent track count plots used during the winter of 1972-73.

The five lines were parallel and were roughly perpendicular to the elevation contours.

Vegetation, snow depth, and crown closure were all measured from the subplots.

Track count and track depth measures were taken from the 50 foot lines between subplots.

All linear and area measures were taken along the ground surface. No attempts were made to correct for effect of slope on horizontal, or map, distance.

Laboratory: The contents of each jar were placed into a 0.1-mm gauge nylon cloth and squeezed to extract excess moisture. The entire contents were then placed into a graduated 500-ml beaker partially prefilled with water in order to determine the total volume. The contents were then thoroughly washed with tap water through number 3½ and number 5 sieves (5.66 and 4.00 mm). The contents remaining on the screens were washed into a white porcelain dish and separated with the aid of forceps. Each plant species of each sample was then placed into the nylon cloth and all excess moisture was squeezed out. Measurements of all samples 1.0 ml and over were done by placing the moist material into a 250-ml. graduated cylinder partially prefilled with water. The volumetric displacement of all species under 1.0 ml. was done by occular estimation with frequent checks for accuracy utilizing a 100-ml. graduated cylinder.

Note: In the event that plants were not identifiable as to species, the volume of the various recognizable rumen components were measured and placed into coded separate plastic bags together with a small amount of 10 percent formalin.

Appendix 3 Method used to analyse the deer rumen samples.

The description of the method used to analyze the rumen samples was provided by the Fish and Wildlife Branch.

Elevation (ft.)	Seral type: Clear slash	Second growth slash	Mature timber	
500 to 1500	0, 8.4, 9.4	0, 2.3, 24.6	3.5, 3.7, 4.1, 4.3, 4.7, 9.9, 14.1, 16.6	
1500 to 2500	0	0, 2.0	2.8, 4.6, 9.2, 9.3, 15.2	South aspect
2500 to 4000	0	no data	0, 2.2, 2.8, 2.8	
500 to 1500	0, 7.0	no data	0, 1.5, 1.5, 4.0	
1500 to 2500	0	no data	0, 1.6, 2.2, 2.2, 4.5	North aspect
2500 to 4000	no data	no data	0, 0.8	

Appendix 4 Summary of the track count data taken during the winter of 1971-72.

The data presented were collected under all snow conditions.

Zero deer use indices were taken many times in the logged habitats, however, only one zero value is given for each logged habitat.

Common name	Botanical name
Red cedar	Thuja plicata
Yellow cedar (cypress)	Chamaecyparis nootkatensis
Douglas fir	Pseudotsuga menziesii
Western hemlock	Tsuga heterophylla
Mountain hemlock	Tsuga mertensiana
True fir	Abies sp.
Salal	Gaultheria shallon
Bunchberry	Cornus canadensis
Twinflower	Linnaea borealis
Deer fern	Blechnum spicant

Appendix 5 Botanical names of the plant species discussed in the text.