SEASONAL DISTRIBUTION AND WINTER HABITAT USE BY SITKA BLACK-TAILED DEER IN THE PRINCE WILLIAM SOUND REGION, ALASKA

A

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MASTER OF SCIENCE

By

Neil Shishido, B.S.

Fairbanks, Alaska

May 1986

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Presented to the Faculty of the University of Alaska

in Partial Fulfillment of the Requirements

for the Degree of

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ABSTRACT

Intensity of winter use of a variety of forest stands by deer (*Odocoileus hemionus sitkensis*) was measured. Information on vegetation, timber type, and topography was collected to find relationships between deer use and habitat variables. Seasonal use of forest stands by deer is best described in terms of: basal area of trees, amount of deer forage (*Vaccinium* spp. and *Coptis aspleniifolia*), deviation in crown closure, and timber volume. Information from radio-collared deer indicated high use of forest habitat, particularly during winter. Alpine areas received more use than any other habitat during summer. South-facing slopes were used more often than other aspects across all seasons. Average winter home range size was 160 ha, significantly smaller than the spring average (282 ha). Most radio-collared deer made seasonal elevational movements within a single drainage. Retention of high timber volume, old growth forest is recommended to maintain preferred deer habitat in Prince William Sound.

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INTRODUCTION

The focus of this study was to determine relationships between Sitka black-tailed deer and the forest habitats they occupy. This information may be useful to forest managers in making land use decisions and timber management plans.

Sitka black-tailed deer were introduced to Prince William Sound in 1916 on Hawkins and Hinchinbrook islands, when 8 animals were transplanted from the Sitka area in southeastern Alaska. From 1917 to 1923 an additional 16 animals from Sitka were released on the same islands (Burris and McKnight 1973). Prior to this introduction, the island range in Prince William Sound had not been occupied by ungulates. Deer populations increased rapidly and dispersed throughout the islands and portions of the adjacent mainland of Prince William Sound. Deer are now well established and occur on all islands of Prince William Sound and areas of the adjacent mainland where there is suitable habitat (Reynolds 1979). Natural access to the area by deer from Southeast Alaska had been prevented by glaciers, ice caps, broad bays and unsuitable habitat along the intervening coast area.

A hunting season on deer in the Prince William Sound area was first established in 1935. Since that time deer have been harvested regularly and have become an important game animal for residents of the region. The 1985 deer hunting season was from August 1 to December 31 with the exception that antlerless deer could be harvested only from

September 15 to December 31. The bag limit was 5 deer per hunter per year. The liberal bag limit and season length reflect the high reproductive potential of deer on this island range and the fact that periodic severe winters indirectly cause a high natural mortality of deer that could otherwise have been utilized by hunters before natural mortality takes its course. The total area of deer habitat is also large in relation to number of hunters and the access available to it. Deer harvest in the Prince William Sound region varies from 500 to 1500 deer per year (Reynolds 1979).

Deer populations in Alaska are characterized by extreme fluctuations in population numbers (Olson 1952, Klein 1965, Merriam 1968, 1970; Reynolds 1979). The severity of winter weather conditions has been cited as the single most important factor influencing population levels of Alaskan deer. Deep and prolonged snow depths restrict the movements of deer and cover forage plants essential for deer survival. Ground forbs that remain green through winter including goldthread (Coptis aspleniifolia), trailing bramble (Rubus pedatus), and bunchberry (Cornus canadensis) are relatively high in nutritional value (Schoen and Wallmo 1979) and are important in enabling deer to maintain body condition during winter (Merriam 1970). When snow cover renders these forbs inaccessible, deer are forced to feed on less nutritious browse, particularly blueberry (Vaccinium spp.) Apparently, deer lose condition rapidly if forced to feed primarily on woody browse for prolonged periods. When this occurs, nutritional stress and eventually starvation result (Merriam 1970). During severe winters up to 80 percent of the deer population may die of starvation

(Reynolds 1979).

During a severe winter, heavy snowfall and low temperatures may result in prolonged and deep snow cover. Under these snow conditions in Southeast Alaska, deer are forced to move to lower elevations and may be restricted to a narrow strip of forest adjacent to the beach (beach fringe) where snowfall is least and the forest canopy intercepts much of the snow (Merriam 1970, Olson 1952). Apparently, snow depths of 45 to 60 cm greatly limit deer movements (Merriam 1970). During a severe winter in Southeast Alaska, Leopold and Barrett (1972) noted high densities of deer in forest stands along the beach, particularly on points, knolls, and ridges which received less snow than other areas. Beach fringe areas where snow accumulation is reduced probably represent the last refuge for deer which are unable to use other areas because of deep snow. Klein and Olson (1960) reported that approximately 90 percent of the deer succumbing to starvation were found within 10 m of the beach.

Throughout most winters in the coastal rainforest areas of Alaska frequent warming may alleviate deep snow conditions. Deer make altitudinal movements in response to changing snow depths and tend to remain at higher elevations if snow conditions allow the availability of forage plants (Merriam 1968, Olson 1952). Even during a severe winter (1970-71), deer were present as high as 215 m in elevation and as far inland as 4.8 km (Leopold and Barrett 1972). Schoen (1978) monitored radio-collared deer at elevations up to 300 m on Admiralty Island during a relatively mild winter (1977-78). Schoen (1978) and Leopold and Barrett (1972) stressed the fact that beach fringe areas by themselves may not be sufficient to maintain existing deer populations.

Studies on deer habitat use in southeastern Alaska have shown that deer are denizens of uneven-aged climax forest (Schoen et al. 1979, Bloom 1978, Leopold and Barrett 1972). Leopold and Barrett (1972) described key deer winter range as mature conifer forest with enough light penetrating through openings in the forest canopy to allow growth of blueberry species. Radio-collared deer were found to use uneven-aged, old growth forest more than any other habitat type throughout the year (Schoen et al. 1979). Use of old growth forest was greatest during winter when at least 90 % of the relocations of instrumented deer occurred in old growth forest.

Some of the characteristics of uneven-aged, old growth forest which contribute to its importance to deer have been identified. The presence of trees of various ages results in a variation of canopy cover which allows sufficient light penetration to permit growth of understory vegetation. Schoen (1978) reported a greater abundance and diversity of understory species in old growth forest compared to mid to late successional stands (30 to 147 years old). Bunchberry, trailing bramble, and goldthread that remain green through the winter and are important deer winter forage were at least 15 times more prevalent in old growth stands than in stands in earlier successional stages. In addition, the overstory canopy in old growth forests intercepts a significant amount of snow so that snow accumulation on the ground is considerably reduced. Several studies have reported that snow depths are least under the forest canopy (Schoen and Wallmo 1979, Bloom 1978, Merriam 1968). In southeastern Alaska, it is becoming increasingly apparent that uneven-aged stands of old growth forest with high timber volume support the highest densities of deer and can be considered optimal deer winter habitat (Schoen and Wallmo 1979, Bloom 1978, Leopold and Barrett 1972).

Old growth forest has been defined as uneven-aged, silviculturally overmature forest with dominant trees exceeding 300 years of age (Schoen et al. 1979). In southeastern Alaska, the removal of old growth forest has occurred at the rate of approximately 5,670 ha (14,000 acres) per year (Harris and Farr 1979). Clearcutting is the only silvicultural method that has been used in recent decades in southeastern Alaska. At the present time, clearcutting is probably the major cause of loss of deer habitat.

Succession of plant growth following a clearcut has been described by Harris and Farr (1974). Immediately following clearcutting there is generally a dramatic increase in the growth of understory vegetation. However, this vegetation is largely unavailable to deer during much of the winter because it is covered with snow. Approximately 15 to 20 years after clearcutting there is generally a dense regrowth of even-aged conifers. At this time regrowth of young saplings is so dense that movement of deer through it is restricted and shading out of many of the forage plants occurs. From about 30 to well over 100 years the forest canopy is closed and there is not sufficient light for growth of understory plant species with the exception of moss. Use of these stands by deer and other wildlife is severely limited because there is little or no forage for them to feed on. Several hundred years are required for openings in the forest canopy to develop and the stand to approach the uneven-aged climax stage. Because of this long regeneration time, which exceeds the cutting cycle of the timber industry, uneven-aged climax forest has been considered a non-renewable resource (Schoen 1978). Due to the near absence of understory vegetation suitable as deer forage in second growth stands for more than 100 years after clearcutting, the long term effects on wildlife use are more important than the immediate effect of timber removal (Leopold and Barrett 1972).

The Prince William Sound region lies within the boundaries of the Chugach National Forest. The Chugach Forest encompasses approximately 2,221,800 ha. This land base takes into account reductions of 291,400 ha that were selected by Alaska natives (through the provisions of the Alaska Native Claims Settlement Act 1971) and approximately 4,100 ha of state selections.

The draft forest management plan for the Chugach National Forest (USDA 1982) presents Forest-wide timber management guidelines. About 145,700 ha of the National Forest has been classified as commercial forest land, but only 41 % of this is considered suitable for timber production due to isolated locations or excessive development costs. The major commercial forest types of the Forest by percent area composition include hemlock/Sitka spruce (<u>Tsuga</u> spp./<u>Picea sitchensis</u>) 55, Sitka spruce/cottonwood (<u>P. sitchensis</u>/<u>Populus balsamifera</u>) 15, cottonwood 9, hemlock 6, Sitka spruce 6, and white spruce (<u>Picea glauca</u>). Sitka spruce is the species in greatest demand. Information on the amount of commercial forest land falling within various timber volume classes is not available. The annual cut (calculated from the period 1975 to 1980) for the Chugach National Forest is 9.2 MMBF (million board feet) (or 21,708 m^3). Most of this timber is shipped to Japan in the form of cants. One of the goals of the Forest plan is to increase annually the amount of timber offered for sale. Management goals for timber production call for an increase in the annual cut to 21 MMBF (49,551 m^3) for 1986 to 1990, 34 MMBF (80,225 m^3) annually for 1991 to 2000 to reach the long term goal of 40 MMBF (44,383 m^3) annual timber harvest. For the Big Islands Management Area, which includes Hawkins, Hinchinbrook, and Montague Islands, the timber harvest goal for the 1986 to 1990 period is 9.3 MMBF (21,944 m^3) annually. This figure represents 44 % of the Forest-wide harvest from approximately 7 % of the total area of the Chugach National Forest. In addition, 31 % of the "Big Islands" area is alpine. Wherever this harvest takes place on the "Big Islands" there will be a significant influence on the deer population in Prince William Sound.

Through the National Forest Management Act of 1976, the Forest Service is directed to manage the national forests on a multiple use basis. The proposed forest plan to increase the annual timber harvest on the Chugach National Forest, makes it increasingly important to identify other resources (primarily fish and wildlife) that are tied to the forest ecosystem. It is also important to ascertain how fish and wildlife species are using the forest and to determine the importance of forest types to these species on a seasonal basis. The emphasis of this study was to determine deer/forest relationships before extensive timber harvests take place.

The specific objectives of this study were: 1) to determine patterns of seasonal habitat use of deer, 2) to describe the significant characteristics of the forest stands and vegetation types used by deer, and 3) to determine movement patterns and seasonal home range areas of radio-collared deer.

Nomenclature for vascular plants follows Hultén (1968). Lists of common and scientific names for the plants mentioned in this thesis can be found in Appendix 1, while common and scientific names for the fish, birds, and mammals may be found in Appendix 2.

The term winter-green ground forbs is used to refer to ground forbs which remain green throughout the winter, turn brown and lose their leaves at the end of winter and grow new leaves during spring. Since they do not retain green foliage for more then one year they are not true evergreen plants. The winter-green ground forbs include bunchberry, goldthread, and trailing bramble.

STUDY AREA

Hinchinbrook Island (60° 23' N, 146° 28' W) is one of the three major islands in Prince William Sound which separate the inner waters of the Sound from the Gulf of Alaska (Fig. 1). It was selected as the study area primarily because the Island supports a relatively stable population of Sitka black-tailed deer and a relatively wide variety of vegetation types are available to deer. It is accessable from Cordova throughout the year by boat or small plane. A small cabin was built in Shelter Bay on the west coast of Hinchinbrook to serve as a base for field operations. The Island is roughly triangular in shape and is approximately 28,000 ha in area. The northern and western coastlines face the protected inner waters of the Sound and are penetrated by several large bays and smaller coves. The outer coast which faces the Gulf of Alaska is exposed to the often inclement Gulf weather. Hinchinbrook Entrance is a 12 km wide water passage between Hinchinbrook and Montague Islands. It is the major transportation corridor for oil tanker and other boat traffic coming into and going from Prince William Sound. Hinchinbrook Entrance is also the major channel through which the tide enters and leaves the inner Sound. Strong currents through Hinchinbrook Entrance often bring floating material (including driftwood, sea weed, and foreign material) into the

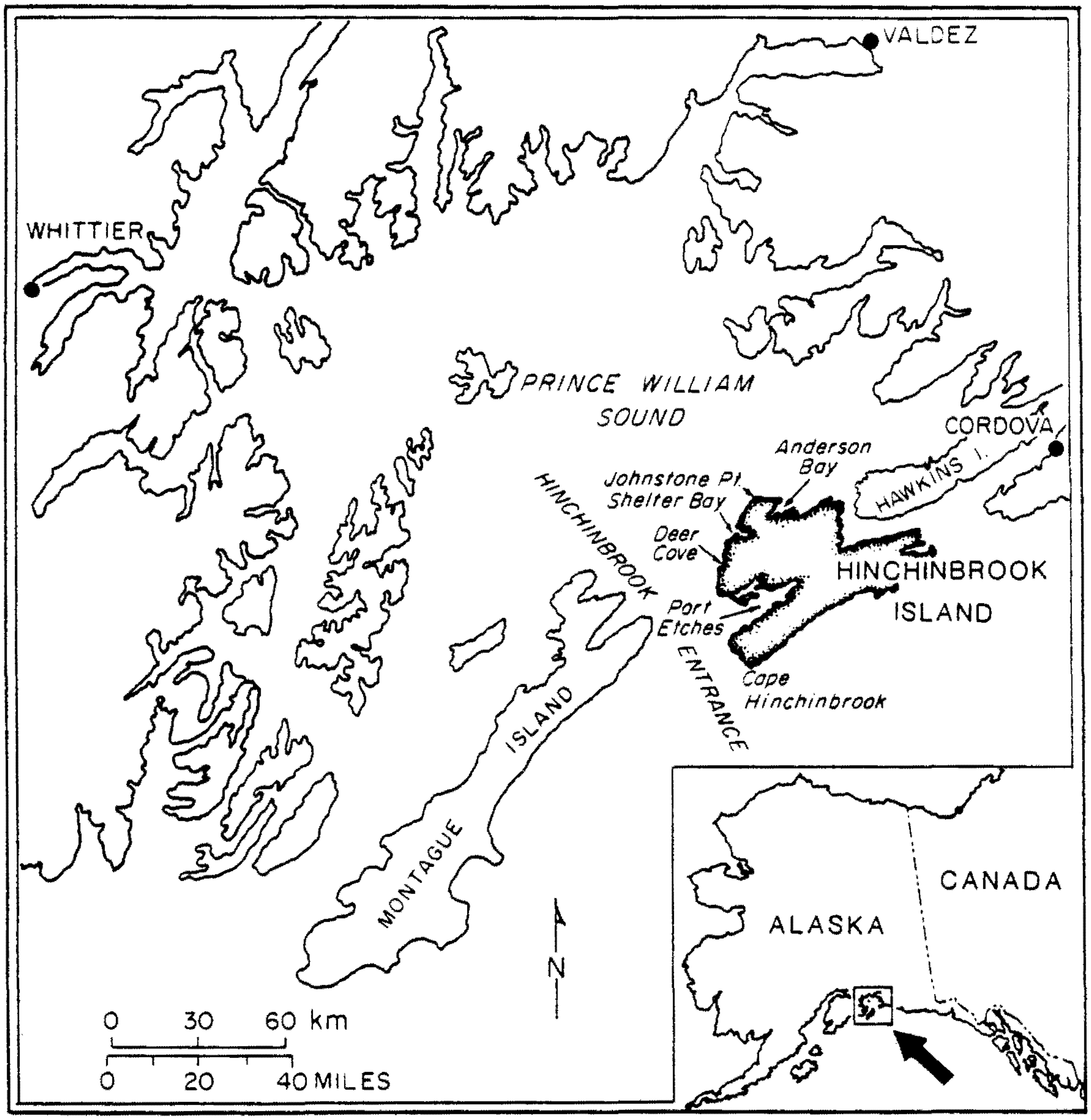

Figure 1. Location of the Hinchinbrook Island study area in Prince William Sound.

Sound and deposit it on the west coast of Hinchinbrook Island.

One of the major features of the Island is a series of three parallel mountain ranges trending from the northeast to southwest. The mountains generally rise abruptly from the sea to approximately 600 m, whereas the highest point on the Island is 890 m. Bedrock in the Prince William Sound region is predominantly marine sedimentary deposits of Mesozoic origin (Moffit 1954). The most common rocks of the region are graywacke, slate, sandstone, and argillite. Soils are generally young and undeveloped.

A major faultline, the St. Elias Fault runs through Prince William Sound. In March of 1964, a major earthquake registering between 8.4 and 8.6 on the Richter scale struck southcentral Alaska including Prince William Sound. The effects of this earthquake are still apparent today. Land on Hinchinbrook Island rose approximately 2 m. Pre-earthquake intertidal beach areas are now above the reach of the tides. In Shelter Bay, this recently created upland is undergoing a slow process of plant succession. The sedge/forb complex growing there now provides seasonal resting and feeding habitat for migratory and resident geese and ducks in spring, brown bears graze on the grass, especially in early spring, and deer feed in this habitat during spring and summer.

Upland vegetation of the Prince William Sound region is a northern extension of the coastal rain forest. Forest stands, interspersed by large expanses of muskeg, dominate the lower elevations. In comparison to southeastern Alaska, forest stands of Prince William Sound have a lower diversity of tree species and generally occupy smaller areas.

This is a product of a lower tree line and the high proportion of land covered by muskeg. Sitka spruce, western hemlock, and mountain hemlock are the dominant tree species of the region. Sitka spruce is common at lower elevations, especially on well-drained river bottoms. Mountain hemlock is found at lower elevations than in southeastern Alaska and is therefore a more common forest component. It also grows as a dwarf shrub at higher elevations, especially near timberline. Many small lakes and ponds punctuate the muskeg that forms on level or gently sloping ground and reflect the generally poorly drained nature of muskeg areas. Cooper (1945) described two common vegetation types in treeless areas of Prince William Sound. Crowberry heath is characteristic of dry, well-drained areas such as rocky knolls. The most common plants growing in this type are crowberry, mountain heather, dwarf blueberry, and Cladonia spp. Sedge bog is typical in very poorly drained areas. The bog type supports a wide variety of plant species including peat moss, sedge, cotton grass, cloudberry, dwarf bogrosemary, and deer cabbage. Transitional areas between heath and bog are very common. Many small streams originating from ice and snow fields high on the mountains generally enter the heads of bays. Timberline begins at approximately 600 m and about 40 % of the island lies above this level.

Hinchinbrook Island is under the influence of a maritime climate. Average annual precipitation is 239 cm (Brower et al. 1977). Winters are generally milder and summers cooler than on the adjacent mainland. Mean annual maximum and minimum temperatures for Cordova on the mainland are 7.6 and -1.0 °C while at Cape Hinchinbrook on the southwest side of the Island comparable temperatures are 7.5 and 3.2 ^{o}C. Average annual snowpack for Cordova is 252 cm while at Cape Hinchinbrook it is 145 cm. Occasional winters in which the snow accumulation is twice the annual mean are not uncommon. Figure 2 shows the total annual snowfall for Cordova during the period 1970 to 1984. Total annual snowfall is not directly related to mean annual snowpack as warming trends often reduce snow depth.

The diversity of habitat types occurring on Hinchinbrook Island support a variety of fish and wildlife species. Freshwater streams provide spawning areas for three species of Pacific salmon which include pink, chum, and silver salmon. The summer and fall run of salmon from the ocean to spawning areas provide the basis for both sport and commercial fisheries. Spawning salmon also provide a major food source for brown bears which are common on the Island. Bald eagles which are common year-round residents also feed on the salmon. The ebb and flow of tide through a narrow channel into Shelter Bay often brings marine creatures into its brackish waters. Sea otters float in on the tide and dive for mussels growing on the channel bottom. Flounders also find their way into the Bay and are often preyed upon by resident river otters. Other mammals that live in the area include the hoary marmot, red-backed vole, beaver, northern water shrew, shorttail weasel, mink, and Sitka black-tailed deer. The intertidal beach is used quite intensively by migrating shorebirds during spring. A variety of ducks and various subspecies of Canada geese use the Bay area as a migratory stopover and the inland forest edge provides nesting habitat for some Canada geese. Some of the

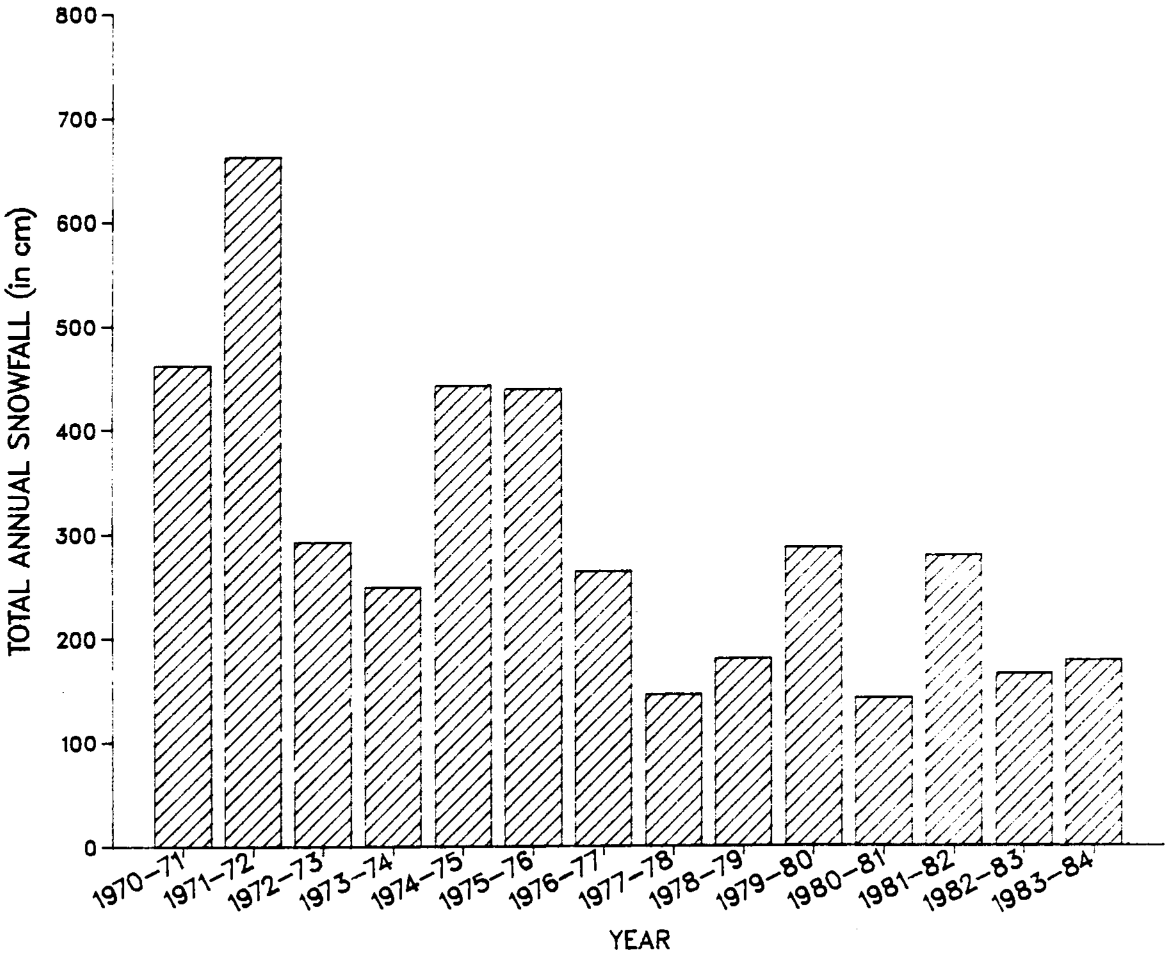

Figure 2. Total annual snowfall for Cordova, 1970-71 to 1983-84.

larger lakes of the Island are used by molting and flightless geese for escape habitat and brood rearing. A complete list of the avian species and their patterns of use of the region can be found in Isleib and Kessel (1973).

DEER WINTER HABITAT USE

Methods

The pellet group count technique (Neff 1968) has been used in Alaska (Schoen et al. 1979, Barrett 1979, Rose 1982) and elsewhere (White 1960, Collins 1981) to estimate the relative amount of winter use by deer in different habitat types. Pellet group transects were used in this study to evaluate the amount of deer winter use in different forest types. Assumptions that were made in using this technique include: 1) the density of winter pellet groups in an area is directly proportional to the amount of deer use in that area and 2) winter pellet groups persist in the environment for approximately 6 months after they have been deposited (Fisch 1979, Rose 1982).

Following winter the number of pellet groups that occurred in 1 m x 10 m plots were counted. A relatively small plot size was used because many small sample units are generally more efficient than fewer larger ones because they require less sampling area for the same accuracy (Neff 1968). Plots with a long and narrow shape were considered to be more accurate than short, wide plots or squares of the same size (Robinette et al. 1958).

During May 1982, pellet group data were collected from 57 locations on Hinchinbrook Island in Prince William Sound. Vegetation data had been collected previously from these same locations (Eck

1983). The vegetation sampling locations were randomly located in stands to cover a wide range of mature forest types. At each location a 10-point variable plot sampling method was used to measure vegetation variables. Pellet group transects were established so that the 0.4 ha (1 acre) vegetation plots could be sampled adequately. At each location 5 parallel transects, 12 m apart were run. On each transect 6 continuous 1 m x 10 m plots were sampled for pellet groups. The transects were centered on the vegetation plots. Thirty pellet group plots were sampled at each of the 57 locations. Three measures of deer use were recorded at each: 1) the number of pellet groups, 2) presence or absence of browsing on blueberry species, and 3) presence or absence of foraging on bunchberry.

The pellet group data were related to the vegetation data so that deer use could be quantitatively described in terms of forest stand characteristics and understory plant species composition. Over 100 variables were measured at each location, but due to constraints in the analysis programs only 39 of these variables were used in the analysis. The variables used included percent canopy cover of 18 understory plant species, biomass estimates of 4 winter-green ground forbs (bunchberry, trailing bramble, 2 species of goldthread), 4 topographic variables, and 5 timber quality and quantity variables (see Appendix 1 for complete list).

Data Analysis

For each location the mean number of pellet groups per plot (30 plots per location) was calculated as well as the proportion of plots that showed evidence of browsing on blueberry species and grazing on bunchberry. The BMDP Statistical Software package (Dixon and Brown 1981) was used to compute basic statistics, construct frequency distributions, and to assess deviations from normality. The distribution of mean pellet group densities was positively skewed due to the presence of a few large values and the predominance of much smaller values.

The distribution of deer in the study area was assumed to be related primarily to forest/vegetation type and secondarily to topography. To see which of the vegetation variables were correlated with the deer use indices (pellet group density, browse index, or forage index) and to get an insight as to the nature of the relationship, I constructed bivariate plots using BMDP6D. The deer use variables were entered as dependent variables and the vegetation variables as independent variables. Since a number of variables showed a significant correlation ($p = 0.05$) with deer use, stepwise multiple regression models (BMDP2R) were used to find the independent variables which best explained the variability in deer use between forest stands. The stepwise regression procedure starts with no variables in the model and enters that independent variable which contains the most information on the dependent variable in the first step. After the information in this variable has been accounted for, the next variable to enter the regression is that which explains the largest portion of the variation left unexplained by the first variable and so on. The criterion for adding a variable is the F-statistic which tests whether or not the slope of the regression line is significantly different from zero.

Although the stepwise regression procedure is useful in selecting those independent variables that are most important in predicting the dependent variable (deer use), there is some subjectivity involved in picking those variables that explain a significant amount of the residual variation in deer use. Although a variable may be statistically significant in explaining what variation is left in the dependent variable, the residual variation may not contain an appreciable amount of information on the dependent variable.

All possible subsets regression was used to find the "best" set of independent variables that cumulatively explained the greatest portion of variation in deer use. All of the independent variables that were statistically significant in the stepwise regression procedure were used as possible candidates for the all possible subsets regression. The Cp criterion (Neter and Wasserman 1974:375) was used to pick the "best" possible set of independent variables. That set with the lowest Cp value was identified as the set of independent variables that best explained the variation in deer use between forest stands.

With measurements on 38 different habitat variables, it was difficult to assimilate the numerous covariance relationships among the variables to reach an overall assessment of the importance of individual variables in defining forest/vegetation types. Principal components analysis takes into account the covariance relationships between variables and the principal components are uncorrelated linear combinations of the original variables. Principal components analysis was used to: 1) reduce the dimensionality of the data set, 2) find those variables that accounted for the greatest proportion of the total sample variance, and 3) reveal relationships which previous analyses failed to uncover and thereby allow interpretations that would not ordinarily result. Since the original variables were measured on vastly different scales the correlation matrix, rather than the raw covariance matrix was factored.

Results and Discussion

Deer Use of Different Forest Types

The forests of Prince William Sound have been classified into 5 distinct types (Eck 1983). To determine if this forest type classification has meaning in relation to deer use, a Kruskal-Wallis test (Conover 1980) was used to test the null hypothesis that all 5 forest types receive the same intensity of winter use by deer. If the null hypothesis is rejected, we can say that there is a difference between forest types but we do not know where the difference lies. Multiple comparisons using the Kruskal-Wallis statistic and the difference in the sum of ranks between the different populations can be used to discover which of the forest types is significantly different from the others.

Pellet group densities per plot ranged from 0 to 2.23. In order to use the multiple comparisons, pellet group densities were broken into 3 categories of equal intervals. The categories were low density (0 to 0.74 pellet groups per plot), medium (0.74 to 1.49), and high (1.5 to 2.23). Plots within each forest type were classified and placed into the appropriate pellet group category. The resulting contingency table was used to compute average ranks, rank sums, and to calculate the Kruskal-Wallis test statistic.

Forest Type Classification

Forest types of the Prince William Sound region have been defined on the basis of the dominant overstory tree species or species group that accounts for the major portion of the forest stand in terms of net board-foot volume (Eck 1983). The 5 species groups that have been identified include: western hemlock, mountain hemlock, Sitka spruce, and mixed species stands of western hemlock/mountain hemlock, and western hemlock/Sitka spruce. Site conditions and understory plant species commonly found in the different forest types have been described by (Eck 1983).

Although early blueberry, Alaska blueberry, and dwarf blueberry occurred in the study area, I have referred to these species as blueberry species or simply blueberry in this study because they exhibit a similar growth form and transition types between the two species occur.

Forest stands dominated by hemlock tend to have a highly variable overstory canopy cover with many openings. These stands have significantly more blueberry stems and greater forb biomass (primarily trailing bramble, goldthread, and bunchberry) than do the spruce types.

In the Sitka spruce forest type, trees tended to be even-aged with fewer dead or defective trees than the hemlock stands, producing a closed and uniform canopy. A dense shrub layer of salmonberry and devils club was often present. Laceflower typically grew where openings in the overstory canopy occurred.

The forest canopy in the mountain hemlock type was generally open. As a result, forb production and above-ground biomass of the winter-green forbs was highest in mountain hemlock stands. In addition, forage variety (the number of different plant species known to be eaten by black-tailed deer) was greatest in this forest type. The understory species most common to mountain hemlock sites were copper-flower and deer cabbage. Net timber volume in this forest type was consistently low.

Forage variety and blueberry density in the western hemlock type was also high, being exceeded only in the mountain hemlock type. Understory plants associated with western hemlock consisted of early and Alaska blueberry, twyblade, and trailing bramble.

Mixed forests of western hemlock, mountain hemlock and Sitka spruce occur quite frequently throughout Prince William Sound, particularly under marginal or extreme site conditions. This mixed forest type (Eck 1983) is usually found in areas of transition such as along forest/muskeg edges and in beach fringe stands. Canopy cover in these stands is relatively open (50 to 70 %) but highly variable (closure variability 15.4 %). The understory plant association is a combination of the western and mountain hemlock associations. Understory plant production is quite high; this transition type ranked second in above-ground biomass of winter-green forbs compared to other forest types.

Test results from the Kruskal-Wallis one-way analysis of variance showed significant differences in deer winter use between forest types ($p = 0.02$). To find which forest types were significantly different from the others, multiple comparisons (Conover 1980) were used. Using a p-value of 0.05, the multiple comparisons test revealed that mountain hemlock forests received more deer use during the winter of 1981-82 than did spruce, western hemlock, or spruce/western hemlock forests.

The transition forest was the only forest type which did not differ significantly from mountain hemlock forests in terms of deer winter use. In order to be classified as mountain hemlock type, at least 50 % of the net timber volume in the stand must be mountain hemlock. It should be noted that results of other analyses suggest that as the mountain hemlock component increases beyond this point deer use may drop off substantially. In addition, the deer use data were gathered during extremely open winter snow conditions.

Environmental Parameters Influencing Deer Use of Different Forest Stands

Deer use as measured by fecal pellet count

With pellet group density as the dependent variable, only 5 of the 39 independent variables were statistically significant ($p = 0.10$) in explaining the variability in deer use in the stepwise regression (Table 1). Basal area entered the regression first, explaining the most variation in deer use. Basal area is the cross-sectional area of trees, at their bases, per acre. Deer use was negatively correlated with basal area; as basal area of a stand increased deer use of the stand decreased. An explanation for this pattern of deer use is that stands with low basal areas generally have open canopies (r between canopy cover and basal area = 0.85) that favor growth of understory vegetation that is preferred deer forage. Although these stands are extremely productive of deer forage (Alaback 1980, Eck 1983), during winters of heavy snow fall the open canopy allows most of the falling snow to accumulate on forest floor, thus the understory vegetation

Table 1. Stepwise multiple regression results using pellet group density as the dependent variable.

Step	Variable Entered	F-to-Enter	Significance Level	Coefficient	Multiple R
1	Basal area	27.7	$p<0.001$	-3.4×10^{-3}	0.33
2	Stems/m^2 blueberry	10.2	$p<0.005$	0.08	0.44
3	Biomass of goldthread	8.3	$p<0.01$	0.21	0.52
4	Deviation in crown closure	5.1	$0.01<p<0.05$	0.02	0.56
5	Net timber volume	4.1	$0.05<p<0.10$	1.6×10^{-5}	0.59

becomes largely unavailable to deer.

The second and third most important variables to enter the model were density of blueberry stems and biomass of goldthread respectively. Other studies of deer in Alaska (Olson 1952, Klein 1965, Reynolds 1979, Schoen et. al 1982) have shown that these 2 understory plant species are important deer winter forages. Goldthread is one of the ground forbs that remains green throughout winter. Data from nutritional analysis of native deer winter forage species (Hanley and McKendrick 1983) indicates that goldthread is relatively high in nitrogen composition (1.81 % dry weight composition). It is also highly digestible (67 % in-vitro dry weight digestibility after 48 hours) and remains so throughout the year. However, it is often unavailable during winter because it grows only several centimeters above the forest floor and would be buried by less than 10 cm of snow. Alaska blueberry, on the other hand, is generally available in snow to depths of approximately 2 m. Although relatively high in nitrogen concentration (1.42 % dry weight of stems), it is comparatively low in digestibility (34 % in-vitro dry weight digestibility of stems) (Hanley and McKendrick 1983).

Deviation in crown closure, which is a measure of the variability in the overstory canopy cover of a stand, accounted for an additional 4 % of the variation in deer use. I interpreted this variable to be a characteristic of uneven-aged old growth forest where the patchiness and layering of the overstory canopy allows light penetration and subsequent growth of understory plants. High closure variability is associated with transition forest types (Eck 1983) such as beach fringe forests and muskeg/forest edge. Track counts conducted during the winter of 1980-81 (N. S. Shishido, unpubl. data) suggested that beach fringe areas receive high use by deer, especially during periods of deep snow. Pellet group data (N. S. Shishido, unpubl. data) collected during the spring of 1981, after a mild winter, indicated that deer use was greater along the forest edge than in interior of forest stands. Side lighting may be of particular importance in contributing to patches of productive vegetation growing in areas more open to one side and under gaps in the overstory canopy (Alaback 1980). The heterogeneous canopy structure in these old growth stands may also allow greater epiphyte growth (Alaback 1980) such as beard lichen, an arboreal lichen highly preferred by deer (Schoen and Kirchhoff 1983), which may become available to deer as litterfall.

The last significant variable to enter the model was net timber volume, measured in board feet per acre. Net timber volume had a positive relationship with deer winter use. Although it is difficult to interpret the importance of this variable in terms of its significance to deer winter use, it may be related to increased forage production and higher forage quality. Studies on understory production in spruce/hemlock forests in southeastern Alaska have shown a positive correlation between understory growth and timber volume in older forests. This correlation was related to the "opening up or diversification of canopy structure with age" (Alaback 1980:68). Schoen and Kirchhoff (1984) found significant differences in forage quality between high and low volume sites. Bunchberry growing in the high volume sites was significantly higher in forage quality, especially in nitrogen content. They attributed this to differences in site quality factors originating from soil type. Schoen and Kirchhoff (1983) also suggest that herbaceous deer forage may be more available in mid-to high-volume hemlock stands during winters with moderate snow conditions. Alaback (1980) noted the growth of herbs on Rhytidiadelphus mats growing on the enlarged bases of hemlock trees. I have noticed patches of bunchberry growing in this situation in the forests of Prince William Sound. These and other vegetated hummocks often form on the bases of old trees (Cooper 1942), and plants growing on them remain available to deer even after deep snow covers vegetation on the forest floor. The presence of these microenvironments may be related to timber volume as it appears that the bases of older and larger trees are more likely to support these productive mats of vegetation. Eck (1983) found an inverse relationship between timber volume and forage production. Her vegetation study included high volume spruce stands on Montague Island that are characterized by dense growth of salmonberry and devils club in the understory. Comparable stands were not included in this pellet group study. Net volume is highly correlated with percentage of spruce ($r = 0.69$). Because of the interaction between percentage of spruce and timber volume, it is difficult to determine which variable has the major influence on forage production.

Results of the all possible subsets regression showed that the subset with the lowest C_p criterion contained 5 variables. These were the same variables that were statistically significant in the stepwise regression model. In addition, all 5 independent variables had the same relationship with pellet group density in the all subsets regression as they had in the stepwise regression.

Deer use measured as browsing of blueberry

Stepwise multiple regression was used to determine which variables accounted for the most variation in deer use of blueberry species. The relative amount of deer use of blueberry (measured as browsing presence) was used as the dependent variable and the 39 vegetation and topographic variables as independent variables.

Results of the regression analysis revealed 5 statistically significant variables which cumulatively explained 51 % of the variation in browse use (Table 2). The amount of blueberry (stems per m^2) was the most important of these variables and accounted for approximately 23 % of the total variation in blueberry use. Net timber volume added another 12 % and was negatively correlated with browse use. An inverse relationship between blueberry density and net timber volume has been reported for Prince William Sound forests (Eck 1983). Therefore it appears that under mild winter conditions, deer tended to use stands with high amounts of blueberry.

Elevation of the stand explained an additional 9 % of the variation and was also a negative correlate with blueberry use. Apparently deer tended to use stands with high blueberry density at lower elevations.

Biomass of bunchberry entered the regression model at step 4 and was negatively correlated with browse use. Initially, this result appeared to be inconsistent with what is known about deer habitat use.

Table 2. Stepwise regression results using relative amount of browsing on blueberry as the dependent variable.

Step	Variable Entered	F-to-enter	Significance Level	Coefficient	Multiple R^2
1	Blueberry % cover	16.4	$p<0.001$	6.5×10^{-3}	0.23
2	Net timber volume	10.1	$p<0.001$	-5.8×10^{-6}	0.35
3	Elevation	9.0	$p<0.001$	-9.5×10^{-3}	0.44
4	Bunchberry biomass	3.7	$0.02<p<0.05$	-3.1×10^{-2}	0.48
5	Goldthread % cover	2.5	$0.10<p<0.25$	5.7×10^{-3}	0.51
6	% Mountain hemlock	3.5	$0.05<p<0.10$	-2.9x10-3	0.54

Schoen and Kirchhoff (1983) have identified bunchberry as one of the most abundant and common forage species in the winter diet of deer in southeastern Alaska. Bunchberry had the highest density and biomass of the winter-green ground forbs in the Prince William Sound region (Eck 1983). My field observations indicate that bunchberry is one of the more heavily used forbs during winter when it is available. However, examination of the correlation matrix shows that bunchberry growth has a weak positive correlation with elevation. Vegetation studies conducted in southeastern Alaska have also found that understory density generally increases with elevation (Alaback 1980). Deer use on the other hand has the opposite relationship with elevation. If bunchberry growth increased with elevation and deer use decreased at higher elevations, one might well expect no correlation or a negative correlation between deer use and bunchberry growth in the regression model.

The amount of goldthread in a stand, which was a significant variable in the regression model with pellet group density, was the fifth variable to enter. Although goldthread did not account for a significant amount of the residual variance in the forward stepping algorithm, in the backward elimination procedure it contained the fourth largest piece of unique information and was also statistically significant. Therefore, although the total information contained within goldthread was not significant (after the first four variables have explained the variation they contain), goldthread does contain a significant amount of unique information not accounted for by any of the other significant independent variables. Goldthread is a well-documented deer winter forage, occurs relatively abundantly throughout the different forest types, and has a high correlation with blueberry use (r = 0.34).

Percent mountain hemlock was the last significant variable to enter the regression model. Percent mountain hemlock in a stand explained a significant portion of the variance in density of blueberry stems and has a high positive correlation with blueberry stems/m^2 (r = 0.51). However, mountain hemlock was negatively correlated in the regression with browse use. This raises the questions of, how the amount of mountain hemlock in a stand relates to deer use, and why deer use drops off as the mountain hemlock component increases? Figure 3 shows that maximum use of forest stands occurs when the composition of mountain hemlock in a stand is approximately 45 to 52 %. After this point as the percent composition increases, deer use consistently declines. Therefore, there appears to be an optimum mix of mountain hemlock with other tree species which allows productive growth of blueberry to which deer respond. On the other hand, the pure stands of mountain hemlock tend to occur at higher elevations. The high elevation and open canopy of these stands allows accumulation of snow and offers very little horizontal or vertical cover. Therefore, deer tend to avoid these stands during winter.

The subset with the lowest Cp criterion contained 6 variables which included percentage of mountain hemlock, percentage of canopy cover of blueberry species, salmonberry, goldthread, twyblade, and net timber volume. Two variables, percentage of canopy

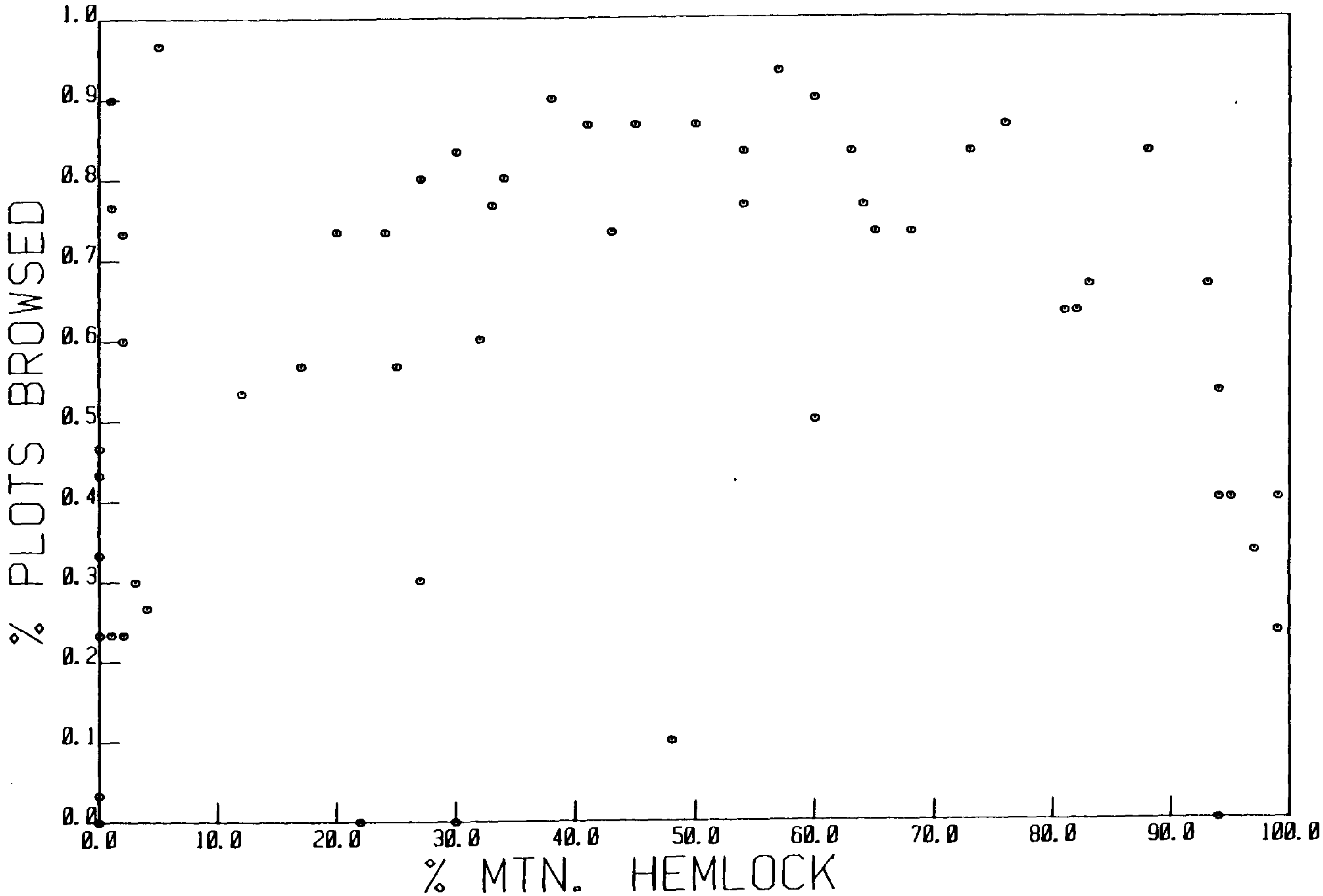

Figure 3. Relationship between the percent of plots showing evidence of browsing on blueberry and percent composition of mountain hemlock in a stand.

cover of salmonberry and twyblade differed from the multiple regression results. Twyblade did not occur on any of the Sitka spruce sites and on only 2 mountain hemlock sites. It is primarily associated with the understory plant community of western hemlock forests. Although it is used by deer in spring and summer, it dies back in the fall and is not available to deer during winter. Twyblade had a negative relationship with browse use, the dependent variable, and a high positive correlation with elevation. Since deer use is negatively correlated with elevation, this result may be a consequence of interaction between these two variables. Salmonberry often forms dense thickets in forest openings (Viereck and Little 1972) and is primarily associated with Sitka spruce forests. Although the new leaves and twigs may be browsed by deer in the early spring, its relationship to deer winter use in this analysis was obscure.

Deer use measured by foraging on bunchberry

Deer use was also measured by the presence of foraging on bunchberry. A regression model using intensity of foraging on bunchberry as the dependent variable was developed. The following variables were statistically significant in the forage regression model and are listed in relative order of significance: distance of the stand from saltwater, amount of skunk cabbage, aspect, and blueberry cover (Table 3). Deer use of bunchberry had a negative relationship with distance to saltwater. Examination of the correlation matrix shows a strong negative correlation ($r = -0.41$) between distance to saltwater and bunchberry use. Since abundance of bunchberry does not

Table 3. Stepwise regression results with relative amount of deer foraging on bunchberry as the dependent variable.

Step	Variable Entered	F-to-enter	Significance Level	Coefficient	Multiple R^2
1	Distance to coast line	9.2	$0.005<p<0.01$	-5.3×10^{-4}	0.17
2	Skunk cabbage % cover	7.0	$0.02<p<0.05$	0.06	0.28
3	Aspect	6.2	$0.02<p<0.05$	-5.3×10^{-3}	0.37
4	Blueberry % cover	2.9	$0.05<p<0.10$	2.9×10^{-3}	0.41

have a strong relationship with distance to saltwater (r between percentage of canopy cover of bunchberry and distance to coast = -0.18), I assumed this result indicated that deer use of bunchberry tended to occur in stands closer to the beach.

Abundance of skunk cabbage and bunchberry were relatively highly correlated (r = 0.39). Field observations indicated that skunk cabbage is a highly preferred forage species. Deer appear to seek out this plant during its early growth stage when the yellow spathe is only several inches above the ground. They consume the entire shoot, often nipping it off below the ground level. During the mild winter of 1982, I noticed deer use of this plant as early as late January. Schoen and Kirchhoff (1983) also noticed high seasonal use of skunk cabbage. In an analysis of deer winter diets, Schoen et. al (1982) found that skunk cabbage occurred in 69 % of the rumens of a sample of 13 deer but was found in only 38 % of the fecal samples. Since it was poorly represented in the fecal samples relative to the rumen samples, it was assumed to be highly digestable. By using a tame Sitka black-tailed deer in southeastern Alaska, Schoen and Kirchhoff (1983) found that young skunk cabbage shoots were a preferred forage when they were available. In Prince William Sound, skunk cabbage tends to occur on wet microsites in transition forest types such as the beach fringe forest (Eck 1983). Deer tend to move into this forest type as snow depth increases. High concentration of use in these areas in past years has contributed toward conspicuous heavy browsing, especially on blueberry.

To determine whether aspect was a factor influencing deer use of habitat, bunchberry use was plotted against aspect. This plot indicated that south to southwest-facing slopes and flat areas (beach fringe stands) received more use than other aspects.

The last significant variable in the forage regression model was the amount of blueberry in the stand. The fact that the stands in which there was high use of bunchberry also had high blueberry cover emphasizes the importance of blueberry in the winter diet of deer.

All possible subsets regression picked different variables to account for the variation in bunchberry use than those identified by the stepwise regression model. The best subset included 5 variables: the amount of blueberry and deer cabbage in a stand, elevation, aspect and net timber volume. Deer cabbage, which dies back to ground level with the first frost and is not available for winter use by deer, had a negative correlation with bunchberry use. In Prince William Sound, deer cabbage grows best in open areas especially along forest edges and in open mountain hemlock forests, presumably because of its high light requirement. I suspect that the areas where deer cabbage grows best also tend to accumulate more snow and hence are avoided by deer during the winter months. The relationship of the other variables to deer use have been discussed elsewhere.

<u>New Interpretations From Principal Components Analysis</u>

Results from principal components analysis suggested that the data set contained a high sample variance that could not easily be summarized by the first few factors. It took 17 factors (Table 4)

Table 4. Unrotated factor loadings from principal components analysis on vegetation variables. VP is the cumulative proportion of total variance explained by the factor. See Appendix 1 for key to abbreviations for variables.

VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3
% SPRUCE	0.70	-0.52	-0.10
% MTHEM	-0.89	-0.21	0.18
% WEST HEM	0.62	0.58	-0.15
VAOV	-0.32	0.74	-0.11
RUSP	0.10	-0.18	0.10
MEFE	-0.35	-0.03	0.04
CLPY	-0.44	-0.23	0.38
ECHO	0.32	-0.02	-0.07
SOSI	-0.28	0.06	-0.02
COCA	-0.70	-0.24	-0.07
COAS	-0.47	-0.09	-0.15
RUPE	-0.37	0.27	-0.24
COTR	-0.56	-0.32	0.10
LYAM	-0.11	0.02	-0.61
FACR	-0.63	-0.42	0.30
STAM	0.16	-0.18	-0.33
TITR	0.55	-0.28	0.12
LICO	-0.22	0.52	0.22
GYDR	0.57	-0.45	-0.15
DRDI	0.56	-0.32	0.01
BLSP	-0.40	0.11	0.43
GMCOCA	-0.75	-0.24	-0.05
GMCOA	-0.65	-0.14	-0.13
GMRUPE	-0.43	0.25	-0.12
GMCOTR	-0.35	-0.21	0.04
GMFORB	-0.84	-0.14	-0.11
WATER	0.33	-0.24	0.53
ELEV	-0.04	0.30	0.77
ASPECT	-0.11	0.44	0.31
SLOPE	0.13	0.46	0.59
CROWNCLO	0.84	0.30	-0.22
DEVCLO	-0.46	0.07	-0.31
SITE	0.72	-0.22	0.22
BASAL	0.89	0.15	-0.00
NETVOL	0.92	-0.09	0.08
BTVAOV	-0.02	0.66	-0.15
STEMVAOV	-0.56	0.29	-0.21
VP	0.28	0.39	0.46

to account for 90 % of the sample variance. Factor 1 accounted for 28 % of the total sample variance. In interpreting the factors, I selected only those variables with loadings greater than 0.499. I interpreted factor 1 as a contrast between forest types dominated by mountain hemlock and those dominated by Sitka spruce. The percentage of composition of Sitka spruce plus those understory plant species associated with Sitka spruce type (foamflower, oak-fern, spreading woodfern) all loaded highly on factor 1. High crown closure and high timber volume, which are also associated with the Sitka spruce type had high positive loadings. On the other hand the percentage composition of mountain hemlock and variables associated with the mountain hemlock type (bunchberry, deer cabbage, goldthread), all had high negative loadings. One exception to the mountain hemlock/Sitka spruce contrast interpretation was percentage composition of western hemlock which had a high positive loading.

Factor 2 accounted for an additional 10 % of the sample variance (cumulative proportion of 39 %) and was more difficult to interpret than factor 1. Percentage of spruce scored highly in a negative direction while percentage of western hemlock, blueberry cover and twyblade scored highly in a positive direction. Both blueberry and twyblade are associated with western hemlock stands.

I interpreted both factors as representing continuous ecological gradients. Factor 1 represented a gradient from mountain hemlock-dominated plant community on one end to Sitka spruce on the other. Factor 2, on the other hand, was interpreted as representing primarily a western hemlock plant community. The western hemlock component increased toward the positive direction.

If the factors can be interpreted biologically, then the factor scores for each observation can be plotted on factor 1 and factor 2 axes. The pellet group density associated with this observation can then be plotted at this point to deteremine how deer use is related to the environmental gradients (Hirst 1975). Pellet group density was broken into 3 classes: low, medium, and high. Low was given a ranking of 1, medium 2, and high 3. Each observational unit, which in this case was a location, was given a ranking according to the density of pellet groups that occurred on that location. This rank was plotted on the factor 1 and factor 2 coordinates for each observation (Fig. 4).

Interpretation of this graph was somewhat difficult. Although there appeared to be a slight increase in deer use as the spruce component increased, the dispersion of high and low ranks along both axes made definitive conclusions difficult. If deer did have a tendency to select certain types of spruce forests, selection may be related to higher forage quality in stands with higher site indices. Eck (1983) found that the spruce type had the highest site index among forest types in Prince William Sound. This relationship is probably due to soil-related factors. In southeastern Alaska, higher forage quality of plants growing on high volume sites (high site index) was attributed to better soil conditions. Deer in Prince William Sound may be responding to higher quality forage which may be available in some spruce type forests. Obviously a large portion of the variance in the system is not explained by factors 1 and 2. Therefore the factors probably represent a more complex ecological gradient than the interpretations I have offered.

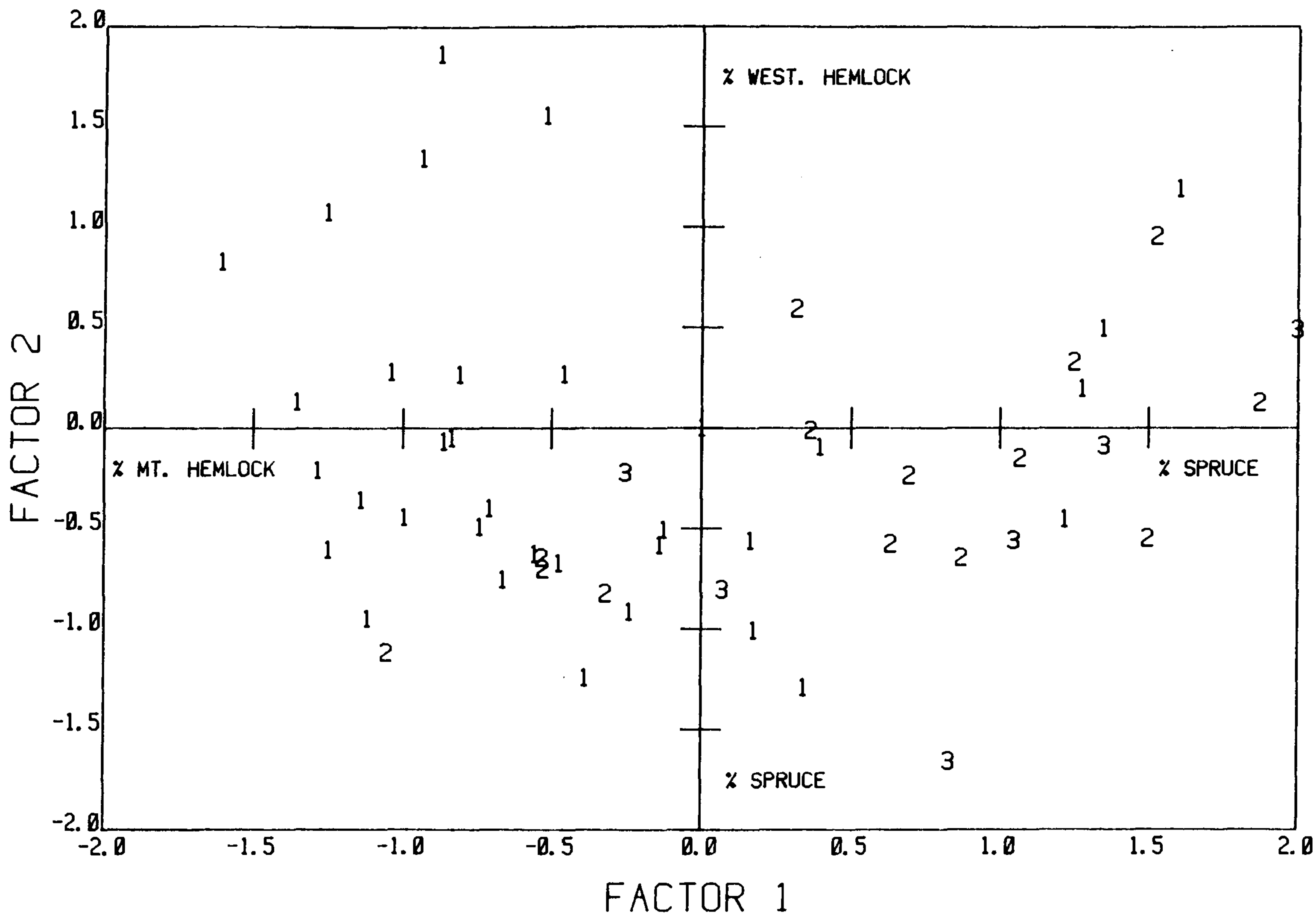

Figure 4. Deer use plotted on principal components factor 1 and factor 2 axes, 1 = low use, 2 = medium use, and 3 = high use.

SEASONAL DISTRIBUTION AND HOME RANGE

Introduction

The objectives of the radio telemetry portion of the study were to determine seasonal patterns of deer movements, seasonal home range sizes, and habitat attributes, such as topographic features and vegetation characteristics used by individual deer.

Recent research on deer habitat use in Alaska has focused on the influence of forest succession after timber harvest (Schoen et al. 1979). In the Prince William Sound region, clearcut logging has not yet taken place on a large scale as has been the case in southeastern Alaska. Therefore, this study involved primarily undisturbed forest systems in contrast to other deer habitat use investigations in Alaska. In addition, the Prince William Sound region is approximately 2 degrees latitude farther north than the northern distribution of deer in southeastern Alaska. This fact has several consequences.

The potential number of heating degree days (5°C baseline) at Juneau, in northern southeastern Alaska is 1,014, whereas Cordova has 851, a difference of 163 degree days. Temperature during the growing season is an important factor affecting tree growth. Farr and Harris (1979) compared and regressed the number of degree days above 5° C against site index of Sitka spruce (at 100 years) for 7 locations along the Pacific coast from southern Oregon to Alaska. An extremely strong negative relationship ($r^2 = 0.99$) was found. Site index decreased from south to north by 1 m of tree height per degree of latitude. Prince William Sound was a notable outlier and not used in the regression. Site index for Prince William Sound was much lower than predicted by the regression equation. This lower productivity was partially attributed to the relatively short growing season, heavy snow pack often extending into the growing season, and younger soils. Timberline is also affected by latitude and is significantly lower in Prince William Sound than in Southeast Alaska. These factors have a direct effect on forest type distribution, tree species diversity, and timber volume. Over the distribution of the species, the most extensive stands of Sitka spruce grow in Southeast Alaska (Farr and Harris 1979). In Prince William Sound there is a very limited extent of high volume timber sites and high volume spruce stands are extremely rare. I hypothesized that these differences in forest type diversity and timber volume would influence the way in which deer use the forest on a seasonal basis.

Radio Telemetry Methods

Chemical Immobilization

Chemical immobilization was used to capture deer to instrument them with radio collars. This method was used successfully in capturing deer in southeastern Alaska (Merriam 1962, Woolf 1970, Schoen et al. 1979). Etorphine hydrochloride (M99) was chosen to immobilize deer primarily because of its wide safety margin which minimizes losses from overdoses and escapes from under doses. In addition, the effects of this drug are fast acting (induction period is approximately 10 to 15 minutes), readily reversible with the antidote diprenorphine (M50-50) and the drugged animal retains essential body functions. Its high potency makes it possible for a small quantity of drug to be used, making it efficient for use in projectiles such as flying darts. The short induction time and early disorientation are important attributes of the drug because the initial flight distance of the animal after injection is a major factor influencing the success of capture. Hebert and McFetridge (1979) describe M99 and some of its chemical properties. Harthoorn (1976) gives a good description of the progressive physiological changes in the animal after injection. These changes were well defined and could be identified in the field and used to estimate the stage of immobilization of the animal at a particular time after injection.

Zylazine hydrochloride (Rompun) was added to the etorphine and the combination was used as an immobilizing solution (Presnell et al. 1973). The chemical properties and physiological effects of Rompun are described by Hebert and McFetridge (1979). When used in combination with etorphine, zylazine reduces or eliminates the initial excitatory stage. It also reduces the total amount of immobilizing drug required and renders the immobilizing agent more effective (through synergism) by reducing the induction time (Harthoorn 1976). Because the sedative effects of zylazine may remain for some time even after the narcotic effects of the M99 have been antagonized (Hebert and McFetridge 1979), the recovery time of immobilized deer was generally prolonged (see Appendix 3).

The dosage I used to immobilize deer was 2 mg M99 combined with 30 mg Rompun. Judging from the induction times (see Appendix 3) and the behavior of the drugged animals, I believe this is a minimum dosage and would recommend a somewhat higher ratio of M99 to Rompun.

Capture Equipment

A Palmer dart gun (Cap-chur rifle) and dart system were used to deliver the immobilizing agent to free-ranging deer. I used a 3 cc dart with a 19 mm barbed needle and a tufted tail piece. The barbed needle proved to be effective in penetrating and remaining in place in the skin of the animal until the drug had been injected into the muscle; whereas the collared needles tended to bounce off of the animal before the drug could be injected. The short needles were used because deer skin is relatively thin and the hair compressible.

The dart was fired from a 32 guage single shot Cap-chur rifle using a .22 blank power load. Four different, color-coded power loads are available for use depending upon the distance of the animal from the shooter. The long distance (red) load can theoretically be used at ranges from 55 to 82 m (Palmer 1979). However, I found that the flight characteristics of the syringe were too erratic to be effective when this load was used. I used the medium or yellow load most often and found that it was relatively reliable and accurate at ranges up to 27 to 32 m.

The fate of darts fired included 11 successful hits, 12 misses, 1 internal charge failure and 3 failures of the .22 load. In addition, in some cases there was incomplete expression of the plunger.

Seven deer were equipped with Telonix radio collars. The transmitters were mounted on a 5-cm-wide butyl collar and contained a lithium cell with an operational life of approximately 34 months. The complete collar assembly weighed approximately 255 grams and cost $225 each. A mortality sensor that increased the pulse rate from 75 to 150 pulses per min 4 hours after cessation of movement was added to the transmitter. Frequencies of the transmitters were in the 150 to 151 MHz range. During immobilization deer were weighed, standard measurements were taken, and sex and age recorded (see Appendix 4).

Capture Techniques

In order to capture and instrument deer with radio collars, deer were hunted in the forested areas and from a skiff during winter when they were on the beach.

During snow-free periods when most of the deer were in forested habitats, we attempted to approach deer on foot to within shooting distance. Occasionally we waited at likely locations in tree stands or in a concealed position and used a call which sounds similar to a fawn distress call.

When snow depths reached approximately 10 to 15 cm (4 to 6 inches) in the forest fringing the beach, deer began appearing on the vegetated and intertidal portions of the beach. At these relatively shallow snow depths most of the herb layer of forest vegetation is unavailable to deer. Coblentz (1970) working with white-tailed deer in Michigan noted that at snow depths of approximately 8 cm (3 inches) deer were forced to feed on browse material rather than the preferred herbaceous plants. When snow conditions became suitable, we used a 5m Boston whaler equipped with an 85 horsepower Johnson outboard motor to approach deer from the salt water. A power trim/tilt to lift the motor partially out of the water helped to avoid obstructions when approaching the beach. Early morning, and especially just after high tide when the water started to run out, proved to be the best time to hunt deer. My observations and those of others (J. Reynolds, D. Klein pers. comm.) indicate that deer go to the beach to feed on kelp (primarily *Laminaria* spp.) that has been deposited by tide and wave action. At high tide loose kelp is often washed into windrows where it is available to deer. This kelp appeared to be most attractive to deer just after the water recedes while it is still fresh and before it freezes.

Hunting from a skiff requires a boat operator and a shooter. We cruised just out from the beaches when snow conditions were favorable and the tide and time opportune. When all conditions were favorable, this form of hunting proved to be the most successful. Deer followed specific patterns in using the beach areas. During February 1982, deer use of the beach appeared to be concentrated near the outer points of bays and later in March on the south-facing beaches of the bays. The protected mouth of a creek along which the tide had deposited kelp was also a good place to see deer. We often waited at these key areas for deer to emerge from the woods onto the beach. When a deer was sighted on the beach, the skiff operator was responsible for smoothly maneuvering the skiff toward the shore, being careful not to unduly disturb the deer and being alert for rocks, shallow water, and breakers. When the shooter was within shooting distance of the deer, the operator tried to keep the boat steady while the shooter took aim and fired. Timing was an important aspect for both the shooter and the skiff operator as the boat was often pitching and rolling.

We attempted to position the dart in a large muscle mass, preferably in the upper hindquarters or in the front shoulder. When the animal was hit it would most often run from the beach into the woods. Generally, 30 to 45 minutes were required for the drug to immobilize the deer (see Appendix 3). We would wait 5 or 10 minutes before tracking the animal to avoid alarming it. Tracking the deer was often difficult and stemmed from having to decipher tracks (or other sign) of the animal of interest from those of other deer. When the drug began to take effect tracking was often easier as the spacing of the tracks of the drugged animal became irregular due to the effects of the drug. Occasionally drugged animals would drag their feet and leave this telltale sign in the snow. Most immobilized deer were found lying on their side in the snow with saliva dripping from their mouths. Once found, immobilized deer were placed in a position of sternal recumbency so that the normal process of eructation could take place. The M50-50 antidote was injected into the animal at the same dosage rate of M99. Then the animal was weighed if possible, measured and outfitted with a radio collar.

The relative success of hunting from a skiff stems from the concentration of deer in the narrow beach fringe under favorable snow conditions and the lack of fear by deer when approached from the water.

Radio Tracking Surveys

The collared animals were tracked from a Super Cub aircraft using an AVM Model LA12 receiver, with two 4-element, null/peak Yagi antennae. The antennae were mounted 30° from the horizontal on each wing strut of the aircraft and were connected to the receiver by way of a right-left switch box which allowed the tracker to listen to the right, left or both antennae simultaneously. This flexibility allowed the tracker to use both antennae when searching for a signal and once the signal was found to switch to the left or right antenna to determine the direction of the signal and to finally pinpoint its location.

The radio-collared animals were aerially monitored approximately once every 2 weeks during late winter and summer of 1982, and during winter of 1983. A total of 115 relocations was obtained. Each relocation was marked on an aerial photo during the monitoring session. Other information recorded during the tracking surveys included elevation of the animal, aspect, and snow cover.

Habitat Use

In order to describe the environment used by deer, habitat values were interpreted from the aerial photos. In doing this analysis I was able to compare the radio telemetry data collected from on individual animals, to habitat use information inferred from the population as a whole, interpreted from pellet group count data. Habitat values interpreted from aerial photos included habitat type, forest type, and percentage of crown closure of the forest stand in which each deer was located. Forest type classification was determined from percent composition of tree species in the stand. Percentage of hemlock and spruce were estimated from the overstory canopy cover. I assumed that percentage of canopy cover of spruce and hemlock in the stand was positively related to percentage of composition by timber volume. Apparently, there is generally a good relationship between gross timber volume and canopy cover but the relationship between net volume and canopy cover is somewhat obscure due to the fact that defect (the amount of unusable timber) cannot be measured accurately by evaluating the canopy (LaBau pers. comm.).

Habitat values were interpreted from 1:15,840 scale, full color aerial photos. Percent canopy cover was estimated by using stereo pairs, a stereoscope, and a U.S.F.S. canopy cover comparator.

Eight habitat types were identified on the study area. These included: beach, beach fringe forest, muskeg, subalpine/krumholtz, deciduous brush/alder slide, alpine tundra, forest and clearcut. Since most of the observations occurred in the forest, it was important to separate this habitat type into component parts.

Home Range and Seasonal Distribution

An x-y grid coordinate system was constructed and overlayed on a 1:63,360 scale topographic map of the study area. Each of the relocations was given an x-y grid number which identified the particular point at which the animal was located. The size of the grid square was 10.4 ha (25.6 acres). This figure corresponded to the accuracy with which the radio-collared deer could be located (Schoen et al. 1979). A data file with the grid number, date of relocation and habitat values was entered into the University of Alaska computer system.

Polygons or circles may not be the most accurate representation of home range configuration (Jennrich and Turner 1969). A circular configuration suggests that the center of locational points is equally variable in all directions from a center of activity which is probably not the usual situation. Koepple et al. (1975) have suggested an ellipse based on a bivariate normal distribution of points as a more accurate representation of home range configuration. The focus of the ellipse (the point x,y) represents the center of activity of the animal. The variance-covariance matrix on the x,y locational points can be decomposed to find the eigenvalues and eigenvectors of the matrix. Then the major and minor axes of the ellipse represent the variance of the group of points.

A plotting program which incorporates the home range ellipse model was developed and used with black-tailed deer in southeastern Alaska (Schoen et al. 1979). This same program was used to construct seasonal home range ellipses and to calculate seasonal home range areas for radio-collared deer in the Prince William Sound region. The following dates defined the seasons used: winter-21 December to 21 March, spring-22 March to 21 June, and summer-22 June to 21 September.

Analysis of Radio Telemetry Data

The data collected on radio-collared animals included date of observation, elevation, aspect, habitat type, forest type and percent crown closure of the forest stand in which the animal was located. All of the variables were entered in a single data file and a series of SPSS (Nie et al. 1975) programs were run to analyze the data.

The Condescriptive program gave basic statistics (means, medians, modes, variance, skewness and kurtosis) on each of the variables. In addition, the absolute and relative frequency of each value within each of the variables was given and a frequency distribution histogram constructed. This output made it possible to check if the program was reading the data file correctly and also gave a general data description on each variable. The frequency distributions and histograms provided insight as to where within the range of values most of the observations fell.

Next, the data were subdivided according to seasons based on equinox dates. My primary objective was to look for seasonal differences in deer use of habitat attributes in the environment. A chi square test was used on the locational variables to test the null hypothesis that there is no seasonal effect in use of the variables. In order to get the required expected value of at least 5 counts in each cell, the values of each variable were divided into 2 categories. The cut points for each of these categories varied depending on the variable.

In their classification system for vegetation of Alaska, Viereck and Dyrness (1980) classified forest systems based on the amount of tree canopy cover. Forest stands with 60 to 100 % canopy cover are classified as closed stands while open stands have from 25 to 60 % closure. Therefore, I used 60 % as the cut point for the categories open and closed forest.

Forest type was determined by the relative amount of spruce and hemlock in the stand. The vegetation data showed that the percentage of spruce in a stand ranged from 0 to 85, with a mean of 12 and a standard deviation of 18. I used the mean (12 %) as a reasonable cut point. The 50 % break for hemlock composition was chosen on the basis of previous vegetation work (Eck 1982) which used this figure as the break point for classifying forest stands as hemlock.

Elevation was divided into categories of 91 m (300 ft) or less and more than 91 m. Prior information based on winter track counts indicated that this elevation was a reasonable estimate for delimitation of concentration of deer winter use.

The effect of aspect was analyzed by looking at south versus north-facing slopes. Aspects north of an east-west line (90° to 270°)

were classified as north-facing slopes, while aspects south of that line were called south-facing. Locations without aspect or flat areas were not used in the analysis.

The chi square test was used first to test the null hypothesis of no seasonal effect. If the null hypothesis can be rejected, then we can test each season individually. For those variables in which a difference in use between seasons was statistically significant, a Mann-Whitney U test was run to see which seasons were significantly different from the others.

In using the Mann-Whitney test, I assumed independence between observations. Since there was a 2-week period between observations, I feel that this assumption was valid. This test also assumes a simple random sample. The sample of radio-collared deer included 1 deer that was captured in the forest and 6 that were immobilized and captured from the beach during the winter. Studies conducted in southeastern Alaska on Sitka black-tailed deer have indicated that there may be migratory and resident portions of the population (Schoen and Kirchhoff 1984). Migratory deer (approximately 75 % of the population) made definite shifts between winter and summer range whereas resident deer showed considerable overlap between summer and winter home ranges. If among Prince William Sound deer there exists a significant portion of the population that remains at a relatively high elevation throughout the year, then a sample collected on the beach would not include this portion of the population. Therefore, the sample of radio-collared deer may not represent a simple random sample of the population.

Finally, I used Wilcoxon Signed rank test (Conover 1980:180) to test the null hypothesis that spring home range size is the same as winter home size versus the alternative that spring home range size is larger than winter home range size. Initially, I wanted to test for a seasonal difference between summer and winter home range sizes. But because I did not have enough observations during summer, I compared spring (March 21 to June 20) with winter. I considered one radio-collared deer an outlier with respect to the rest of the sample and therefore excluded this individual from the analysis. This animal was a male captured as a fawn. His winter home range size was over 6 times the area of his spring home range size.

Results and Discussion

Habitat Type

The chi square test indicated that there was a seasonal difference with respect to habitat use. However, because 44 % of the cells had expected frequencies of less than 5 counts, the chi square value and resulting significance level were invalid. As a more conservative test, the chi square contributions of each cell with expected frequency less than 5 were subtracted from the overall chi square statistic. The resulting chi square value still showed a significant differential pattern of habitat use between seasons ($0.01<p<0.025$).

Throughout winter and spring, the majority of the deer were located in the forest (Table 5). Ninety three % of winter observations and 75 % of spring observations were in forest. Even during summer 41 % of the observations occurred in the forest. These results illustrate the importance of this habitat type for deer not only during winter but throughout the entire year. The extremely high winter use of the forest suggests that this habitat type is critical to the overwinter survival of deer. Therefore, the particular forest types which are important to overwinter survival should be identified and described in terms of their outstanding characteristics.

During summer, alpine areas received more use than any other habitat type. In addition, 83 % of the summer relocations were above 91 m. By putting the elevation and summer forest use results together,

Table 5. Chi square test results on seasonal use of habitat type by radio-instrumented deer. The upper and lower number in each cell represent the number and percent respectively, of observations for that variable during a particular season.

HABITAT	SEASON WINTER 1.	SPRING 2.	SUMMER 3.	ROW TOTAL
1. BEACH FRINGE				
No. observed	1	14	1	16
% observed	3.6	22.2	4.5	14.2
2. ALPINE				
No. observed	1	2	12	15
% observed	3.6	3.2	54.5	13.3
3. FOREST				
No. observed	26	47	9	82
% observed	92.9	74.6	40.9	72.6
COLUMN	28	63	22	113
TOTAL	24.8	55.8	19.5	100

it was also apparent that deer were associated with the upper elevation forests during summer. The high use of the beach fringe during spring (22 %) was probably related to the early green-up of nutritious vegetation in this type (Klein 1965). Field observations suggest that new alder buds and early skunk cabbage growth are especially important in the diet during this time. In early March, 1982, when there was still 10 cm of snow in the beach fringe, the rumen contents of a 13-year-old doe consisted of approximately 75 % bunchberry, 15 % alder buds, lichen, and hemlock sprigs, and 10 % kelp.

Seasonal Use of Habitat Values

Crown closure

During winter most of the radio-collared deer in the sample were located in open-canopied stands; 64 % of the relocations were in forest stands of less than 60 % crown closure (Table 6). This finding supports the pellet group count data which indicated that during mild winter conditions, deer use was highly correlated with open stands.

During spring, deer use of open and closed stands was approximately equal. However, during summer much greater use was made of open stands (82 % of the observations). In summer, because of the higher elevation and variation in aspect, portions of the alpine vegetation are in an early growth stage while plants at lower elevations have already begun to mature. Klein (1965) indicated that plants in early physiological stages of growth are more nutritious and have higher digestibility than mature plants. In addition, alpine plants (especially those growing on south slopes) have the advantage of

Table 6. Chi square test results on seasonal use by radio-instrumented deer of forest stands in relation to overstory crown closure.

CROWN CLOSURE	SEASON WINTER 1.	 SPRING 2.	 SUMMER 3.	ROW TOTAL
1. 60 % OR LESS				
No. observed	18	28	18	64
% observed	64.3	45.9	81.8	57.7
2. MORE THAN 60 %				
No. observed	10	33	4	47
% observed	35.7	54.1	18.2	42.3
COLUMN TOTAL	28 25.2	61 55	22 19.8	111 100

Chi square = 9.2 with 2 degrees of freedom   p = 0.10

being exposed to a greater quantity and quality of sunlight due to the absence of shade-producing overstory plants.

Spruce

The chi square analysis showed a highly significant ($p = 0.001$) seasonal difference in the pattern of use with respect to the amount of spruce in a stand (Table 7). Mann-Whitney U tests indicated that significant differences in use of spruce occurred between winter and summer and between spring and summer. There was no difference in use between winter and spring. During both winter and spring deer use was distributed evenly between stands of less than 12 % spruce and those with 12 % or more. But during summer 91 % of the observations were in stands with less than 12 % spruce. The most likely explanation for these seasonal differences is that deer tend to move to higher elevations during summer to feed on highly nutritious alpine forage that grows above the presence of spruce. Secondly, during early summer, before there is much vegetative growth in alpine areas, deer use is correlated with upper elevation forest. Since the amount of spruce in a stand and elevation of the stand are negatively correlated ($r^2 = -0.26$) the interaction between these factors most likely accounts for the inverse correlation between deer use and percent spruce. In addition, deer in forested areas in summer were associated with open-canopied stands whereas spruce types tend toward closed canopies (r^2 between crown closure and percentage of spruce = 0.45).

Table 7. Chi square test results on seasonal use of forest type variables by radio-instrumented deer.

SPRUCE %	WINTER 1.	SPRING 2.	SUMMER 3.	ROW TOTAL
1. 12 % OR LESS				
No. observed	12	31	20	63
% observed	42.9	50.8	90.9	56.8
2. MORE THAN 12 %				
No. observed	16	30	2	48
% observed	57.1	49.2	9.1	43.2
COLUMN TOTAL	28 25.2	61 55	22 19.8	48 100

Chi square = 13.5 with 2 degrees of freedom p = 0.001

HEMLOCK %	WINTER 1.	SPRING 2.	SUMMER 3.	ROW TOTAL
1. 50 % OR LESS				
No. observed	6	11	6	23
% observed	21.4	18	27.3	20.7
2. MORE THAN 50 %				
No. observed	22	50	16	88
% observed	78.6	82	72.7	79.3
COLUMN TOTAL	28 25.2	61 55	22 19.8	111 100

Chi square = 0.85 with 2 degrees of freedom p = 0.65

Hemlock

There was no significant difference in the pattern of use with respect to the amount of hemlock across seasons. However, chi square results indicate a more pronounced use of stands with more than 50 % hemlock compared to stands with less than 50 % hemlock throughout all seasons. During winter, spring, and summer approximately 79, 82 and 73 % of the relocations respectively, were in stands with more than 50 % hemlock. When results of use of hemlock stands are examined in light of the spruce use results, it becomes apparent that mixed stands or perhaps the combination of use between nearly pure spruce stands and pure hemlock stands are used by deer during spring and winter.

Aspect

Although there was no significant difference in use of south versus north-facing slopes between seasons, south-facing slopes received more use in all seasons (Table 8). During winter, 90 % of the observations were on south-facing slopes, while during spring and summer use of this aspect was 80 and 82 % respectively. I suspect that this pronounced use of south slopes across all seasons is indicative of the generally higher productivity, earlier snow melt, and longer growing season associated with south-facing slopes.

Elevation

Although most of the observations during winter and spring were at low elevations (89 % and 83 % respectively were below 91 m), there was

Table 8. Chi square results on seasonal use of elevation and aspect by radio-instrumented deer.

ELEVATION		SEASON WINTER 1.	SEASON SPRING 2.	SEASON SUMMER 3.	ROW TOTAL
1. 91 METERS OR LESS					
No. observed		25	52	4	81
% observed		89.3	82.5	16.7	70.4
2. ABOVE 91 METERS					
No. observed		3	11	20	34
% observed		10.7	17.5	83.3	29.6
	COLUMN TOTAL	28 24.3	63 54.8	24 20.9	115 100

Chi Square = 42.5 with 2 degrees of freedom $p < 0.001$

ASPECT		SEASON WINTER 1.	SEASON SPRING 2.	SEASON SUMMER 3.	ROW TOTAL
1. SOUTH-FACING					
No. observed		16	28	14	58
% observed		88.9	80	82.4	82.9
2. NORTH-FACING					
No. observed		2	7	3	12
% observed		11.1	20	17.6	17.1
	COLUMN TOTAL	18 25.7	35 50	17 24.3	70 100

Chi square = 0.67 with 2 degrees of freedom $p > 0.70$

a pronounced shift in use of elevation during summer when 83 % of the relocations were above 91 m (300 ft) (Table 8). This shift in elevation reflects the fact that most of the deer appeared to move to higher elevations and utilize alpine areas during late summer. This interpretation has been supported by other portions of this analysis.

Schoen and Kirchhoff (1984) classified radio-collared deer based on the amount of overlap between winter and summer home ranges of individual deer. Migratory deer showed no overlap between seasons while resident deer exhibited at least some overlap. During all seasons migratory deer were located at significantly higher elevations than resident deer. The most conspicuous difference between the two groups was during summer when mean elevation of use of migratory deer was 627 m (2,057 ft) compared to 133 m (436 ft) for resident deer. This difference was primarily due to use of alpine areas by migratory deer while resident deer remained at lower elevations. Apparently, sufficient overlap in the elevational range of these two groups occurred during the fall rut to allow genetic interchange and prevent distinct subpopulations from evolving.

According to the definitions used by Schoen and Kirchhoff (1984), all of the individuals in my sample were resident deer. This does not necessarily support the conclusion that migratory deer do not exist in Prince William Sound. As indicated earlier (see Methods section), the sample of radio-collared deer does not necessarily represent a random sample of the population due to the fact that most of the deer were captured on the beach and therefore most likely would be individuals of the resident group (see seasonal home range section for discussion of individual differences).

The short distance between seasonal home ranges exemplified by the overlap in summer and winter home ranges of Prince William Sound deer may be partially a result of a collapse in variance of the system as a whole in contrast to Southeast Alaska. Due to the relatively low elevation of timberline, deer in the Prince William Sound region have easy access to alpine areas. The mean elevation used by deer during summer was 238 m (780 ft). Additionally, the distance from beach to alpine is relatively short. Lower altitude of timberline and shorter beach to alpine distance, compared to Southeast Alaska, both contribute to a decrease in distance between seasonal home ranges. Southeastern Alaska deer probably have to make longer migrations to suitable alpine habitat. Hence, in Southeast Alaska, the variability in habitat types along a migration route should be large and the probability of deer finding suitable summer range short of the mountain tops would be quite high. Prince William Sound deer, on the other hand, are limited in the choice of high quality summer range available to them below timberline. Therefore, one might expect an overlap in winter and summer ranges of deer living in Prince William Sound even though they may migrate to alpine areas during summer.

During spring, 83 % of the relocations were at 91 m or lower. The fact that even after an extremely mild winter deer were using relatively low elevations during spring was at first surprising. But as discussed under habitat type these observations indicate that during spring deer tend to feed at low elevations where green-up of understory vegetation occurs first. Alder buds seemed to be particularly appealing during this stage. Apparently, deer tend to follow the band of nutritious new growth of vegetation as green-up progresses up the mountain.

Seasonal Difference in Home Range Size

The Wilcoxon Signed rank test showed that there was a significant difference in home range size between spring and summer ($p = 0.03$). Even though the data were collected under mild winter conditions, spring home range areas tended to be larger than winter areas. Average size of spring home ranges was 282 ha compared to 106 ha for average winter home range size. Schoen et al. (1981) reported mean home range areas of 1521 and 122 ha during spring and winter, respectively for deer in southeastern Alaska. In general, most northern deer have adapted to winter conditions of low food availability by restricting their energy expenditure through reduced food intake and travel. Deer in Prince William Sound appear to retain this tendency even during mild winters. In a typical year, snow melt during the spring allows deer to travel to areas previously covered by deep snow. In addition, during the latter part of spring green-up has begun and deer are able to follow the progression of early plant growth.

General Movement Patterns

The longest straight line distance traveled between successive locations was 13.3 km for an adult doe between June 2 and June 25, 1982 from Deer Cove on the west coast of Hinchinbrook to Anderson Bay on the north side of the Island. No other such extensive movements were observed among radio-collared deer. Most deer tended to make elevational movements within a single drainage.

Although all of the radio-collared animals had overlapping spring and winter home ranges, one adult male used a winter range that was completely enclosed within his spring home range (see Fig. 8 in Appendix). The center of activity for spring and winter (the foci of the ellipses) were almost identical.

Six of the seven radio-collared deer were located above timberline at least once during summer. Only one of the radio-collared animals was never located above timberline. This animal was an old buck whose movements tended to parallel the coastline during winter, while his spring and summer movements were oriented toward and away from the coast. His winter home range size (612 ha) was nearly equal to his spring use area (570 ha).

All of the deer in the sample used low elevation areas (less than 30 m) during the winter.

SUMMARY

Deer use was measured using pellet group indicies. There was a significant difference in deer winter use between 5 forest types. Mountain hemlock forests (more than 50 % timber volume in mountain hemlock) received the heaviest use during the winter of 1981-82, a winter of mild snow conditions. This is probably related to the open canopy and dense understory growth (deer forage) associated with mountain hemlock stands. As the mountain hemlock component in a forest stand increased beyond 50 % deer use decreased.

Five of 39 forest inventory variables were meaningful in defining characteristics of forest stands used by deer during winter. Forest stands with low basal areas received greatest deer winter use. These stands generally have an open canopy which is associated with high production of understory vegetation that provides forage for deer. Although these stands are productive of deer forage, during winters of heavy snow accumulation the understory vegetation in these stands would be largely unavailable to deer.

The amounts of blueberry and goldthread in a forest stand were also important variables in defining deer winter use. These 2 understory plant species are outstanding deer winter forages.

High deer use was associated with high deviation in crown closure. High variability in the overstory canopy is characteristic of unevenaged, old growth forests. Apparently, the variability in the canopy allows sufficient light penetration to allow growth of understory plants while intercepting a significant amount of the snowfall to allow deer access to forage plants within the stand.

Stands with high timber volume also received high deer winter use. Sites that are capable of producing large trees would presumably also be capable of producing high biomass of understory plants of high nutritional quality as forage given sufficient light penetration through the forest canopy. If deer are able to select forage of high nutritional value (Hanley and McKendrick 1985), high volume stands may provide high quality feeding areas for deer. In addition, Schoen and Kirchhoff (1983) found snow depths to be less in mid-to high volume stands than in low volume stands. Availability of high quality deer forage is affected primarily by snow accumulation.

Information from radio-collared deer revealed a significant seasonal difference with respect to habitat use. The percentage of relocations in forest types during winter was 93, 75 during spring, and 41 during summer. The extremely high winter use of forest suggests that this habitat is critical to the overwinter survival of deer.

High use of beach fringe during spring was related to early green-up of vegetation in this habitat type. During summer, alpine areas received more use than any other habitat type.

Spring home range areas were significantly larger than winter home range areas. Average winter home range size was 160 ha while the average for spring was 282 ha.

Most of the radio-collared animals tended to make seasonal elevational movements within a single drainage rather than long cross-country migrations.

South-facing slopes received greatest use in all seasons.

CONCLUSIONS

Deer winter use was found to be high in stands that supported a high biomass of blueberry species and winter-green forbs. I suspect that in a severe winter deer would select stands in which forage availability was high. This may not necessarily be stands in which forage production is high. High forage production is associated with an open overstory canopy that allows penetration of sunlight as well as accumulation of snow on the forest floor. Therefore under conditions of high snow accumulation, deer in Prince William Sound, as is the case in Southeast Alaska, would most likely use old growth forest stands with trees of different age classes. The layering of the overstory canopy allows light to penetrate for growth of understory vegetation and large trees with well-developed upper canopies intercept and hold large snow loads thus accounting for low snow accumulation on the forest floor. Another characteristic of high volume, old growth stands that relates to forage availability is the development of moss-covered hummocks at the bases of some of the larger trees. These hummocks generally support dense growth of herbaceous winter-green forbs, particularly bunchberry and goldthread. The forage growing on raised hummocks remains available to deer even after the herbaceous plants growing on the forest floor have been covered by snow.

Mountain hemlock stands received heavier use than other stands during the winter of 1981-82. This species is quite prevalent in

Prince William Sound even at low elevations where it is mixed with Sitka spruce and western hemlock. These stands are generally associated with low site productivity for timber and have an open overstory canopy. The tapered bole typical of mountain hemlock (Harlow and Harrar 1941) supports low snow loads. For these reasons I would expect low deer use of these stands in winters of heavy snow accumulations.

RECOMMENDATIONS

Beach fringe forest stands receive high deer use even during mild winters. The larger trees in this habitat also provide primary nesting sites for bald eagles. Therefore, I feel it is important to retain these stands in their natural state. However, beach fringe stands are only one critical element of deer seasonal habitat. There is evidence of heavy browsing by deer on blueberry shrubs in beach fringe stands as a consequence of past winters of heavy snow accumulation. When snow conditions ameliorate, deer tend to move out of beach fringe stands to forest stands at higher elevation or farther inland. These "relief" stands are important to deer because they offer browse material which is in good condition. Deer use of these stands also allows severely browsed plants in the beach fringe to recover. Therefore, large blocks of high volume, old growth forest should be left in other areas used by deer in addition to beach fringe areas. Due to its northern latitude and low site productivity for timber production, the Prince William Sound region has relatively poor timber in contrast to Southeast Alaska. Other resource values may exceed those of timber, thus justifying protection of the old growth forests from extensive timber harvest.

In the draft forest plan for the Chugach National Forest one of the stated management goals is to maintain or improve existing habitats used by species which serve as indicators of management effects. In order to carry out this goal, proposed sites of timber sales should be evaluated comprehensively for wildlife habitat values as well as timber resources. The full scale impacts of development for timber harvest on wildlife, including entry, road building, timber removal, and the long term effects of the regrowth of successional forests should be addressed.

Nearly pure stands of high volume spruce grow on the south end of Montague Island. These stands are unusual in that the trees they contain are among the largest in the region and they represent the only large expanse of Sitka spruce stands in Prince William Sound. Very little is known about deer use in these stands, particularly under severe winter conditions. Before cutting of these stands takes place their wildlife relationships and seasonal use patterns should be clarified.

Although some of the characteristics of deer habitat use in Prince William Sound during winter have been identified in this study, similar studies should be carried out during severe winters when deer are existing closer to their environmental limitations.

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Appendix 1. Topographic and vegetation variables used in analysis of deer winter use of forest stands.

Variable	Common Name	Abrev.	Unit of Measurement
Picea sitchensis	Sitka spruce	% SPRUCE	% composition
Tsuga heterophylla	western hemlock	% WEST HEM	"
Tsuga mertensiana	mountain hemlock	% MTHEM	"
Vaccinium ovalifolium	early blueberry	VAOV	% canopy cover
Vaccinium caespitosum	dwarf blueberry	VAOV	"
Vaccinium alaskensis	Alaska blueberry	VAOV	"
Rubus spectabilis	salmonberry	RUSP	"
Menziesia ferruginea	rusty menziessia	MEFE	"
Cladothamnus pyrolaeflorus	copper-flower	CLPY	"
Echinopanax horridum	devils club	ECHO	"
Sorbus sitchensis	mountain ash	SOSI	"
Cornus canadensis	bunchberry	COCA	"
Coptis aspleniifolia	goldthread	COAS	"
Coptis trifoliata	"	COTR	"
Rubus pedatus	trailing bramble	RUPE	"
Lysitchiton americanium	skunk cabbage	LYAM	"
Fauria crista-galli	deer cabbage	FACR	"
Streptopus amplexifolius	twisted stalk	STAM	"
Tiarella trifoliata	foamflower	TITR	"
Listera cordata	heartleaf twayblade	LICO	"
Gymnocarpium dryopteris	oak-fern	GYDR	"
Dryopteris dilitata	spreading woodfern	DRDI	"

Blechnum spicant	deer fern	BLSP	"
Cornus canadensis		GMCOCA	grams per m^2
Coptis aspleniifolia		GMCOAS	"
Rubus pedatus		GMRUPE	"
Coptis trifoliata		GMCOTR	"
Distance to salt water		WATER	kilometers
Elevation		ELEV	meters
Aspect		ASPECT	degrees
Slope		SLOPE	degrees
Crown closure		CROWNCLO	%
Deviation in crown closure		DEVCLO	standard deviation units from mean
Site index		SITE	height of dominant trees at 100 years
Basal area		BASAL	ft^2 per acre
Net volume		NETVOL	board feet per acre
Mean height of *Vaccinium*		HTVAVO	meters
Mean number of stems of *Vaccinium* spp.		STEMVAVO	stems per m^2

Scientific and common names of other plants mentioned in the text:

Cladonia spp.	pixie cup
Usnea spp.	beard lichen
Sphagnum spp.	peat moss
Rhytidiadelphus	fern moss
Empetrum nigrum	crowberry
Phyllodoce aleutica	mountain heather
Eriophorum angustifolium	cotton grass

Andromeda polifolia	dwarf bogrosemary
Rubus chamaemorus	cloudberry

Appendix 2. Scientific and common names of invertebrate, fish, bird, and mammal species mentioned in the text.

Scientific Name	Common Name
Mytilus edulis	common mussel
Oncorhynchus gorbuscha	pink salmon
Oncorhynchus keta	chum salmon
Oncorhynchus kisuch	silver salmon
Platichthys stellatus	starry flounder
Haliaeetus leucocephalus	bald eagle
Branta canadensis	Canada goose
Sorex palustris	northern water shrew
Ursus arctos	brown bear
Lutra canadensis	river otter
Enhydra lutra	sea otter
Mustela vison	mink
Mustela erminea	short-tail weasel
Clethrionomys rutilus	red-backed vole
Castor canadensis	beaver
Marmota caligata	hoary marmot
Odocoileus hemionus sitkensis	Sitka black-tailed deer

Appendix 3. Immobilization results using 2 mg M99 and 30 mg Rompun on Sitka black-tailed deer.

DATE	INDUCTION TIME (minutes)	RECOVERY TIME (minutes)	SEX	AGE	WEIGHT (kilograms)
1-21-82	33	38	male	fawn	29
2-23-82	34	41	male	adult	73 (est)
3-1-82	25	39	female	adult	-
3-12-82	45+	0	male	adult	-
3-13-82	41	35	male	adult	61
3-13-82	46	19	male	adult	54
3-16-82	40	50	male	adult	64

Appendix 4. Standard measurements taken on immobilized Sitka black-tailed deer during 1982. Lengths in centimeters, weights in kilograms, and age in years.

Date Captured	1-21	2-23	3-1	3-7	3-12	3-13	3-13	3-16
Sex	male	male	female	female	male	male	male	male
Age	fawn	adult	adult	13	adult	adult	adult	adult
Weight	29	73(est)	-	41	-	61	54(est)	64
Body Length	121	163	140	135	-	145	147	155
Tail Length	13	15	16	14	-	17	14	18
Hindfoot Length	36	43	38	43	-	45	40	46
Heart Circum.	72	97	84	84	-	99	88	96
Neck Circum.	31	43	33	37	-	41	39	41
Head Length	-	34	27	28	-	31	29	32

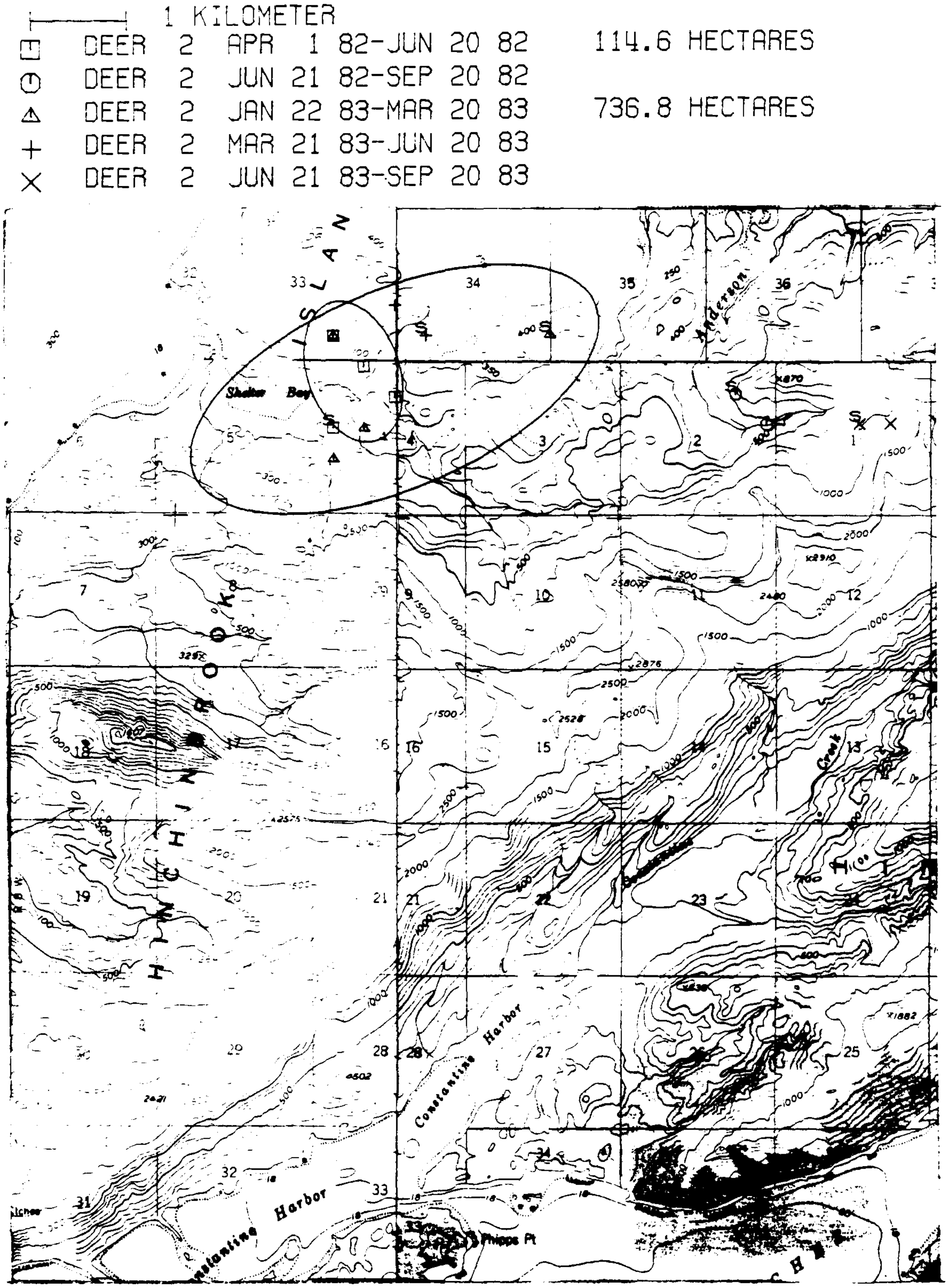


Figure 5. Seasonal home range ellipses for deer 2.

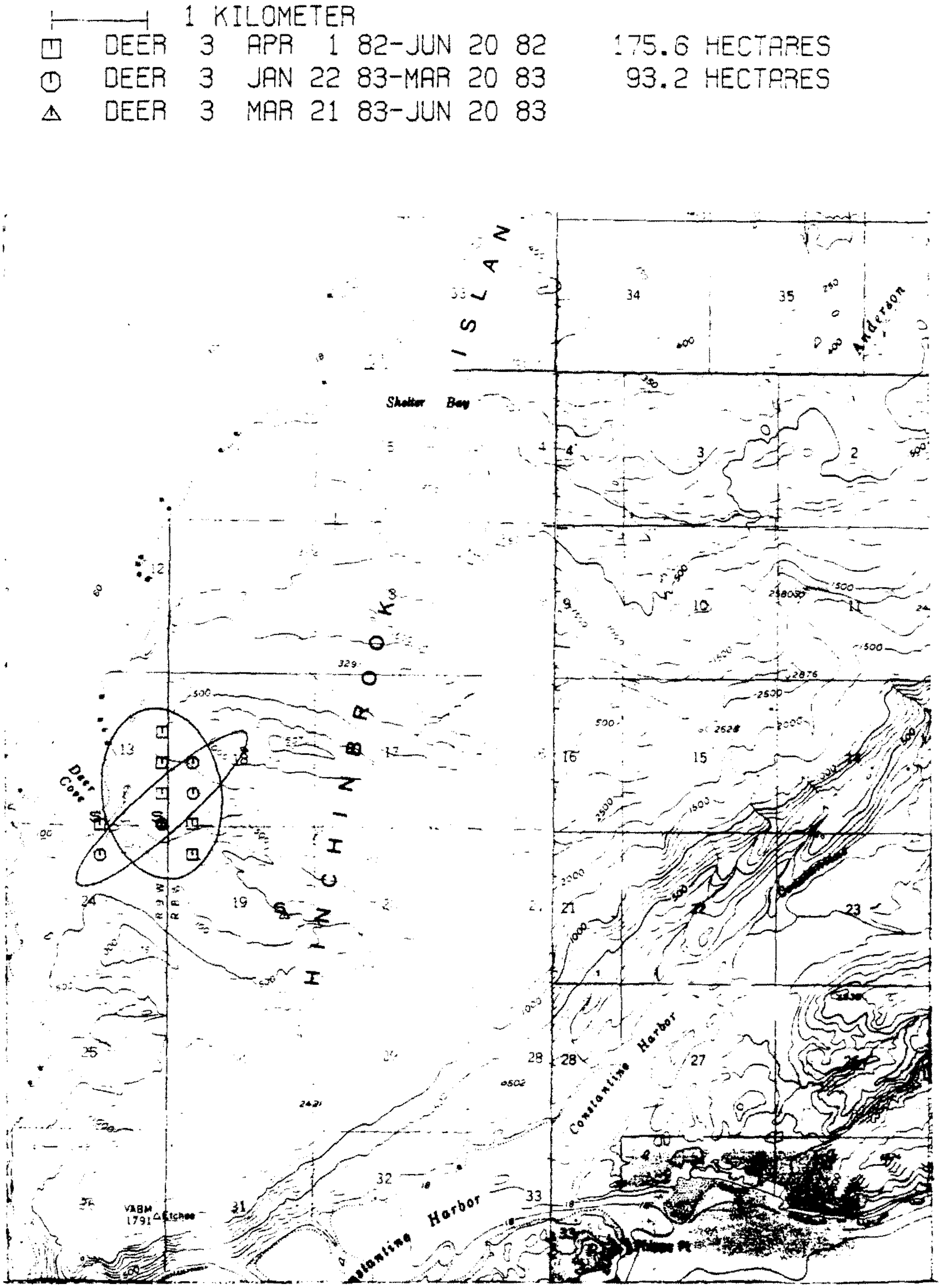


Figure 6. Seasonal home range ellipses for deer 3.

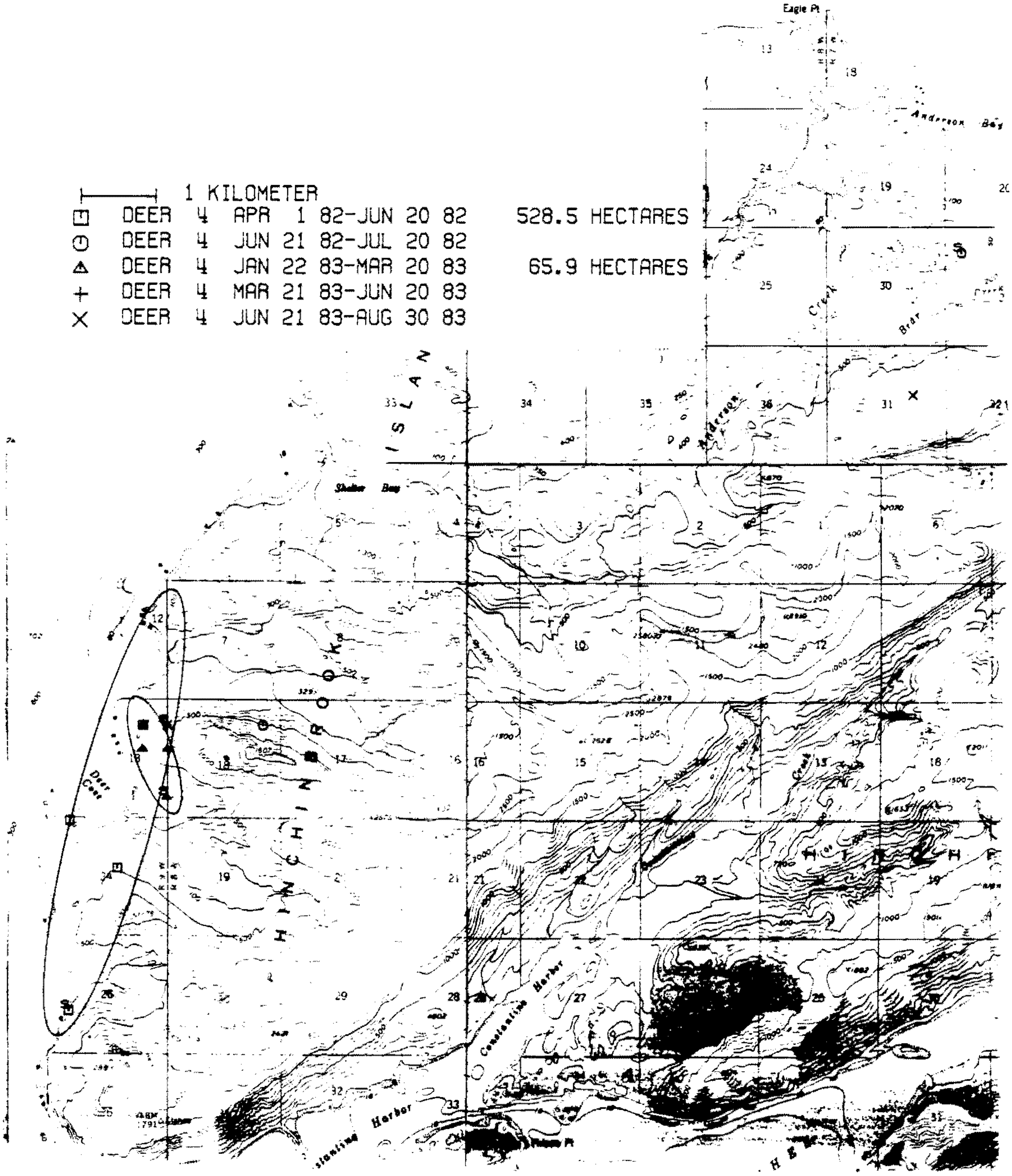


Figure 7. Seasonal home range ellipses for deer 4.

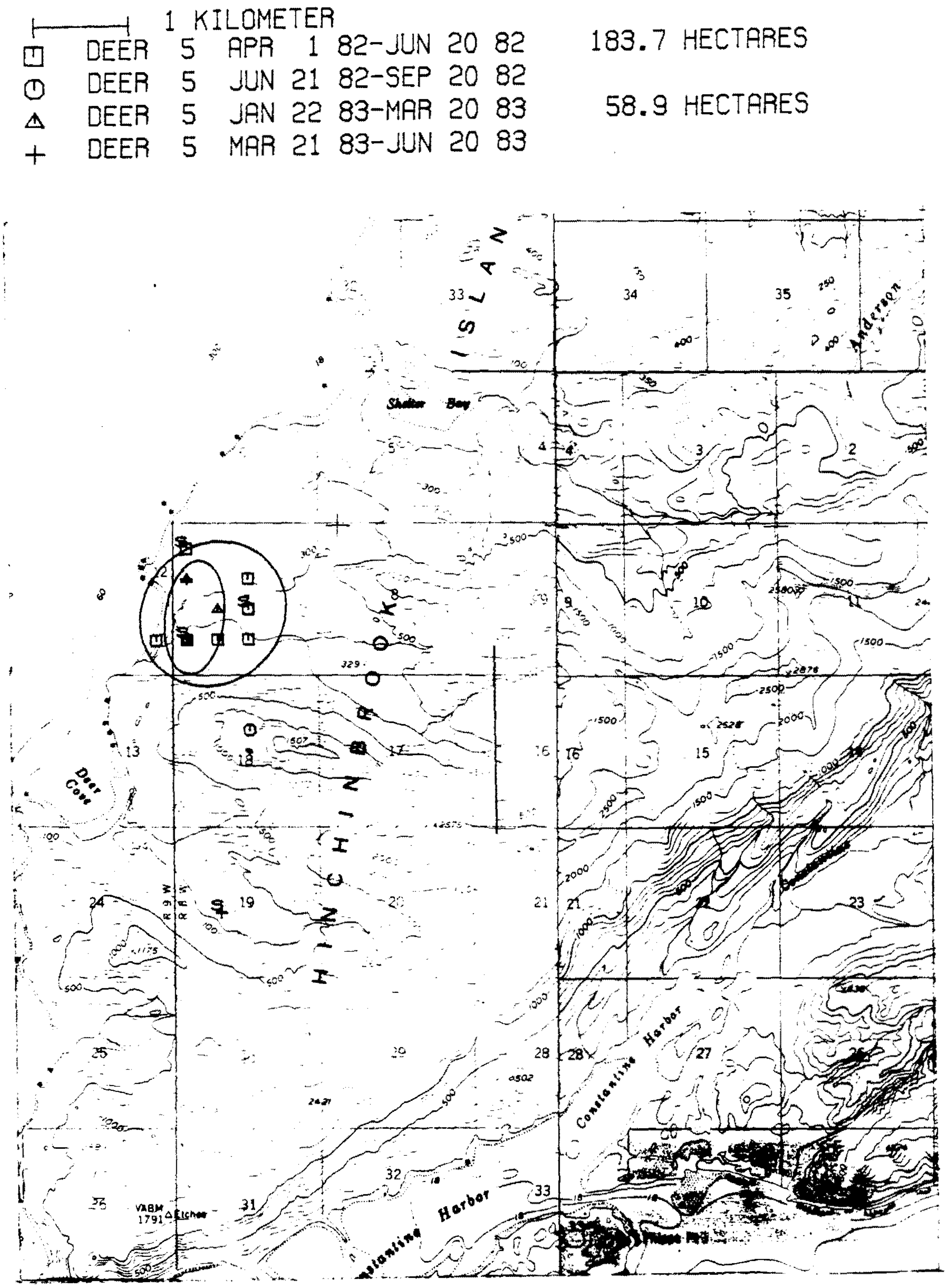


Figure 8. Seasonal home range ellipses for deer 5.

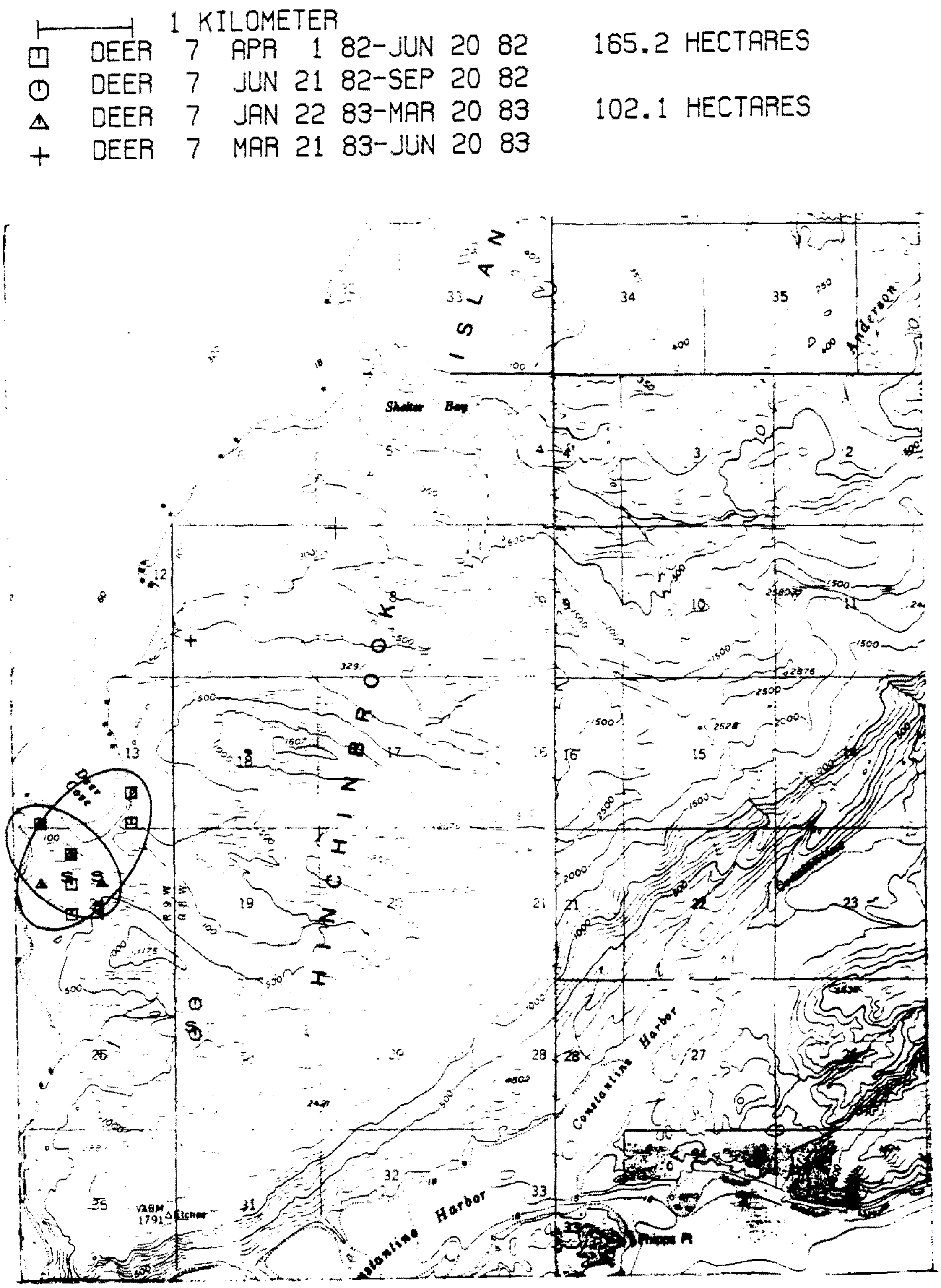


Figure 9. Seasonal home range ellipses for deer 7.

1 KILOMETER　　　　1 MILE

□	DEER	8	APR 1 82-JUN 20 82	81.9 HECTARES
⦶	DEER	8	JAN 22 83-MAR 20 83	29.5 HECTARES
△	DEER	8	MAR 21 83-JUN 20 83	

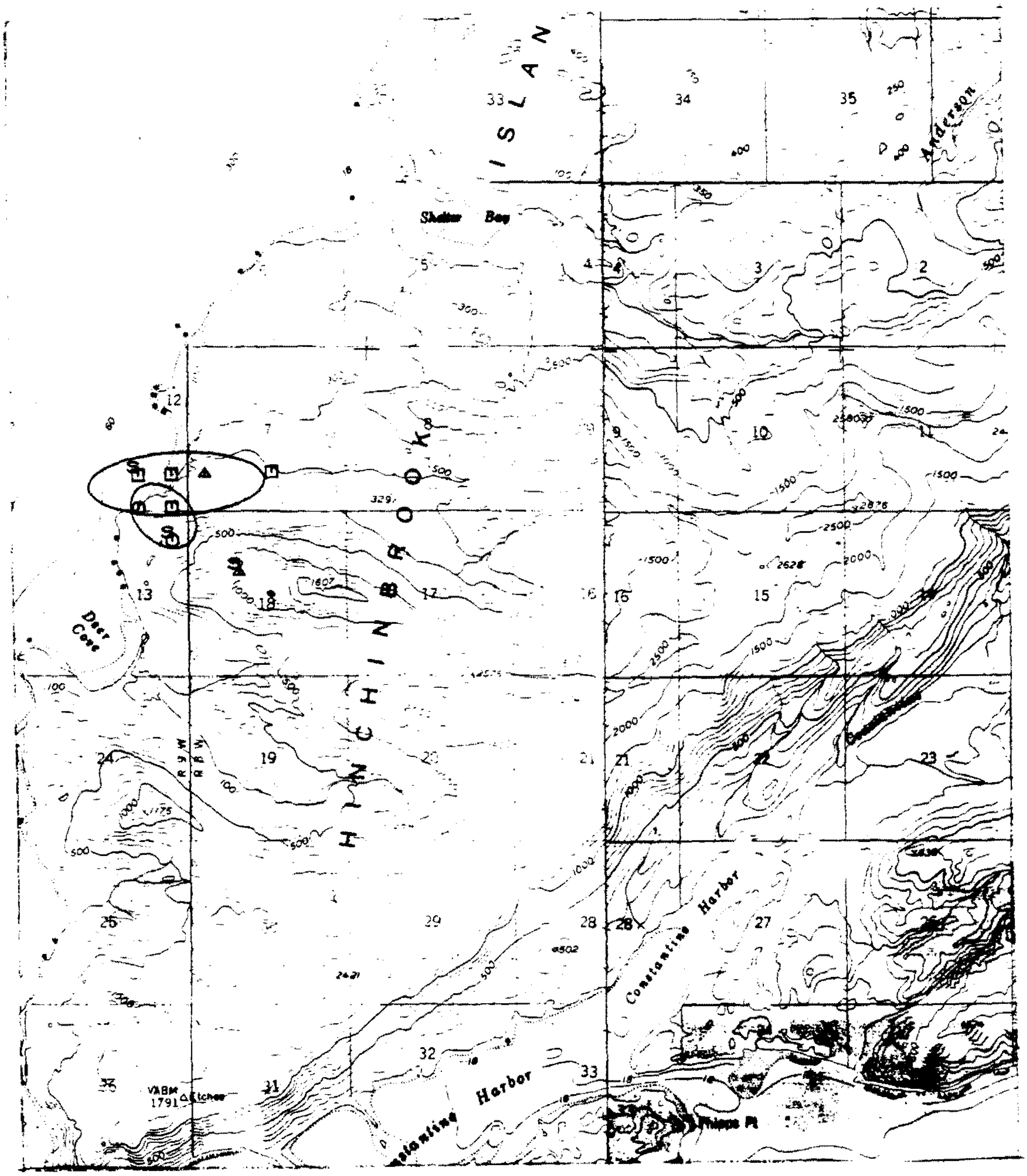
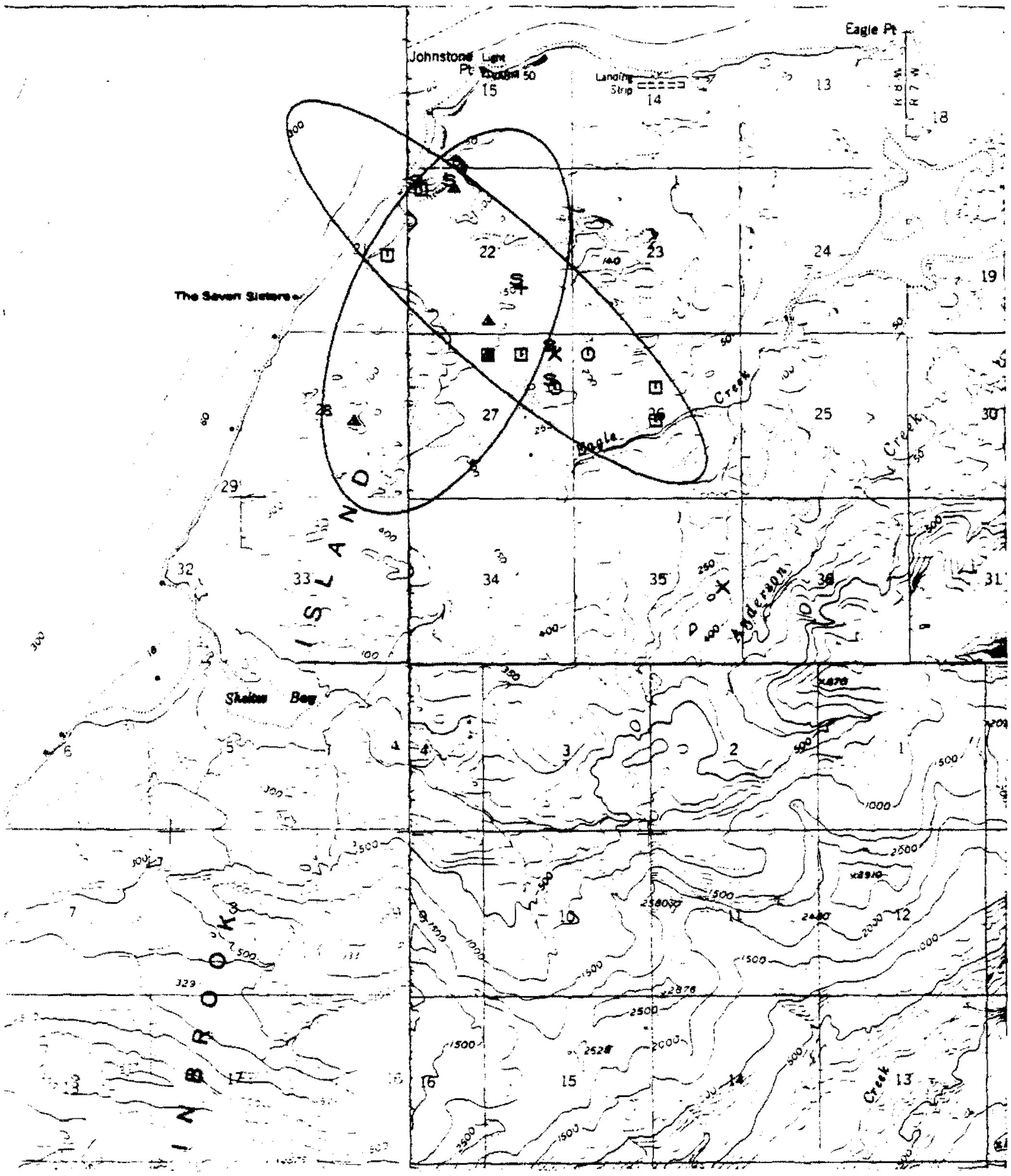


Figure 10. Seasonal home range ellipses for deer 8.



× DEER 9 JUN 21 83-AUG 30 83
+ DEER 9 MAR 21 83-JUN 20 83
△ DEER 9 JAN 22 83-MAR 20 83 611.8 HECTARES
◷ DEER 9 JUN 21 82-JUL 20 82
⊡ DEER 9 APR 1 82-JUN 20 82 569.8 HECTARES
|——| 1 KILOMETER

Figure 11. Seasonal home range ellipses for deer 9.