

Alaska Department of Fish and Game
Division of Wildlife Conservation

Federal Aid in Wildlife Restoration
Research Final Report

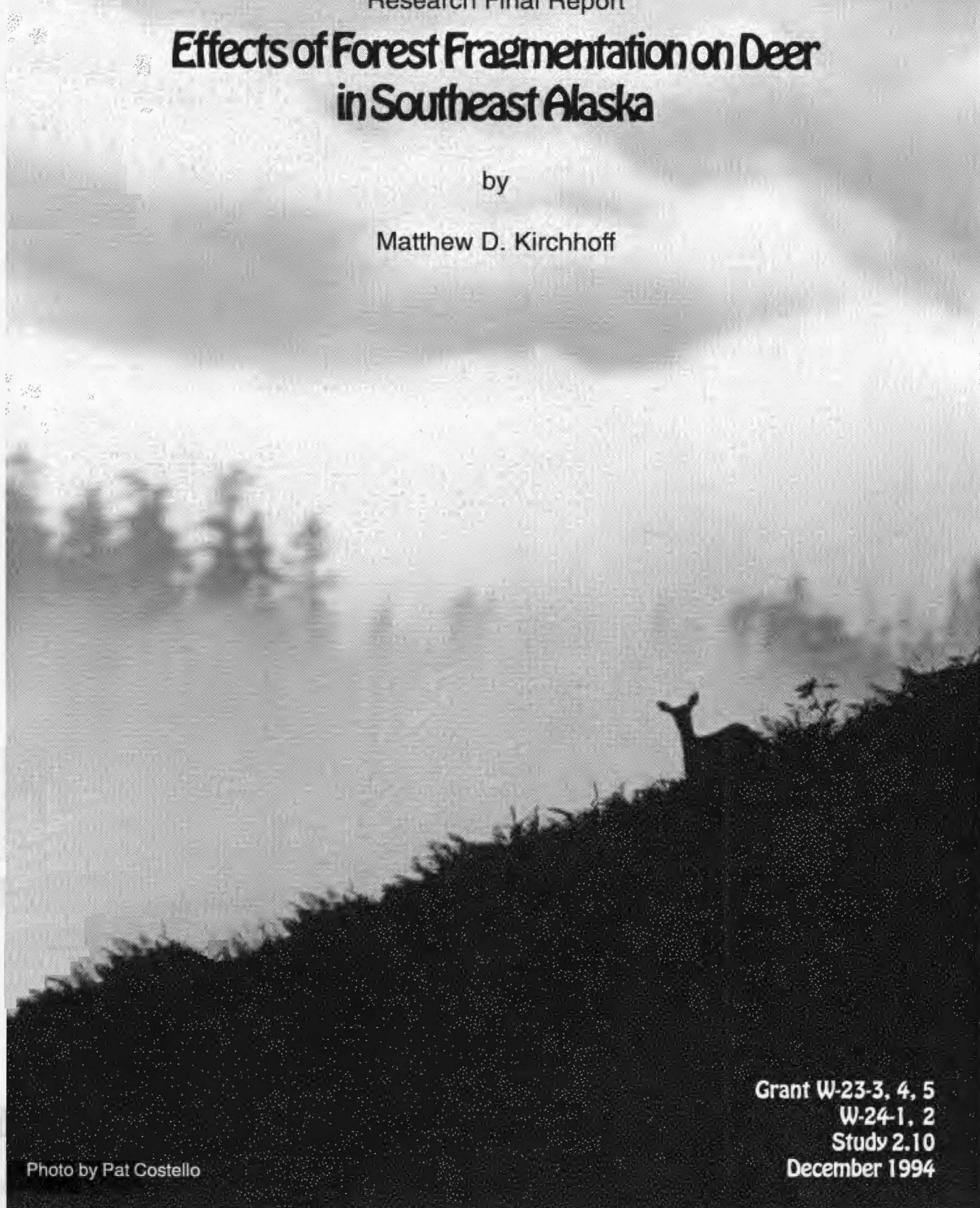
Effects of Forest Fragmentation on Deer in Southeast Alaska

by

Matthew D. Kirchhoff

Grant W-23-3, 4, 5
W-24-1, 2
Study 2.10
December 1994

Photo by Pat Costello



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FINAL REPORT (RESEARCH)

State: Alaska

Project No: W-23-3,4,5,6 Project Title: Wildlife Research and Management

Study No.: 2.10 Study Title: Effects of Forest Fragmentation on Deer in Southeast Alaska

Period Covered: 1 July 1990 - 30 June 1993

SUMMARY

Populations of Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) were monitored on 97 small islands in Sea Otter Sound from 1989 to 1993. Habitat quality on each island was measured in terms of the composition, quality and availability of forage resources, as well as indices of habitat fragmentation (patch size and insularity). Regression analysis showed that relative isolation, or the swimming distance separating a sample island from a large land area, was the most significant factor influencing deer densities. For deer on small islands, increased insularity represented reduced risk of predation by wolves (*Canis lupus ligoni*).

The "effective area" of an island varies as a function of actual size, and the distance separating it from other similar habitat islands (Harris 1984). Because sample islands were sometimes clustered, or located near larger islands, most effective areas were larger than individual island size. Deer densities increased significantly ($P < 0.001$) with increasing effective area.

Deer densities also increased significantly with increased biomass of *Vaccinium parvifolium* (red huckleberry) ($P < 0.01$), and *Listera* spp. (twayblade), a deciduous forb ($P < 0.001$). Huckleberry browse, which had higher concentrations of crude protein and lower levels of fiber and lignin than other *Vaccinium* species ($P < 0.001$), was strongly preferred by deer. Mass-diameter regressions show available browse biomass decreases on large plants because many of the stems are beyond the reach of deer.

Listera spp. are relatively small, deciduous forbs which, while relatively nutritious, probably do not comprise a large portion of the deer's diet. Correlating high deer use with important herb-layer forage is complicated by the fact that where deer densities are high, selective foraging by deer reduces or eliminates preferred plants. Deer density also increased with increasing mean basal area ($P < 0.05$). Preference for islands with higher basal area was probably related to lower snow depths and increased availability of nutritious herb-layer plants.

In the second phase of this study, deer use was compared on fragmented and unfragmented forest blocks at Lindenberg Head, Chichagof Island during winter, 1991. The fragmented block had been clear-cut 19 years earlier, leaving a small strand of old growth along the beach and a island of old growth in the center of the clear-cut. The nearby, unfragmented block was 100% old growth.

Available *Vaccinium* browse was significantly higher ($P < 0.001$) in the fragmented block than in the unfragmented block, reflecting high production within both the clear-cut and fragmented old-growth habitats. High browse production in the fragmented old growth was partially due to edge effects, but was also a function of lower site productivity in the unlogged patches (i.e., low basal area and relatively open canopy). Despite extreme differences in the amount of browse available, deer densities in the fragmented and unfragmented blocks did not differ ($P < 0.05$). Over winter, deer in the unfragmented block presumably had greater access to evergreen herb-layer plants and arboreal lichens than deer in the fragmented block.

Snow accumulations in northern Southeast Alaska were unusually deep from January through April 1991. Deep snow in the clear-cut forced deer into the residual old growth during much of that winter. Old-growth habitat in the fragmented block had the highest percent browse use, the highest browse consumption (kg/ha), and the highest deer density measured in the study area. Deer survival in these small old-growth patches, however, appeared to be low. Nearly twice as many winter-killed deer were found in the fragmented area as in the unfragmented area.

Residual old-growth patches should be sufficiently large to receive deer from adjoining clear-cut habitat and sustain them through winters of moderately deep snow. The size of the old-growth area required will vary depending on total number of deer, the availability of forage in the old growth, and the length of time young clear-cuts are unavailable. In this specific instance, leaving 1/3 of the landscape in old growth was apparently inadequate to maintain the deer population.

The effects of habitat fragmentation on deer will vary, depending on predation risks, depth and duration of snowpack, age of secondgrowth, and the effective area and relative insularity of remaining old-growth habitat. From this study, a number of general conclusions may be drawn. First, habitat insularity is desirable if it reduces predation risk (e.g., as with true islands isolated by water); it is undesirable, however, if it *increases* predation risk (e.g., as with small old-growth patches accessible from roads).

Secondly, deer require large effective areas. If deer are able to move freely about the landscape in response to changing snow conditions, effective area is essentially unlimited. However, should snow accumulation or lack of forage in surrounding managed stands concentrate deer in residual patches of old growth, effective area may be limiting. Depending on the depth and persistence of the snowpack, deer confined to small patches of old growth risk exhausting available food supplies and suffering high mortality. Maintaining small islands of old-growth within clearcuts, or within

intensively managed landscapes, confers little benefit to deer in the long term. Orienting old growth retention in linear corridors that go up and down the hillsides (rather than along contours) will increase the effective area and generally provide greater benefits to deer.

Key words: biogeography, black-tailed deer, browse, effective area, fragmentation, insular, islands, *Odocoileus hemionus sitkensis*, old growth, pellet-groups, Southeast Alaska, *Vaccinium*.

TABLE OF CONTENTS

	<u>Page</u>
SUMMARY	i
BACKGROUND	2
OBJECTIVES	3
STUDY AREAS	
Sea Otter Sound	4
Lindenberg Head	4
METHODS	
Sea Otter Sound	
Deer Density	5
Habitat Attributes	6
Fragmentation Indices	10
Statistical Analyses	11
Lindenberg Head	
Deer Density	13
Habitat Attributes	13
Deer Mortality	13
Statistical Analyses	13
RESULTS AND DISCUSSION	
Sea Otter Sound	
Deer Density and Landscape Attributes	14
Lindenberg Head	
Deer Density and Landscape Attributes	18
Deer Mortality	18
Effects of Fragmentation	
Insularity	19
Effective Area	20
Edge	20
ACKNOWLEDGMENTS	21
LITERATURE CITED	21
FIGURES	
Figure 1. Hypotheses regarding the optimal design of old growth reserves	28
Figure 2. Sea Otter Sound study area, Southeast Alaska	29
Figure 3. Fragmented and unfragmented blocks, Lindenberg Head, Southeast Alaska	30
Figure 4. Sampling design for deer use and vegetative characteristics	31
Figure 5. Available browse biomass as a function of basal stem diameter of <i>V.</i> <i>alaskensis/ovalifolium</i> and <i>V. parvifolium</i> , Sea Otter Sound	32
Figure 6. Browse biomass consumed per twig as a function of terminal twig diameter of <i>V. alaskensis/ovalifolium</i> and <i>V. parvifolium</i> , Sea Otter Sound	33

TABLES

Table 1. Old-growth characteristics in fragmented and unfragmented blocks, Lindenberg Head	34
Table 2. Edge and patch-size attributes in fragmented and unfragmented blocks, Lindenberg Head	34
Table 3. Number of browsed twigs/plant, and diameter/twig, for <i>Vaccinium</i> spp., Sea Otter Sound	35
Table 4. Ratio of oven-dry weight to green weight for <i>Vaccinium</i> browse, Sea Otter Sound	35
Table 5. Diameter-mass regression equations for biomass available and consumed, by browse species, Sea Otter Sound	35
Table 6. Twenty most common forest plants, and their standardized oven-dry weights, Sea Otter Sound	36
Table 7. Habitat variables considered in regression analysis to predict deer density, Sea Otter Sound	37
Table 8. Protein and fiber constituents of <i>V. alaskensis/ovalifolium</i> and <i>V. parvifolium</i> browse, Sea Otter Sound, April	37
Table 9. Protein and fiber constituents of <i>Vaccinium</i> browse in Sea Otter Sound compared with other studies	38
Table 10. Protein and fiber constituents of <i>Vaccinium</i> browse as a function of stem size, Sea Otter Sound, April	39
Table 11. Regression statistics for habitat attributes that significantly predict deer densities, Sea Otter Sound	39
Table 12. Deer density, forage availability, and forage use in fragmented versus unfragmented blocks, Lindenberg Head, May 1991	40
Table 13. Deer density, forage availability, and forage use in a fragmented block, by habitat type, Lindenberg Head, May 1991	40

APPENDICES

A. Location of 97 islands sampled 1989 through 1994, Sea Otter Sound	41
B. Deer use and habitat attributes on 97 small islands, Sea Otter Sound	51

BACKGROUND

Clear-cut logging in Southeast Alaska has to date converted nearly 375,000 ha of productive old-growth forest into young clear-cuts or even-aged second-growth stands (USDA 1991). Under current long range plans, the cumulative area harvested will approach 1 million ha (USDA 1991, 1993), and will have removed, on average, over half of the commercial old growth in all drainages open to logging, and up to 98% in the most intensively managed drainages (Schoen et al. 1985). Much of this logging activity is concentrated along the lower slopes of steep hillsides, and on more productive forestlands, impacting Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) disproportionately (Wallmo and Schoen 1980, Schoen et al. 1988, Schoen and Kirchhoff 1990). This patchwork conversion of more accessible and/or productive forested sites,

leaving remnant stands of varying size and degrees of isolation, has been termed forest fragmentation (Burgess and Sharpe 1981, Harris 1984). Timber sales in Southeast Alaska are currently being planned with minimal forethought given to landscape design elements (e.g., corridors, patch sizes and shapes) that might be beneficial to deer or other wildlife. A better understanding of how habitat fragmentation affects deer ecology should lead to useful prescriptive measures for mitigating the effects of timber harvesting on deer populations.

Concerns about the effects of habitat fragmentation are founded on the work of MacArthur and Wilson (1967), whose theory of island biogeography postulated that species richness on oceanic islands was controlled by an equilibrium between colonization and extinction, and that those same principles might also be applicable to habitat fragments, or "islands" in a terrestrial setting. Although the relevance of the underlying theory has been much debated (e.g., Gilbert 1980, Simberloff and Abele 1982), empirical studies provide ample evidence that habitat fragmentation does affect species diversity, population structure, and predator-prey interactions (e.g., reviews in Burgess and Sharpe 1981, Brown and Gibson 1983, Harris 1984, Lovejoy et al 1986, Wilcove et al. 1986, Saunders et al. 1991).

Much of the empirical research on habitat fragmentation has focused on birds; few studies have included reptiles, amphibians, and mammals (Verner 1986). In the only published study I've found that relates island biogeography theory to deer, Picton and Mackie (1980) found that populations of mule deer (*O. hemionus hemionus*) had lower turnover rates on larger montane islands than on smaller islands, which suggested to them that a single large reserve provided higher quality habitat than several small reserves. This conclusion is seemingly at odds with the widely-held perception that deer respond favorably to forest fragmentation (e.g., Leopold 1933, Reynolds 1966, Resler 1972, Alverson et al. 1988). While this may be true in some circumstances, it should not be assumed universally. The magnitude, and even the direction of the response, will vary with many factors, including the proportion of forest area removed, the size and dispersion of remnant patches, the amount and age of edge created, vegetative and snow conditions in the patches, and specific predation risks.

OBJECTIVES

The objectives of this study are to determine how habitat fragmentation affects deer in Southeast Alaska and to develop guidelines for the design of old-growth reserves that mitigate adverse impacts associated with logging. Conservation biology literature suggests a number of hypotheses regarding the design of old-growth reserves based on island biogeography theory (Fig. 1). This study examines the general applicability of these hypotheses to deer in southeast Alaska.

STUDY AREAS

Sea Otter Sound

Sea Otter Sound, in southern Southeast Alaska (55° 56' N, 133° 25' W) encompasses a 300 km² area with hundreds of islands ranging in size from < 1 to over 1,000 ha (Fig. 2). In the early 1970s, extensive logging occurred on the larger islands in the Sound (e.g., Tuxekan, Marble, Orr); however, most of the smaller islands (< 50 ha) are still unlogged. These smaller islands support low- to moderately-productive stands of old-growth forest (*sensu* Boughton et al. 1992), dominated by western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*) and red cedar (*Thuja plicata*). The understory plant types are predominantly hemlock/blueberry (*Vaccinium* spp.) and cedar/blueberry (DeMeo et al. 1992). Maximum elevation on most islands is < 100 m. Winters are typically mild and snowfall is light. Wolves (*Canis lupus ligoni*) and black bear (*Ursus americanus*) live throughout the study area but are not resident on the smaller islands. Human population and hunting/trapping pressure in the study area are low.

Lindenberg Head

Lindenberg Head, in northern Southeast Alaska (57° 30' N 135° 00' W) is located on the north shore of Peril Strait on Chichagof Island. Overstory and understory plant types are similar to those in Sea Otter Sound, except that red cedar is replaced by Alaska yellow cedar (*Chamaecyparis nootkatensis*). Topography is steep, with elevations > 800 m within 2 km of the shore. Treeline occurs at about 650 m elevation. Winters are relatively cold, with 25-100 cm of snow accumulating at sea level 2-3 months per year. Natural predation in the area is uniformly light. Both wolves and black bears are absent from Chichagof Island. Brown bears (*Ursus arctos*) inhabit these islands, but they are not considered significant predators on deer (Klein and Olson 1960). Human hunting pressure is light.

The study area includes 2 adjacent blocks of forestland, one heavily fragmented by logging and the other intact. The upper boundary of each block is defined by the 180 m elevation contour line and the lower boundary by the shoreline. Approximately 93 ha (62 %) of the fragmented block was clear-cut in 1975, leaving a narrow fringe of timber along the beach and a small island of old growth in the middle of the clear-cut (Fig. 3). Vegetation in the clear-cut is typical of 15-20 year old stands, with an abundant growth of tall shrubs and regenerating conifers (Alaback 1982). The unfragmented block, located 4.8 km to the east, is still entirely in old growth. This area has higher basal area, more spruce, and less cedar than old growth in the fragmented block (Table 1). Slope exposure and snowfall are the same on both areas. Edge and patch-size attributes for the two blocks are given in Table 2.

METHODS

Sea Otter Sound

Patterns of deer use and/or habitat attributes were measured seasonally over 5 years (1989 to 1993) on 97 different islands. A total of 112 islands were visited at least once during the study. Fifteen islands were dropped from the analyses because they were either too large to be sampled adequately or data were collected 1 season only and variables were missing. Field work was normally conducted during a 5-6 week period in April and May with the assistance of 4-6 person field crews. Sampling was timed to shortly follow snow melt but be completed before new spring growth was fully leafed out. These conditions are required to ensure accurate pellet-group counts and browse use surveys (Kirchhoff and Pitcher 1988). In 1993, field work was postponed until June to assess understory composition and biomass. Pellet-group and browse surveys were not conducted that year.

Deer Density

To reflect average use, deer populations were monitored on all islands for at least 2 years, and on most islands, 3 or 4 years (median=3, N=97). Relative deer density was determined by measuring both fecal pellet-group density (Neff 1968) and browse use (Shafer 1963, Pitt and Schwab 1988). Both techniques measure persistent indicators of deer presence, not deer themselves, so density estimates reflect cumulative use over relatively long periods of time. In Southeast Alaska, pellet-groups persist for 6-8 months in forest habitats, depending on weather conditions (Rose 1982, Schoen and Kirchhoff 1983). Browsed twigs persist even longer, reflecting deer use over > 3 years (Kirchhoff, unpubl. data).

On each island 2-4 transect lines were established from suitable landing sites on the beach and oriented to achieve maximum coverage of the island. Starting from the forest edge and following a strict compass bearing, 1 member of each 2-person field crew pulled a surveyor's cable in a straight line across the island. At 20 m intervals, the first crew member would stop and record vegetative data, while the second crew member carefully searched within 0.5 m of the cable for pellet-groups (Kirchhoff and Pitcher 1988). A pellet-group was defined as one or more fecal pellets that, on the basis of appearance and position relative to other pellets, were judged to be a discrete "group" or dropping. All pellet-groups, regardless of age, were counted if the estimated center of the group fell within 0.5 m of the cable. Pellet-group densities were converted to equivalent deer densities by assuming a 12.6 groups/day defecation rate (Kirchhoff 1990) and 240 day persistence time (Schoen and Kirchhoff 1983).

Habitat Attributes

Animals will preferentially use habitat patches (or islands) where there is more forage or higher-quality forage available (Stephens and Krebs 1986). I measured habitat attributes related to the production, availability and quality of winter forages for deer on each island, including overstory conditions (species, age class, basal area), biomass and quality of available browse, and herb-layer composition and biomass. Vegetation was remeasured with each deer survey to increase precision of the estimates. As noted below, some procedures were changed to either improve sampling efficiency or acquire information on additional parameters. The year(s) a method was applied are identified parenthetically.

Overstory. The overstory functions primarily to provide thermal cover and snow interception (Kirchhoff and Schoen 1987, Nyberg and Janz 1990), reducing energy costs and making understory plants more available to deer. Red cedar and western hemlock, when accessible, have some value as forage as well (Pierce 1981, Hanley and McKendrick 1983). Overstory attributes were measured at the end-point of each 20-m pellet-group plot. Total basal area and percent composition (relative basal area) were measured with a relaskop (Forestry Supply, MS), and included only live trees > 15 cm dbh (diameter at breast height). Age class, volume class, and (in 1991) understory plant type (DeMeo 1992) were estimated with reference to a 20 x 20 m (0.04 ha) area bisected by the pellet-group cable (Fig. 4). Mean volume per ha for the island was calculated using volume class midpoints. Age class and understory plant type for each island were assigned based on the most common type.

Browse Biomass and Use. The edible twigs (i.e., browse) of *Vaccinium* plants are an important component of the winter diet of Sitka black-tailed deer (Pierce 1981, Hanley et al. 1989). Methods used to assess browse biomass and use include reconnaissance techniques, clip-and-weigh methods, and regression estimates (Telfer 1981, Pitt and Schwab 1988). All of these methods were used in this study.

In 1989, estimates of percent browse use were made by examining *Vaccinium* plants near the end-point of each pellet-group plot. Following procedures used by Mankowski and Peek (1989), crews estimated the percent of available green stems that had been browsed in 1 of 8 categories: 0-1%, 2-5%, 6-10%, 11-25%, 26-50%, 51-75%, 75-95%, and 96-100%; actual counts of browsed and unbrowsed twigs were not made. Crews experienced difficulty, however, in deciding which plants to evaluate. Even in the same plot, different species and different-sized plants often showed different levels of use.

In 1990, crews used fixed-area plots to select stems for sampling. Plot centers were randomly located by blindly tossing a flagged plumb bob backwards from the end-point of each pellet-group plot (Fig. 4). A plot pin with radius cord was used to circumscribe the boundaries of a circular 3-m² plot. The number of *Vaccinium* stems rooted in the

plot were identified to species (*V. alaskensis* and *V. ovalifolium* were later combined due to difficulty identifying young plants from stem characteristics). Very small plants (< 3mm basal diameter or < 10 cm tall) were not measured. For all other stems, we measured the minimum basal diameter 1 cm above the moss layer (to 0.1 mm) and total plant height (to maximum of 250 cm). Crews estimated percent use of available browse in 1 of 5 categories: < 2%, 2-20%, 21-50%, 51-80%, and > 80%. Finally, working from the base to the top of each stem, crews measured and recorded the terminal diameter (to 0.1 mm) of all browsed twigs.

In 1991, further changes reduced the number of *Vaccinium* stems measured per plot and increased sampling efficiency. Plots were located similarly, but plot size was reduced from 3-m² to 2-m². When more than 10 *Vaccinium* stems were rooted in the plot, a random sample was selected for measurement. The number of stems to sample was determined from the equation

$$N = Y/X$$

where,

N = the number of stems to sample,

Y = the number of stems rooted in the plot, and

X = a number such that (5 < N < 10).

Once the sample size, N, was determined, measurement stems were selected by moving the radius cord clockwise through the plot, selecting every Xth stem. By this method, an unbiased sample 5-10 stems were measured on every plot.

In 1991, browse use was measured by the twig-count method, which converts counts of browsed twigs to weight of browse consumed by using an average weight per twig (Shafer 1963, Telfer 1969). Eliminating diameter measurements of individual browsed twigs greatly reduced the time spent per plot. Because variation in browsed twig diameter was relatively small (90% CI=0.4-2.3, n=11,816), substituting mean diameter values (Table 3) had a small effect on the estimate per plot, while allowing many more plots to be sampled per island.

Mass-diameter regressions. The regression estimate method is most commonly used to predict biomass available and/or consumed on individual plants (Alaback 1986a, Pitt and Schwab 1988). To develop regression equations for browse biomass, crews collected 251 blueberry plants (*V. ovalifolium* and *V. alaskensis*) and 226 huckleberry plants (*V. parvifolium*) from islands throughout the study area. Plants were selected to reflect the full range of size, shape and vigor extant on the islands. On each sampled plant, crews measured minimum basal diameter and clipped all green twigs less than 5 mm in diameter, growing within 1.5 m of the ground. From previous observations, this represented the maximum diameter and the maximum height deer can browse. Crews recorded the green weight (free of dew or precipitation) of each sample (to 0.01 g) in the

field. A random subsample ($n=58$) of these was oven-dried at 40 degrees C for 48 hours, and the ratio of dry to "wet" weight computed for each species (Table 4). That ratio was used to convert undried sample weights to equivalent dry weight (Bonham 1989). All subsequent regressions were based on dry weight.

Conventional regression methods were used to arrive at a best-fit model. The response variable (browse biomass) was log-transformed to correct for heteroscedasticity (Pitt and Schwab 1988), and second-order polynomial terms added when residuals indicated a likely curvilinear relationship (Zar 1974). Independent variables were selected using stepwise methods (Draper and Smith 1981). The final regression equations (Table 5) were highly significant ($P < 0.001$) for both species. The back-transformed equations show the relationship between available browse and basal diameter (Fig. 5). Mean browse biomass available to deer on each island was summarized by plot, and averaged across years.

The r^2 terms reported in this study are significantly lower than r^2 terms reported by others (Nyberg 1985, Alaback 1986a, Yarie and Mead 1989). This is because *available* biomass is inherently more variable than total biomass, especially when subjected to browsing by deer. Variability in growth form and size is also introduced when plants are collected from different sites (Alaback 1986b), or subjected to different levels of browsing (Hanley 1987). And although sampling of plants is usually stratified by size class, there is considerable discretion on the part of the researcher as to which plants to sample. Plants exhibiting poor vigor or unusual growth form are sometimes excluded (e.g., Nyberg 1985), artificially reducing unexplained error.

To develop regression equations for browse biomass *consumed* by deer, crews collected unbrowsed twigs from 118 plants throughout the study area. Care was taken to clip twigs that were representative of the full range browsed by deer. The mean diameter at point of clipping was 1.47 mm for blueberry ($SD=0.35$ $N=73$) and 1.54 for huckleberry ($SD=0.51$, $N=45$), which closely approximates the mean diameter of twigs browsed by deer (Table 3). Individual clipped twigs were oven-dried at 40 degrees C for 48 hours and weighed to the nearest 0.001 g. Dry weights were square-root transformed to stabilize the variance, and regressed against twig diameter. Zero-intercept regression equations were significant at $P < 0.001$, with r^2 terms of 0.98 (Table 5). The back-transformed equations show how biomass consumed varies with terminal diameter of browsed twigs (Fig. 6).

Browse Quality. Forage *quality* is potentially limiting for deer in Southeast Alaska (Hanley and McKendrick 1985). Selective browsing pressure on individual *Vaccinium* species (Table 3), suggests significant differences in nutritional quality and/or palatability. To investigate potential nutritional differences, I collected 28 browse samples from islands throughout the study area in April, 1991 and 1992. Each sample was a composite of 5-10 randomly selected plants of a particular species from a particular island. To reflect browse typically consumed by deer, I clipped from each

plant the green twigs less than 3 mm in diameter, growing within 1.5 m of the ground. Although somewhat larger twigs are consumed on densely populated islands, observations indicated twigs in this size class were commonly browsed throughout the study area. For *V. parvifolium*, most twigs were < 3 years old; for *V. alaskensis/ovalifolium*, most twigs were < 2 years old.

In 1991, a subsample of dried browse was separated into 1 of 3 categories based on approximate size: coarse (> 2.5 mm), intermediate (1.0-2.5 mm), and fine (<1.0 mm). These classes were analyzed separately to examine possible effects of stem age and size on nutritive quality.

Samples were stored frozen, oven-dried at 40 degrees C for 48 hours and delivered to the Washington State Habitat Lab (Pullman, WA) for analysis. There, fiber constituents were analyzed using a modified sequential detergent analysis (Goering and Van Soest 1980, Mould and Robbins 1982). The Kjeldahl technique (AOAC 1984) was used to measure crude protein. Results were expressed in terms of % crude protein (% Nitrogen x 6.25), % neutral detergent fiber (i.e., cell wall fraction), % acid detergent fiber (i.e., hemicellulose and cellulose fraction), % lignin (i.e., lignin and cutin fraction), and % residual ash.

Herb-layer biomass. When available, herb-layer plants constitute a major portion of the diet of Sitka black-tailed deer (Hanley et al. 1985). Herb-layer biomass measurements were made in June 1993 after most plants had leafed out, but before foraging by deer altered biomass levels significantly. We did not distinguish new growth from the previous year's growth (in the case of evergreen forbs and half-shrubs), although it was evident on some islands that deer had largely consumed the previous year's production.

On each island, 1 or more transect lines were established from convenient landing points on the beach and oriented perpendicular to the shore. Starting from just inside the forest edge, and following a strict compass bearing, a 20-m cable was extended in consecutive 20 m increments across the island. With the cable lying straight and flat, rectangular 0.1 m² plot (20 x 50 cm) were located at 5 m intervals on alternate sides of the line. In each plot, the percent coverage for each plant species was recorded to the nearest 1% (up to 10%), or the nearest 5 % (from 10-100 %). All plants < 25 cm in height were measured. Where a species grew in abundance, with overlapping layers (e.g., *Gymnocarpium dryopteris*, *Gaultheria shallon*, and *Maianthemum dilatatum*), layers were mentally separated and added. Thus, it was possible for cover to exceed 100 percent. Paper templates and corresponding marks on plot frames (showing 2%, 5%, 10% cover etc.) were used to improve accuracy of cover estimates. Crews switched recording and estimating duties on alternate 20 m segments to minimize bias.

To convert percentage cover estimates to dry weight equivalents, in late June I clipped and arranged typical leaves to cover 100% of a square 250 cm² template (1/4 the size of our field plots). Plants were clipped in the manner a deer might eat them, so varying

amounts of stem material (depending on the species) was included in each sample. Each sample was oven-dried at 40 degrees C for 48 hours and weighed to the nearest 0.001 g. I assumed a linear relationship between available biomass and percent cover, running from the origin through each sample point (dry weight at 25% cover). From this relationship, equivalent dry-weights were calculated for each species (Table 6).

Fragmentation Indices

Island size. Because islands have definite boundaries, they can be conveniently described by the amount of area encompassed and by proximity to other habitats (Wilcox 1980). For this study, a coastline map was generated from a Geographic Information System (GIS)(G. DeGayner, USFS, pers. comm.). This GIS computed the area of all islands > 0.04 ha in the study area.

Effective Area. The "effective area" of an island may be more meaningful, ecologically, than island size alone because it considers the size and proximity of nearby, similar patches (Harris 1984). From a deer's perspective, a small island close by an adjoining large island is *effectively* much larger than an island that is completely isolated. I tried to define effective area in terms of the land area that might regularly be used by an individual deer. I assumed that (1) deer are probably "aware" of all islands within 500 m of current island location, (2) deer will likely *use* those islands that can be reached by successive swims < 250 m, and (3) deer will likely *not* use islands that are inhabited by wolves. Thus, effective island size in these terms could be calculated as "the maximum cumulative area of all wolf-free islands intercepted by a 500 m-radius circle, reachable by successive swims of less than 250 m." While the criteria are overly absolute in terms of what might occur in nature, they offer an approximate and objective index of effective area.

Edge/Area Ratios. As large blocks of habitat are broken into increasingly smaller fragments, the amount of "edge" increases dramatically. The creation of edge is usually accompanied by significant and wide-ranging ecological change (Franklin and Forman 1987, Saunders et al. 1991). A single island of given size has a lower edge/area ratio than a cluster of small islands that cumulatively comprise the same area. Looking at the effective areas of each sample island, I counted the number of smaller islands > 0.4 ha that contributed to the total effective area. That number was assumed to be an index of relative edge/area ratio.

Insularity. Insularity varies as a function of the distance separating 2 patches and the character of the habitat that separates them. The greater the distance, and the more hostile the habitat, the greater the insularity. Where the intervening habitat is uniform (e.g., water), insularity between islands can be expressed in terms of distance alone.

In the context of this study, the main effect of increasing insularity is to reduce predation risk or the likelihood of an animal being killed by a predator. Empirical studies have shown that animals change foraging behavior or habitat use in response to predation risk (e.g. Gilliam 1990, Sih 1992). In most field and experimental studies, risk is expressed in terms of frequency of exposure to predators, distance to predators, and/or distance to security cover.

The wolf is the only significant natural predator of deer in Southeast Alaska (Klein and Olson 1960). The large islands of Prince of Wales and Kosciusco, which bound the study area to the east and north (Fig. 2) both support year-round resident wolf populations (Person 1993). Monitoring of radio-telemetered wolves, and personal observations of howling, indicate that wolves regularly move from Prince of Wales onto Tuxekan and El Capitan islands, and from Kosciusco onto Marble and Orr islands (D. Person, pers. comm.). Although Tuxekan, El Capitan, Marble and Orr islands do not support permanent, populations of wolves (Person 1993), they probably support individual wolves or small groups for periods of weeks or months (D. Person, pers. comm.). Wolves are capable of making feeding forays onto small, relatively remote islands in the Sound. Wolf scat or wolf-killed deer were found on 6 of 97 sample islands during the course of this study, including one (# 11) that is quite insular. Although there is predation risk associated with every small island, in comparison with the larger land areas, it is relatively low. For ease of reference, I will refer to the small islands as "wolf-free" islands.

The risk of predation on wolf-free islands can be expressed in terms of proximity to a "source" island (i.e., Prince of Wales or Kosciusco). I used an electronic planimeter and 1:40,000 scale nautical charts to measure the swimming distance and overland distance wolves would have to travel to reach each small island from the nearest source island. In tracing this distance I followed the most likely route of travel, minimizing swimming and following low-elevation contours. In addition to swimming distance and overland distance traveled, I also tallied the number of discrete water segments involved in the travel. Wolves probably do not make long, straight-line swims to a distant island, but use intermediate islands along the way as stepping stones. Although this makes the overall swim easier, it also requires wolves make a series of decisions to swim away from the source island (to which they must inevitably return). Thus, the security deer realize on a distant island is probably a function both of distance and number of swims.

Statistical Analyses

More than 100 habitat attributes were measured on each of the 97 islands sampled in Sea Otter Sound. These attributes can be classified into overstory characteristics, shrub composition and biomass, understory composition and biomass (including evergreen forbs and deciduous forbs), and indices of fragmentation and insularity. The question I answer is how these independent variables contribute to explaining the great difference in

deer density we see from one island to the next. Multiple regression analysis is well suited for this purpose.

In deciding which variables to include, both subjective and objective criteria were applied. First, I wanted to ensure that the different "categories" of variables were represented, since I felt they functioned more-or-less independently. Those categories were: (1) overstory characteristics, (2) shrub biomass (3) evergreen forb biomass (4) deciduous forb biomass (5) fragmentation indices, and (6) security indices. Secondly, variables which have a low range of values, or are rare, are not effective predictors (Draper and Smith 1981). For example, the importance of *Coptis aspleniifolia* cannot be assessed because there were many independent variables relative to the number of observations (97 islands), the list of independent variables needed to be reduced (Draper and Smith assessed if its biomass on 91 of 97 islands is the same or zero. Consequently, I excluded from the analysis any plant species which had zero biomass on half or more of the islands sampled (Table 6). I also excluded any other variables missing (not sampled) on more than 3 islands.

Finally, when certain independent variables are highly intercorrelated, problems may arise in the interpretation of partial regression coefficients (Kim and Kohout 1975). A Pearson correlation matrix was generated to examine remaining independent variables for highly correlated pairs. Most were not significantly correlated ($P < 0.05$) and only two pairwise comparisons (swimming segments with swimming distance, $r=0.79$; and total distance with overland distance, $r=0.99$) were very highly correlated. I chose to include swimming distance (instead of segments) and total distance (instead of overland distance) because I felt these had more explanatory power. I identified 11 independent variables to examine in the regression analysis (Table 7). Nonsignificant variables ($P < 0.05$) were eliminated from the model using a stepwise method (Draper and Smith 1981). Residuals were analyzed graphically for heteroscedasticity and nonlinearity (Kim and Kohout 1975), and found acceptable.

Plant chemistry data were tested for normality using a Kolgomorov-Smirnov goodness of fit test (Norusis 1990). Comparisons of nutritional quality between 2 species of *Vaccinium* and among 3 sizes of twig were made with t-tests and ANOVA respectively.

Lindenberg Head

This study area, consisting of adjoining fragmented and unfragmented blocks (Fig. 3) was measured by a 6-person field crew from 6 May through 14 May, 1991, with support from a 65' charter vessel that served as a base camp. Approximately 63% of the fragmented block was clear-cut in 1975 leaving remnants of old growth along the beach and in the center of the clear-cut; the unfragmented block is still entirely old growth (Table 2). Field methods used at Lindenberg Head were identical to those used in 1991 at Sea Otter Sound. Methods are briefly summarized here, with reference to previous discussion for details. Field work on habitat fragmentation in terrestrial landscapes, such

as at Lindenberg Head, was terminated after the 1991 field season due to unexpectedly high time and cost requirements per sampling area.

Deer Density

Deer density was measured along parallel transect lines, spaced approximately 50 m apart, extending from the shoreline to 180 m elevation in both the fragmented and unfragmented blocks. Along each transect, crews carefully searched consecutive 1 x 20 m plots for pellet-groups (see previous detailed description).

Habitat Attributes

Basal area and percent composition (relative basal area) of the overstory were measured from the end-point of each pellet-group plot using a relaskop. Other overstory attributes, including understory plant type, volume class, and age class were identified with reference to the larger 20 m x 20 m (0.04 ha) plot bisected by the pellet-group cable (Fig. 4). Shrub attributes were measured in a circular 2-m² plot randomly located within each 0.04 ha plot. The *Vaccinium* stems rooted in each plot were counted, identified to species, and a subsample (N= 5-10 stems) randomly selected for measurement. For each stem sampled, crews recorded the minimum basal diameter, plant height, number of browsed twigs, and % browse use (in categories < 2%, 2-10%, 21-50%, 51-80%, and > 80%). The biomass of available browse, and amount of browse consumed, were calculated using previously developed regression equations, and mean diameter of browsed twigs (see previous discussion). Composition and biomass of herb-layer plants were not measured.

Deer Mortality

In areas of steep topography and heavy winter snow, deer move down in elevation during winter (Schoen and Kirchhoff 1985). Klein and Olson (1960) reported that 90% of the deer that die from winter starvation die within 30 m of the beach. Although the true proportion is probably lower (Schoen and Kirchhoff 1983), beach mortality counts do serve as an index of winter mortality. On 12 May, field crews thoroughly searched a 1.5 km length of coastline below the logged area, including the fragmented study block, and a 1.7 km length of coastline below unlogged area, including the unfragmented block. The area searched extended from the high-tide line inland 75 m. When evidence of mortality was found, crews noted the location, habitat type, and if determinable, the sex, age, and condition (Cheatum 1949) of the animal at death.

Statistical Analysis

Deer density, browse available, browse consumed, and mortality were summarized by block (fragmented-unfragmented) and by habitat type (clear-cut/old growth). The distribution of these data were tested for normality with a Kolgomorov-Smirnov

goodness of fit test (Norusis 1990), and found nonnormal. Nonparametric methods (Mann-Whitney U test) were used for significance tests.

RESULTS AND DISCUSSION

Sea Otter Sound

A large body of information has been accumulated on the vegetative composition, abundance, structure, and deer use on 97 small islands in Southeast Alaska. These islands represent potentially useful ecological isolates which other forest ecologists, island biogeographers, or wildlife biologists may wish to use in their research. Maps identifying island location, and summaries identifying selected habitat attributes for each of the islands sampled are included in Appendices 1 and 2. Persons interested in doing further work on these islands are encouraged to contact me for additional data or further information.

Deer Density and Landscape Attributes

Deer Densities. Variation in deer densities from island to island was high. A total of 4,280 1x20 m plots were surveyed on 97 islands. As measured by pellet-group counts, densities ranged from 0 (on 4 islands) to over 100 deer/km² (on 4 islands), and averaged 35.6 deer/km² (SD=29.6, N=97).

Percent browse use, another index of relative deer density, was significantly correlated with deer density ($r=0.39$, $P < 0.001$, $N=97$), but not as highly as might be expected. Percent use estimates are more meaningful when expressed relative to forage availability (Aldous 1944). Relatively few deer can heavily impact browse in stands where biomass is low (e.g., closed-canopy, second-growth). Conversely, browsing is less obvious in stands where biomass is abundant. Measures of availability are most important when different areas are being compared; they are less important when monitoring deer use in a single area over time.

Crews experienced difficulty with reconnaissance-level estimates due to variable browsing pressure on different species of browse, and on individual plants of the same species. Deer densities were not correlated ($P < 0.05$) with estimated % use of blueberry (*V. alaskensis/ovalifolium*), the most common and abundant browse on the study area. They were correlated ($P < 0.001$) with estimated percent use of huckleberry (*V. parvifolium*). For reconnaissance-level surveys, there should be a clear protocol for objectively selecting plants to base estimates on.

Browse use results may also be complicated by the availability of nonwoody forage plants. Lichens, for example, fall at varying rates from the canopy (primarily old growth) and are a source of readily available energy for deer in the winter (Rochelle 1980, Hanley and McKendrick 1983). Forbs and half-shrubs are the most nutritious

forages, and constitute the majority of the deer's diet when available (Hanley and McKendrick 1983, 1985, Hanley et al. 1989). On islands where these forage classes are relatively abundant and available, deer densities will tend to be underestimated by browse use indices.

Overstory Characteristics. All islands were 100 percent forested, primarily with low-volume old growth. Basal area of sampled islands ranged from 12-70 m²/ha ($\bar{x}$ =41.3, SD=11.2, N=97). Taller trees, reflecting more productive sites, were associated with larger islands ($P < 0.001$). Percent species composition (based on basal area) for all islands was 19% spruce, 38% cedar, and 42% hemlock. Cedar was more concentrated around the peripheries of islands, with increased percentages of spruce and hemlock inland. Due to generally low snowfall, minimal topographic relief, and strong marine influence near these islands, deep snow accumulations are relatively rare and/or short-lasting. The effect is to lessen the functional importance of the overstory to deer.

Browse Availability. The availability of *Vaccinium* browse also varied widely from island to island. For the 3 *Vaccinium* species combined, available biomass averaged 76.3 kg/ha (SD=51, N=97). This is approximately 2 times higher than has been reported elsewhere in Southeast Alaska (Hanley and McKendrick 1985). The difference is due partly to methodology. Hanley and McKendrick (1985) limited their sample of browse to current annual growth (CAG), whereas I included older green twigs less than 5 mm in diameter. This was determined from direct observation of browsed stems, and probably represents a more accurate approximation of the total browse resource available to deer.

Published equations for predicting the biomass of *Vaccinium* spp. (e.g., Alaback 1986) may significantly overestimate the browse biomass available to deer. Typically, the biomass of plant fractions increases exponentially with increasing plant size (Nyberg 1985, Alaback 1986, Pitt and Schwab 1988). On large plants, however, the browse that is *available* decreases (Fig. 5), primarily because it grows beyond the reach of deer. On islands where deer are abundant, intensive browsing by deer may also alter the growth form of plants.

Browse Quality. Based on evidence of browsing, huckleberry is highly preferred over blueberry by deer. Deer consumed only 13% of the available blueberry browse, but 43% of the available huckleberry browse across all islands. Blueberry and huckleberry differed significantly ($P < 0.05$) in crude protein, NDF, ADF, and lignin (Table 8). The strong preference by deer for *V. parvifolium* can probably be attributed to its higher nutritional quality. Factors relating to palatability and plant structure (as it affects bite size and foraging efficiency) may also be important. Tannins, which are carbon-rich compounds that decrease protein digestibility and digestible energy in plants, are concentrated in the leaves, not the stems, and so have little effect on browse quality (Robbins et al. 1987).

Although huckleberry was of higher nutritional quality than blueberry, the quality of both was relatively low compared to studies elsewhere (Table 9). The lower quality may be attributable to the fact that browse measured in this study included green twigs > 1 year old. Analysis of nutritional quality relative to stem coarseness revealed significant differences ($P < 0.05$), with larger stems having more fiber and, presumably, lower digestibility (Table 10). Ellis (1984) found that nitrogen also decreased with increasing twig size. Although my data suggest a similar trend, the differences were not significant ($P < 0.05$). Hanley (1987) found no difference in either digestibility or nitrogen between browsed and unbrowsed plants. This was probably because he compared current annual growth only. Differences in diet quality are not due to physiological changes (Hanley 1987), but rather to mean twig diameter under different browsing intensities.

As populations increase in an area, not only does the biomass of available browse decline (Hanley 1987), but so does crude protein (Ellis 1984) and digestibility (this study). The implications for deer are quite significant. If the only forage available to deer was blueberry browse of similar quality to that sampled in this study (Table 8), digestible protein would be insufficient for adult maintenance (Hanley and McKendrick 1983, Robbins 1987), and fall far short of meeting the minimal requirements of a productive deer population (Hanley and McKendrick 1985).

Salal (*Gaultheria shallon*) is a highly preferred winter forage for deer in British Columbia (Bunnell 1990). Salal was recorded on 22 of 97 islands sampled in Sea Otter Sound. Where salal occurred it was abundant, averaging 141.6 kg/ha and reaching 1,000 kg/ha ($SD=261.7$, $N=97$). Despite its reported importance in British Columbia, I saw no evidence of browsing on salal, and biomass of salal was not correlated with deer density in Sea Otter Sound ($r=-0.06$, $N=97$).

Herb-layer Plants. Deer in Southeast Alaska must supplement their diet with relatively nutritious forbs and half-shrubs to meet minimum dietary requirements (Hanley and McKendrick 1985). Mean biomass of herb-layer plants in summer was 30.3 kg/ha ($SD=60.6$, $N=97$). Biomass varied dramatically among islands, ranging from 0.3 to 339.3 kg/ha. Most of this biomass comes from a few species, including *M. dilatatum* ($x=17.2$ kg/ha), *C. canadensis* ($x=5.4$ kg/ha), *G. dryopteris* ($x=1.7$ kg/ha) and *P. alata* ($x=1.6$ kg/ha). No other herb-layer species averaged over 1 kg/ha.

Only 5 plants occurred in 5% or more of 5,872 sample plots: *Maianthemum dilitatum*, *Cornus canadensis*, *Prenanthes alata*, *Listera* spp., and *Gymnocarpium dryopteris* (Table 6). Of 22 Southeast Alaska deer forages analyzed by Hanley and McKendrick (1983), *Listera* spp. and *Maianthemum dilitatum* had especially high neutral detergent solubles (i.e., cell cytoplasm and its constituents), and high dry-matter digestibility. These plants are exceptionally nutritious for deer. Of the 5 most common plants measured, only *C. canadensis* is evergreen, and potentially available to deer in the winter. In contrast to most forages, half-shrubs are more digestible in winter than in summer (Hanley and

McKendrick 1983). *Coptis aspeleiiifolia*, which is quite common throughout Southeast Alaska, was found on just 6 islands in Sea Otter Sound. .

Given the importance of these plants in deer diets, one might expect islands with more abundant herb-layer plants to support higher deer populations. However, simple correlations of this sort are complicated by the fact that deer eat many of the important plants. Where deer are at low densities, important forbs may be extremely abundant. Where deer are at high densities, important forbs have been consumed. This is most problematic with evergreen forbs and half-shrubs (e.g., *Cornus canadensis*, *Rubus pedatus*) which are available to deer year-round.

Plants that are important food items but are not completely removed by deer (e.g., woody browse plants, *Lysichiton americanum*) are more likely to show positive correlations. Likewise, there may be some species that deer do not eat but which are themselves associated with important food plants or habitat conditions for deer. For example, *Moneses uniflora*, a small evergreen herb, is relatively uncommon (34% of islands, 1.5% of plots) and contributes minimally to herb-layer biomass ($x=0.1$ kg/ha). Nevertheless, it was significantly correlated with deer density ($r=0.42$, $P < 0.001$, $N=97$). Hanley (1987) compared abundance of different understory plants inside and outside deer exclosures in Southeast Alaska, and found just one species, *M. uniflora*, more abundant outside the exclosure. These observations suggest that *M. uniflora*, while not preferred by deer, may be more common in habitats where heavy deer use has reduced competition from other plants.

Insularity. Overland distances swimming distances, and number of swims needed for wolves to reach individual islands varied considerably. The mean travel distance (overland plus swimming) to reach an island was 11.23 km ($SD=6.9$, $N=97$). The swimming distance was much smaller, averaging 1.1 km ($SD=0.9$, $N=97$). Using intermediate islands as stepping stones, the median number of swims to reach a sample island was 4. Maximum swimming distance was 4.4 km; maximum number of swims was 12.

Island Size and Effective Area. The size of individual islands sampled in this study was relatively small ($x=5.3$ ha, $SD=15.9$, $N=97$). Most islands, alone, can not sustain deer. Presumably, deer use a larger area which includes the sample island in their annual foraging activity. This larger area, termed "effective area" (*sensu* Harris 1984), was defined as the cumulative area of all wolf-free islands within 500 m of the sample island, reachable by successive swims of 250 m or less. Effective areas ranged from 0.24 to 240 ha, averaging 42.4 ha ($SD=58.1$, $N=97$).

Regression Results. A multiple regression analysis was run on a subset of appropriate independent variables (Table 7) to identify those that significantly influenced deer density, and by inference, habitat quality. The final regression model, which included 5 independent variables, was highly significant ($P < 0.001$, $r^2=0.44$)(Table 11). The

significant independent variable, in order of relative importance, were: (1) insularity (swimming distance to source island), (2) effective area, (3) biomass of *Listera* spp. (a deciduous forb) (4) biomass of *V. parvifolium* browse (a preferred shrub), and (5) mean basal area.

Lindenberg Head

Deer density and Landscape Attributes

Browse Availability. Available *Vaccinium* browse was 10 times higher in the fragmented block than in the old-growth block (Table 12). Although the clear-cut provided most of this biomass, production in the fragmented old growth was quite high relative to the unfragmented old growth (15.8 versus 2.5 kg/ha). High browse production recorded in the old-growth fragments may have been due to edge effects (e.g., Billings and Wheeler 1979), but another important factor was difference in site condition (e.g., Table 1), which resulted in a more open old-growth canopy and increased browse production.

Browse Consumption. Browse consumption was much higher in the fragmented than in the unfragmented block ($P < 0.001$) (Table 12). On the unfragmented block, 2.5 kg/ha were available (in spring), and 2.4 kg/ha were consumed (over winter) (Table 12). On the fragmented block, less than half of what was available was consumed (Table 12). Based on consumption of *Vaccinium* browse alone, deer densities would expectedly be higher on the fragmented block.

Deer Density. Despite rather large differences in the amount of browse available, and the amount consumed, deer densities in the fragmented and unfragmented blocks did not differ ($P < 0.05$) (Table 12). These results are not as incongruous as they first seem if one accepts the likely possibility that more nonwoody forage was available in the unfragmented stand. In the fragmented block, both the clear-cut and the relatively open old growth would have accumulated considerable snow over winter. Very likely, the only forage available in the fragmented block much of that winter was *Vaccinium* browse and conifers. In contrast, the unfragmented block would have had lower snow depths (Kirchhoff and Schoen 1987), more available herb-layer forage (Hanley and McKendrick 1985), and more available lichens (Rochelle 1980) than the fragmented block. Although neither abundance nor consumption of these forages were measured, field observations (e.g., residual stems of *C. canadensis*) indicated almost all of the herb-layer forage in that block had been consumed.

Deer Mortality

Extremely heavy snow conditions occurred in northern Southeast Alaska from January through April, especially at lower elevations, with record snowpack (13-15 year periods of record) reported at most measurement sites (USDA Soil Conservation Service 1991). Snow depth was not monitored on the study area, but I assume it was sufficiently deep to

make the clear-cut unusable over much of winter. The old-growth stands in the fragmented block obviously received heavy use that winter. The old-growth fragments had the highest percentage *Vaccinium* use, the highest browse consumption (kg/ha), and the highest deer density measured in the study area (Tables 12 and 13).

Deer mortality under these circumstances would be high. A search of the beach fringe area beneath the fragmented forest yielded 10.00 deer per km surveyed; surveying the beach fringe beneath the unfragmented old growth yielded 5.88 deer per km surveyed. Statistical tests could not be run because data were collected on just 2 transects, but the differences appear significant.

Effects of Fragmentation

Most studies on the effects of habitat fragmentation have simply documented the extent of species loss in heavily fragmented systems (Verner 1986, Soule and Kohm 1989). Not all fragmentation studies have resulted in reduced species richness (e.g., Rosenberg and Raphael 1986). The effect on individual species may instead result in altered population stability, demographic characteristics, and/or predator-prey dynamics (e.g., Kareiva 1987, Crowley 1981). This study identified 2 effects of habitat fragmentation, increased insularity and decreased effective area, which affect habitat suitability and predator-prey dynamics of deer in Southeast Alaska.

Insularity

Insularity, or isolation, of habitat fragments in a given landscape is influenced by several factors, including the distance separating the fragments, the time since isolation, and the degree of connectivity between them (Saunders et al. 1991). The design of this study (with true islands) holds the time and connectivity factors constant, and measures insularity in terms of distance effects alone. Insularity is considered detrimental for some species because it limits their potential for dispersal and colonization. This is particularly threatening to those species that behave as a "metapopulation" or a shifting mosaic of temporary populations (Primack 1993).

In this study, more insular islands had higher deer populations, not because deer *prefer* insular habitat per se (in fact, the opposite is likely true), but because insularity provides a measure of protection from wolves. This prey response (termed "packing") has been described elsewhere, and for other species (Brown and Gibson 1983). This functional response of deer to predation risk may apply as well on habitat islands in terrestrial landscapes. Land management activities which make it easier for wolves to successfully access and/or kill deer reduce effective insularity. Perhaps the most obvious example of this is the creation of a network of logging roads connecting patches of low-elevation old-growth timber. We know from general observation that many of these roads are used extensively by wolves, and we know from previous deer research that the old-growth stands these roads connect function as important habitat for deer in winter (Schoen and

Kirchhoff 1990, Yeo and Peek 1992). Wolves are relatively intelligent animals and will undoubtedly use roads if this increases their hunting efficiency. Observations of wolves on Prince of Wales suggest that wolf packs do exploit the patches of old-growth left between clearcuts in this way (D. Person, pers. comm.).

Effective Area

Large habitat remnants are generally desirable because they contain greater habitat diversity, support larger populations, and are more resistant to external factors (e.g., edge effects) than small fragments (Saunders et al. 1991). The species generally assumed at greatest risk from this effect are those that utilize large, undeveloped landscapes (Terborgh 1974, Harris 1984). Under special circumstances, however, effective area can also be limiting for deer. Those circumstances include the unique situation of a small island, on which deer find insufficient food to survive, or to small fragments of old growth, when deer are effectively "trapped" in deep snow.

The concept of "effective area" as a limiting factor for deer is probably not a significant concern, as long as the forested landscape still maintains a fair degree of connectivity (i.e., clear-cuts appear as patches within a forest, rather than the forest appearing as patches within a clear-cut). Management actions being contemplated in Southeast Alaska today include placing small "islands" of old growth within large clear-cuts to "mitigate" impacts of logging on deer. This will have the opposite of the intended effect when snow (in the short term) and dense secondgrowth (in the longer term) effectively isolate these small islands. Alternatively, old-growth retention should be allocated to the *edges* of cutting units, or allocated to corridors *through* the unit. In so doing, connectivity and effective area of suitable habitat for deer are increased, not decreased.

Edge

The effect of clear-cutting on the abiotic and vegetative environment of forest edges is well-documented (Chen and Franklin 1990, Chen et al. 1992). The perceived benefits for deer are related to increased light penetration and resultant forage production in the forest edge (e.g., Billings and Wheeler 1979, Kirchhoff et al. 1983). What often goes unacknowledged, however, is that clear-cuts eventually mature into close-canopied second-growth stands. Under that scenario, the second-growth edge will function very differently than the clear-cut edge, and may, in fact, exert a *negative* influence on understory production extending some distance into the old-growth stand. More consideration needs to be given to the consequence of creating these types of edges, because they will dominate future landscapes.

Edges in fragmented landscapes have been characterized as "ecological traps" (*sensu* Gates and Gysel 1978) because of their tendency to attract predators. Numerous empirical studies have documented the loss of bird species in forest fragments, primarily from nest predation and brood parasitism (e.g., Burgess and Sharpe 1981, Andren and

Angelstam 1988, Wilcove et al. 1986, Shafer 1990). We might speculate that deer, like birds, may be more-or-less susceptible to predation along forest edges than in interior forest habitats. Certainly, if deer are concentrated along forest/clear-cut edges, and wolves have easy access to those edges, predation rates could increase. Additional research is needed on how edges, both natural and man-made, affect predator-prey relationships between wolves and deer.

ACKNOWLEDGEMENTS

Thanks to the many individuals who worked with me in the field from 1989 through 1993, including, P. Alaback, S. Alaback, D. Baichtal, S. Bloom, A. Campbell, V. Cano, B. Carney, B. Dinneford, E. Erikson, C. Fordyce, A. Fuller, A. Gates, J. Gustafson, M. Ingle, L. Francis, K. Hartnett, M. Kirchhoff, P. Kirchhoff, R. Kirchhoff, S. Kelley, B. Koehler, J. Koehler, A. Landvik, S. Lewis, C. McNutt, L. McNutt, K. Meddleton, P. Mooney, J. Palmes, T. Pasteris, T. Paul, A. Post, T. Satre, K. Savage, E. Sellig, M. Sigman, J. Szarzy, S. Szepanski, M. Thomas, Z. Throwell, G. Vose, J. Whitney, and N. Zimmerman. Thanks are also extended to Sylvia Geraghty, of Tokeen, who provided field facilities and logistical support in Sea Otter Sound, and to Dale Anderson, skipper of the *M.V. Princeton Hall*, who provided transportation and field support in Peril Strait. J. Martin and G. DeGayner of the U.S. Forest Service provided maps, aerial photos, and GIS support for this project. I received helpful review comments on this manuscript from J. Schoen. M. Hicks provided editorial assistance.

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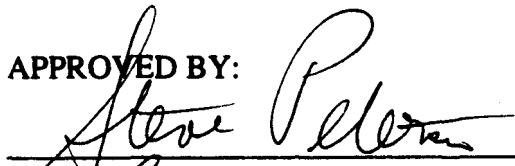
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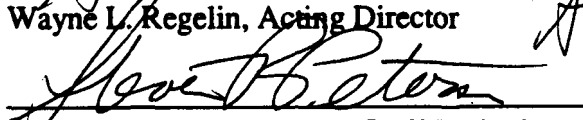
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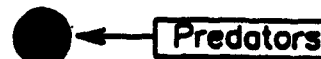
 for
Steven R. Peterson, Senior Staff Biologist



Ho: Large Patches Are Preferable to Small Patches.



Ho: Clumped Patches Are Preferable to Dispersed Patches.



Ho: Remote Patches are Preferable to Accessible Patches.



Ho: High-edge Patches Are Preferable to Low-edge Patches

Figure 1. Hypotheses regarding the optimal design of old-growth reserves for deer in Southeast Alaska.

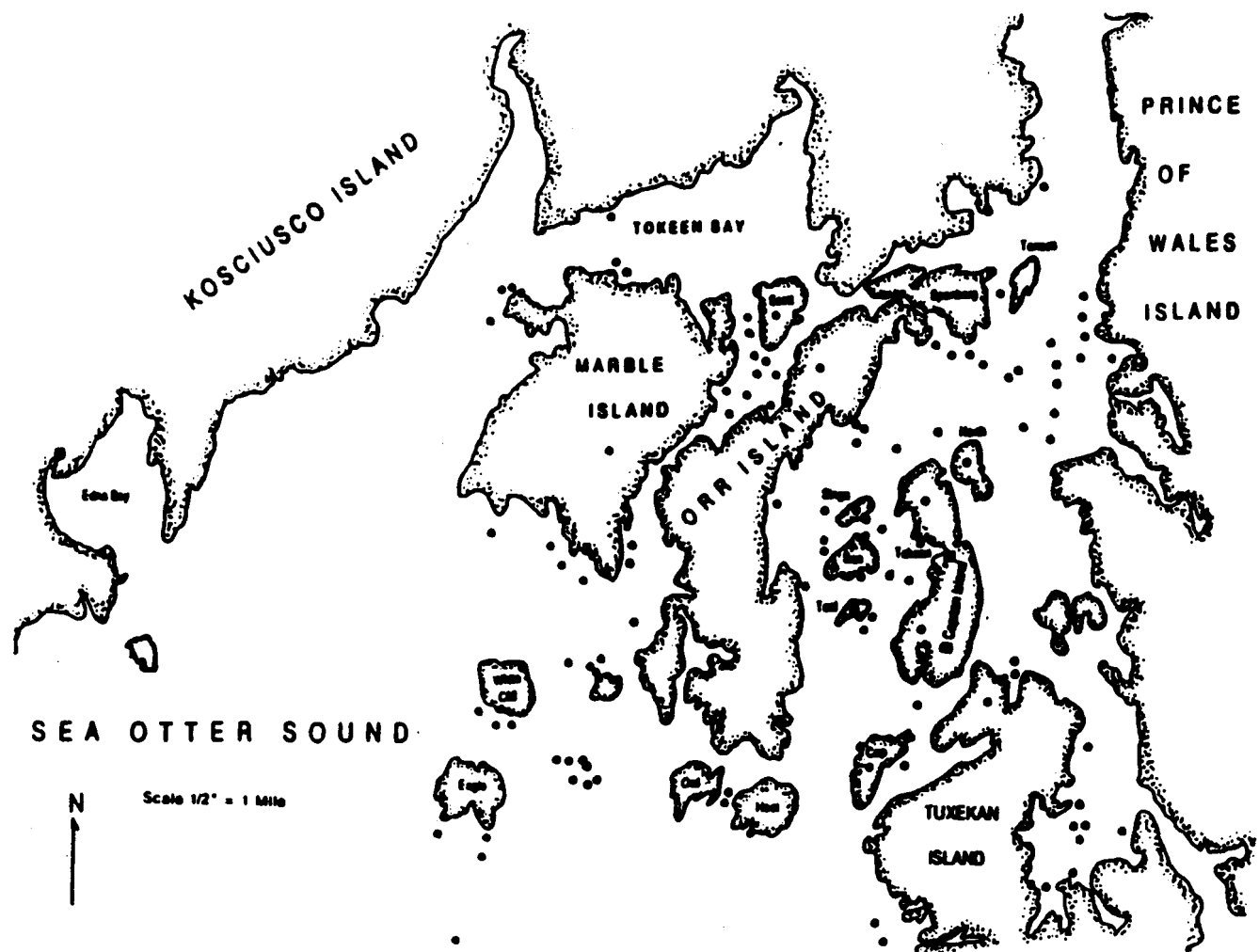


Figure 2. Study area in Sea Otter Sound, Southeast Alaska. For clarity, small islands have not been drawn. Circles represent location of islands sampled in this study.

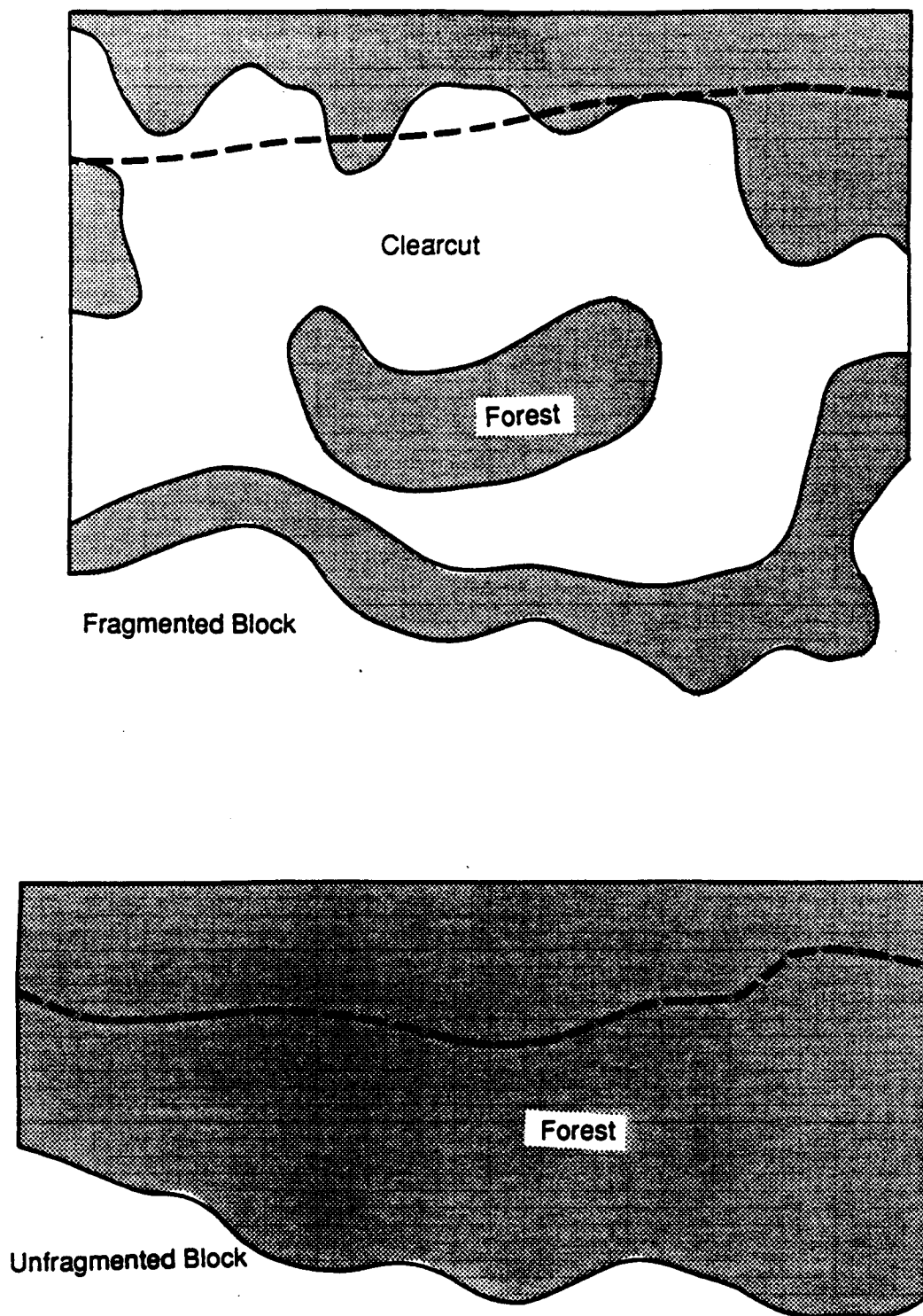


Figure 3. Fragmented and unfragmented blocks at Lindenberg Head, Southeast Alaska. Lower Boundary is the shoreline; upper boundary (dashed line) is the 180 m elevation contour.

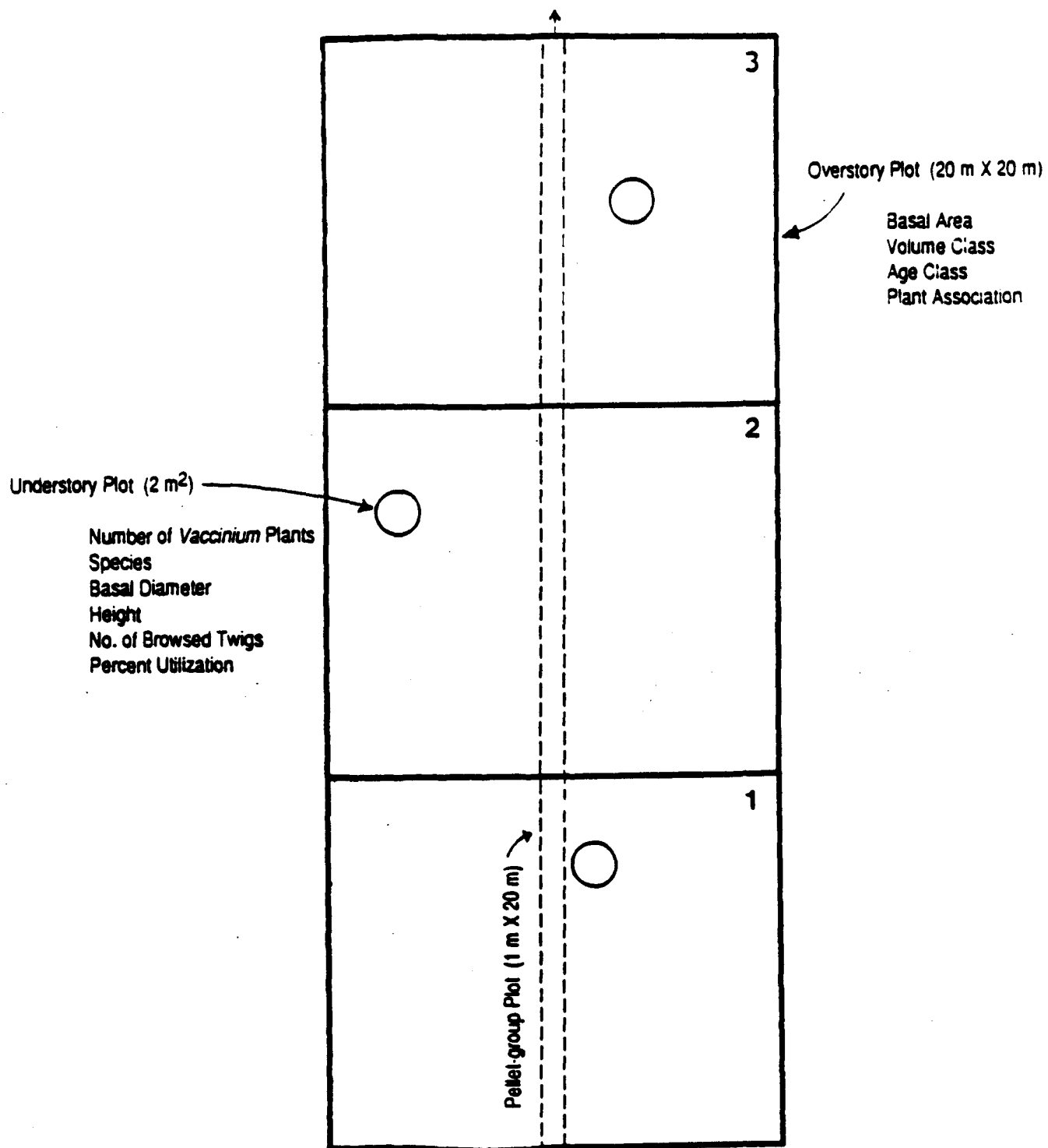


Figure 4. Sampling design for measuring deer use and vegetative characteristics.

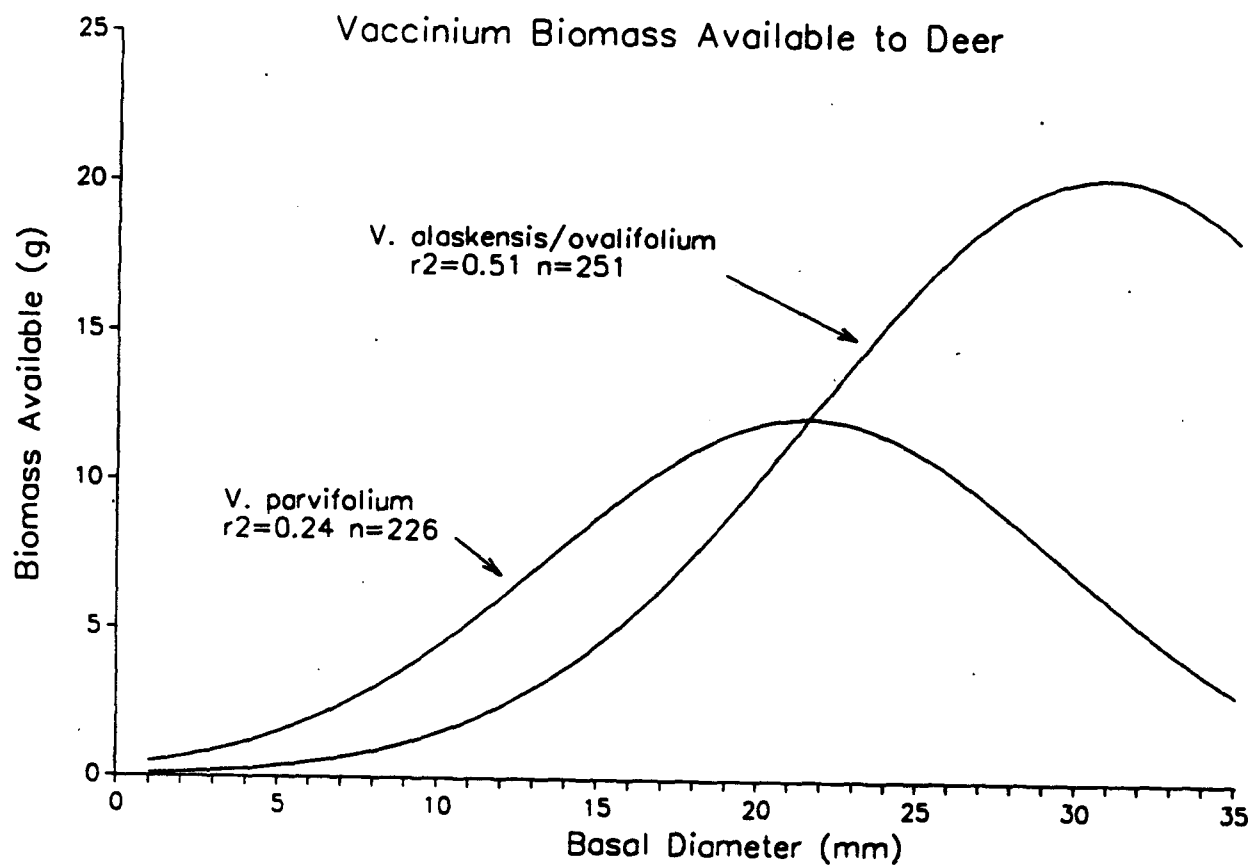


Figure 5. Available browse biomass as a function of basal diameter for blueberry (*V. alaskensis/ovalifolium*) and huckleberry (*V. parvifolium*), Sea Otter Sound.

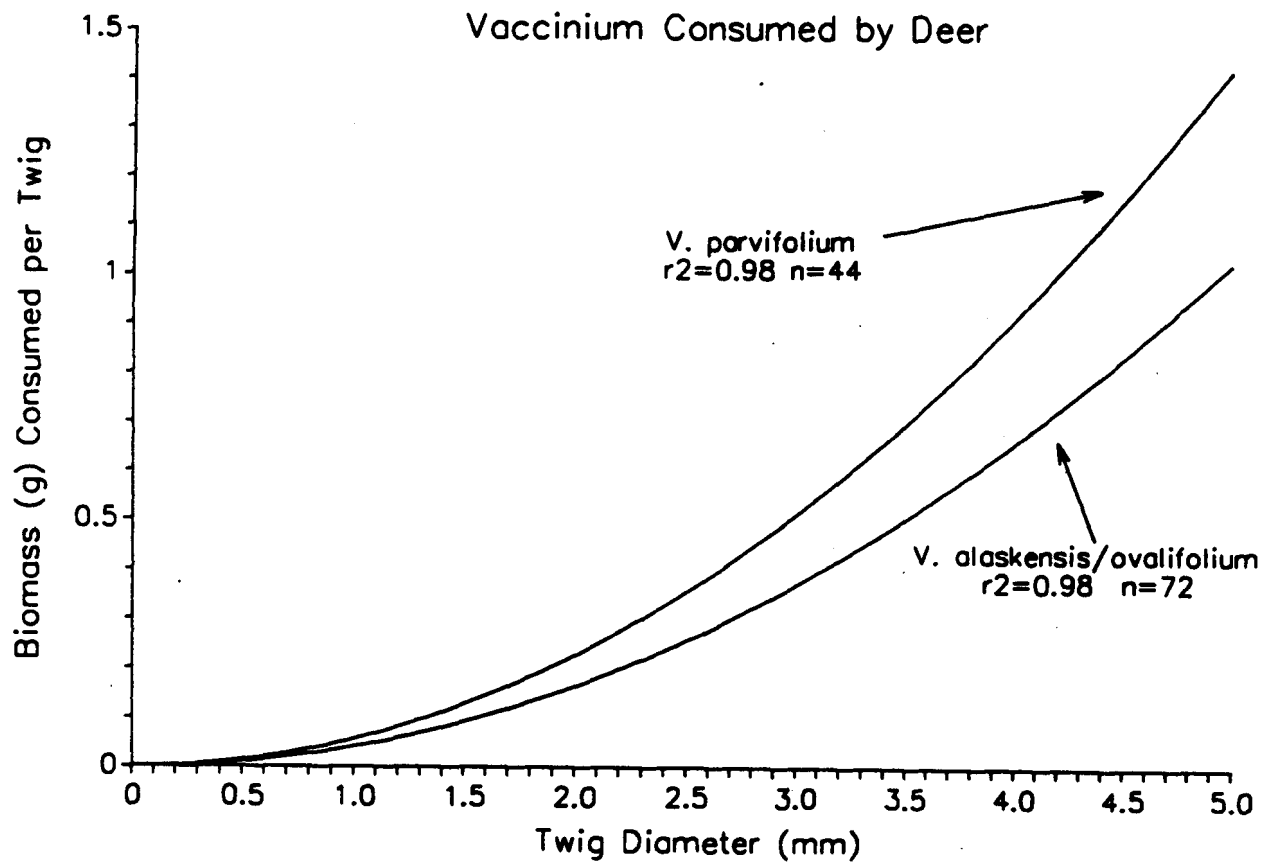


Figure 6. Browse biomass consumed as a function of terminal twig diameter for blueberry (*V. alaskensis/ovalifolium*) and huckleberry (*V. parvifolium*), Sea Otter Sound.

Table 1. Old-growth characteristics in fragmented and unfragmented blocks near Lindenberg Head, Southeast Alaska.

	<u>x (SD)</u>		P ¹
	Old growth (fragmented) n=44	Old growth (unfragmented) n=160	
% <i>Picea sitchensis</i>	11.5 (26.9)	24.3 (26.8)	0.000
% <i>Chamaecyparis nootkatensis</i>	9.7 (15.3)	3.5 (10.9)	0.001
% <i>Tsuga heterophylla</i>	78.8 (27.0)	72.2 (28.2)	0.133
Net volume (MBF/ac)	23.9 (8.8)	35.5 (11.7)	0.000
Basal Area (m ² /ha)	58.2 (58.9)	91.3 (54.6)	0.000

¹ Mann-Whitney U test.

Table 2. Edge and patch-size attributes in fragmented and unfragmented blocks, Lindenberg Head, Southeast Alaska.

Attribute	Fragmented	Unfragmented
Block size (ha)	150	100
Block perimeter (m)	5,358	4,666
Old growth (ha)	57	100
Clear-cut (ha)	93	0
% Clear-cut	62	0
Clear-cut edge (m)	5,600	0
Shore edge (m)	2,166	1,917
Clear-cut edge/block size ratio	37	0
Shore edge/block size ratio	14	19
Distance to alpine (m)	704	603

Table 3. Mean number of browsed twigs and mean diameter at point of browsing on *Vaccinium* spp., Sea Otter Sound, May 1990.

Species	Twigs per Plant x (SD)	Plants N	Diameter (mm)/Twig x (SD)	Twigs N
<i>V. alaskensis/V. ovalifolium</i>	3.0 (7.2)	1,710	1.3 (0.6)	4,756
<i>V. parvifolium</i>	16.5 (37.2)	808	1.4 (0.6)	7,060
<i>Vaccinium</i> spp.	7.3 (22.8)	2,518	1.4 (0.6)	11,816

Table 4. Ratio of oven-dry weight to green weight for *Vaccinium* browse¹ collected in Sea Otter Sound, May, 1990.

Species	x	(SD)	N
<i>V. alaskensis/V. ovalifolium</i> (Blueberry)	0.46	(0.43)	42
<i>V. parvifolium</i> (Huckleberry)	0.48	(0.25)	16
<i>Vaccinium</i> spp.	0.47	(0.39)	58

¹ Hardened green twigs < 5 mm in diameter growing within 1.5 m of the ground.

Table 5. Regression equations to predict browse biomass available, and consumed, for blueberry (*V. alaskensis/ovalifolium*) and huckleberry (*V. parvifolium*), Sea Otter Sound, Southeast Alaska. Final models are significant at $P < 0.001$.

Species	a	b ₁	b ₂	r ²	n	Model ¹	Range
Available							
<i>V. alaskensis/ovalifolium</i>	-2.677	0.370	-0.006	0.51	251	log	1-35
<i>V. parvifolium</i>	-1.032	0.329	-0.008	0.24	226	log	1-35
Consumed							
<i>V. alaskensis/ovalifolium</i>	0.0	0.203		0.97	72	sqrt	0-5
<i>V. parvifolium</i>	0.0	0.238		0.95	44	sqrt	0-5

¹ log: $y = \exp(a + b_1 \text{ basal} + b_2 \text{ basal}^2)$

² sqrt: $y = (a + b_1 \text{ twigd})^2$

Table 6. Twenty most common forest plants recorded on 5,872 plots, on 96 islands, in Sea Otter Sound, June, 1993. Shown also are standardized oven-dry weights of deer forage (leaves and new stems) per 250 cm² leaf area for each species.

Species	Frequency of Occurrence		Grams/250 cm ²
	Plots	Islands	
<i>Vaccinium</i> spp. ^{1,4}	1,350	91	1.70
<i>Maianthemum dilitatum</i>	769	55	0.62
<i>Menziesia ferruginea</i> ⁴	513	67	0.90
<i>Cornus canadensis</i>	507	58	1.25
<i>Prenanthes alata</i>	453	45	0.40
<i>Listera</i> spp. ²	436	57	0.40
<i>Gymnocarpium dryopteris</i>	418	37	0.41
<i>Tiarella trifoliata</i>	251	36	0.55
<i>Gaultheria shallon</i>	176	22	2.86
<i>Streptopus</i> spp. ³	150	21	0.47
<i>Rubus pedatus</i>	134	29	0.90
<i>Moneses uniflora</i>	90	33	1.13
<i>Dryopteris dilitatum</i>	56	28	0.90
<i>Polypodium vulgare</i>	49	31	1.15
<i>Lysichiton americanum</i>	37	9	0.84
<i>Polystichum munitum</i>	29	14	2.23
<i>Rubus spectabilis</i> ⁴	29	11	1.03
<i>Opolpanax horridus</i> ⁴	24	7	0.96
<i>Blechnum spicant</i>	20	9	1.39
<i>Coptis aspleniifolia</i>	15	6	1.18

¹ includes *V. alaskensis*, *V. ovalifolium*, and *V. parvifolium*.

² includes *L. cordata* and *L. caurina*.

³ includes *S. roseus*, *S. streptopoides*, and *S. ampiflexus*.

⁴ seedlings and plants < 25 cm tall

Table 7. Habitat variables considered in multiple regression analysis to predict deer density on islands, Sea Otter Sound.

Variable	Rationale
Overstory Characteristics	
Basal Area	Correlated with snow interception
% Cedar	Descriptive of forest type; some forage value
Browse Plants	
<i>V. Parvifolium</i>	Most preferred browse species
<i>V. alaskensis/ovalifolium</i>	Most common and abundant browse species
Evergreen Plants	
<i>C. canadensis</i>	Most common and abundant forb in winter
Deciduous Plants	
<i>M. dilatatum</i>	Most common and abundant forb in summer
<i>Listera spp.</i>	Next most common and not correlated w/ <i>M. dilatatum</i> .
Fragmentation Indices	
Effective Area	Area available to and used by deer in vicinity of island
Fragment	Number of discrete patches within effective area
Security Indices	
Total Distance wolves	Travel distance from nearest large island w/resident wolves
Water Distance	Water distance to nearest large island w/resident wolves

Table 8. Protein and fiber constituents of blueberry (*V. alaskensis/ovalifolium*) and huckleberry (*V. parvifolium*) browse in Sea Otter Sound, Southeast Alaska, April, 1990 and 1991.

	<u>x (SD)</u>		P ¹
	<i>V. alaskensis/ovalifolium</i> N=16	<i>V. parvifolium</i> N=12	
Crude Protein (%)	4.33 (0.88)	5.28 (0.90)	0.012
Nuetral Detergent Fiber (%)	81.44 (3.14)	78.49 (3.02)	0.023
Acid Detergent Fiber (%)	65.43 (3.50)	60.09 (4.18)	0.002
Acid Detergent Lignin (%)	34.26 (6.67)	27.32 (4.44)	0.003
Acid Insoluble Ash (%)	1.39 (0.79)	1.42 (1.66)	0.955

¹ 2-tailed t-test.

Table 9. Protein and fiber constituents of *Vaccinium* browse in Sea Otter Sound compared with other studies. Comparisons are for browse gathered in forested sites, in winter/early spring. Variation in species, exact collection date and methodology is documented in footnotes.

Study and location	% Crude Protein	% NDF	% ADF	% Lignin	% Ash
Brown (1961)					
W. Washington ¹	8.3	-	-	-	4.6
W. Washington ²	7.2	-	-	-	4.2
W. Washington ³	7.1	-	-	-	4.4
Schoen & Wallmo (1979)					
Southeast Alaska ⁴	9.1	62.1	49.0	35.5	2.9
Billings & Wheeler (1979)					
Southeast Alaska ⁵	8.7	-	-	-	-
Southeast Alaska ⁶	9.1	-	-	-	-
Rose (1982)					
Southeast Alaska ⁷	8.1	-	-	-	-
Hanley & McKendrick (1982)					
Southeast Alaska ⁸	9.4	66.6	50.3	20.5	3.3
Southeast Alaska ⁹	9.6	70.6	51.6	16.7	3.2
Ellis (1984)					
Vancouver Island ¹⁰	8.6	-	-	-	6.5
Vancouver Island ¹¹	7.1	-	-	-	5.2
Van Horne et al. (1988)					
Southeast Alaska ¹²	9.6	-	-	-	-
Happe et al. (1990)					
Olympic Peninsula ¹³	5.4	67.1	-	17.2	-
Hanley et al. (1992)					
Southeast Alaska ¹⁴	7.7	60.3	-	19.8	
This study (1994)					
Southeast Alaska ¹⁵	4.3	81.4	65.4	34.3	1.4
Southeast Alaska ¹⁶	5.3	78.5	60.1	27.3	1.4

¹ *Vaccinium* spp., clear-cuts and old growth, winter. ² *Vaccinium* spp., clear-cuts and old growth, winter.

³ *Vaccinium* spp., clear-cuts and old growth, winter. ⁴ *V. ovalifolium*, old growth, Spring (included new buds). ⁵ *V. ovalifolium*, well-drained old growth, Feb.. ⁶ *V. ovalifolium*, poorly-drained old growth, Feb.. ⁷ *V. alaskensis*, old growth, Feb. ⁸ *V. alaskensis/ovalifolium*, old growth, Jan.. ⁹ *V. alaskensis/ovalifolium*, old growth, Mar. ¹⁰ *V. parvifolium*, old growth, coarse stems (10 cm long), Mar(?)

¹¹ *V. parvifolium*, old growth, fine stems (5 cm long), Mar(?) ¹² *V. alaskensis*, collected in 5 stands (incl. 1 OG, 4 clear-cut), Oct. ¹³ *V. parvifolium*, old growth, Jan. ¹⁴ *V. alaskensis*, old growth, winter. ¹⁵ *V. alaskensis/ovalifolium*, old growth, Apr. ¹⁶ *V. parvifolium*, old growth, Apr.

Table 10. Protein and fiber constituents of *Vaccinium*¹ browse as a function of stem size, Sea Otter Sound, April, 1991.

	Coarse N=9	$\bar{x}$ (SD) Intermediate N=16	Fine N=7	ANOVA Sig of F
Crude Protein (%)	4.34 (0.90)	4.53 (1.13)	4.90 (0.43)	0.507
Neutral Detergent Fiber (%)	86.00 (4.12)	80.26 (3.73)	76.73 (2.78)	0.000
Acid Detergent Fiber (%)	69.01 (4.41)	64.89 (4.92)	60.80 (4.40)	0.006
Acid Detergent Lignin (%)	32.34 (7.57)	32.53 (7.44)	33.72 (1.87)	0.907
Acid Insoluble Ash (%)	2.01 (0.44)	2.09 (1.03)	1.60 (0.76)	0.437

¹ *V. alaskensis*, *V. ovalifolium*, *V. parvifolium*.

Table 11. Regression statistics for habitat attributes that significantly predict deer densities, Sea Otter Sound, Alaska. $r^2=0.44$.

Variables	B	SE B	Beta	T	Sig T
Water Distance	11.53	3.012	0.338	3.83	0.000
Effective Area	0.150	0.041	0.297	3.66	0.000
<i>Listera</i> spp.	47.043	13.292	0.284	3.53	0.000
Huckleberry Browse	0.135	0.052	0.233	2.60	0.011
Basal Area	0.448	0.217	0.168	2.06	0.042
(Constant)	-12.906	10.217		-1.26	0.210

Analysis of Variance

Source of Variation	SS	df	MS	F	Sig. of F.
Regression	36189.9	5	7238.0	14.1	0.000
Residual	45359.8	88	515.5		
Total	81549.7	3	7753.5		

Table 12. Deer density, forage availability, and forage use in fragmented and unfragmented forest blocks, Lindenberg Head, May 1991.

	<u>x (SD)</u>		P ¹
	Fragmented N=169	Unfragmented N=161	
Deer density (deer/km ²)	66.8 (59.5)	76.3 (66.3)	0.237
% Browse use (estimate per plot)	48.8 (34.5)	71.7 (27.5)	0.000
<i>Vaccinium</i> ² height (cm)	69.1 (45.6)	33.8 (35.5)	0.000
<i>Vaccinium</i> ² available (kg/ha)	25.9 (44.9)	2.5 (7.5)	0.000
<i>Vaccinium</i> ² consumed (kg/ha)	11.6 (20.8)	2.4 (7.2)	0.000
Deer Mortality (deer/km coast) ³	10.00	5.88	

¹ Mann-Whitney U-test.

² *V. alaskensis*, *V. ovalifolium*, *V. parvifolium*

³ 1.5 km surveyed below fragmented block; 1.7 km surveyed below unfragmented block.

Table 13. Deer density, forage availability, and forage use in old growth and 19-year-old clear-cut habitat in a fragmented forest block, Lindenberg Head, May 1991.

	<u>x (SD)</u>		P ¹
	Clear-cut n=125	Old growth n=44	
Deer density (deer/km ²)	58.2 (58.9)	91.3 (54.6)	0.000
% Browse use (estimate per plot)	39.8 (32.5)	73.7 (27.4)	0.000
<i>Vaccinium</i> ² height (cm)	75.1 (48.6)	52.3 (30.9)	0.013
<i>Vaccinium</i> ² available (kg/ha)	29.5 (47.4)	15.8 (35.4)	0.057
<i>Vaccinium</i> ² consumed (kg/ha)	10.0 (16.8)	15.9 (29.1)	0.096

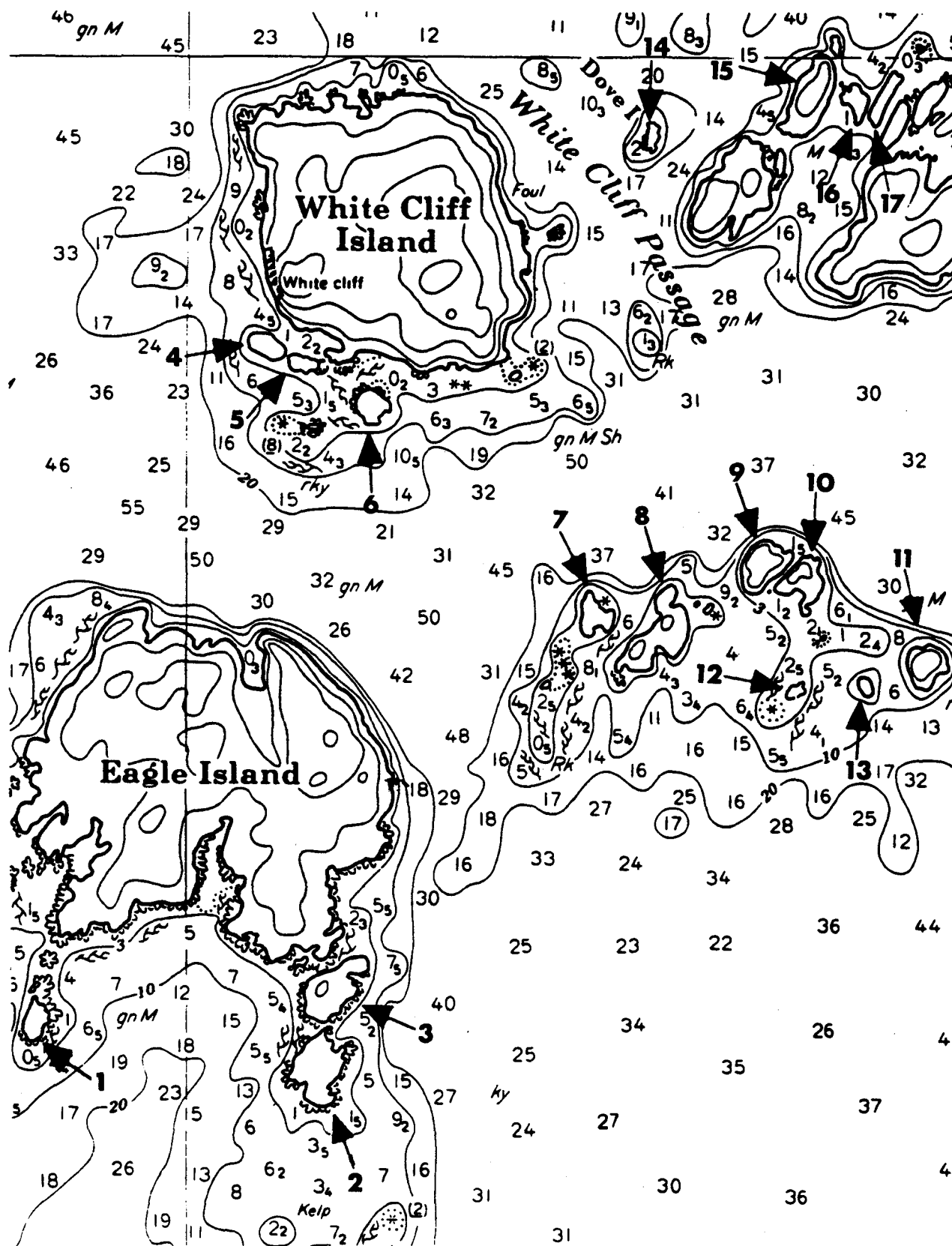
¹ Mann-Whitney U test.

² *V. alaskensis*, *V. ovalifolium*, *V. parvifolium*

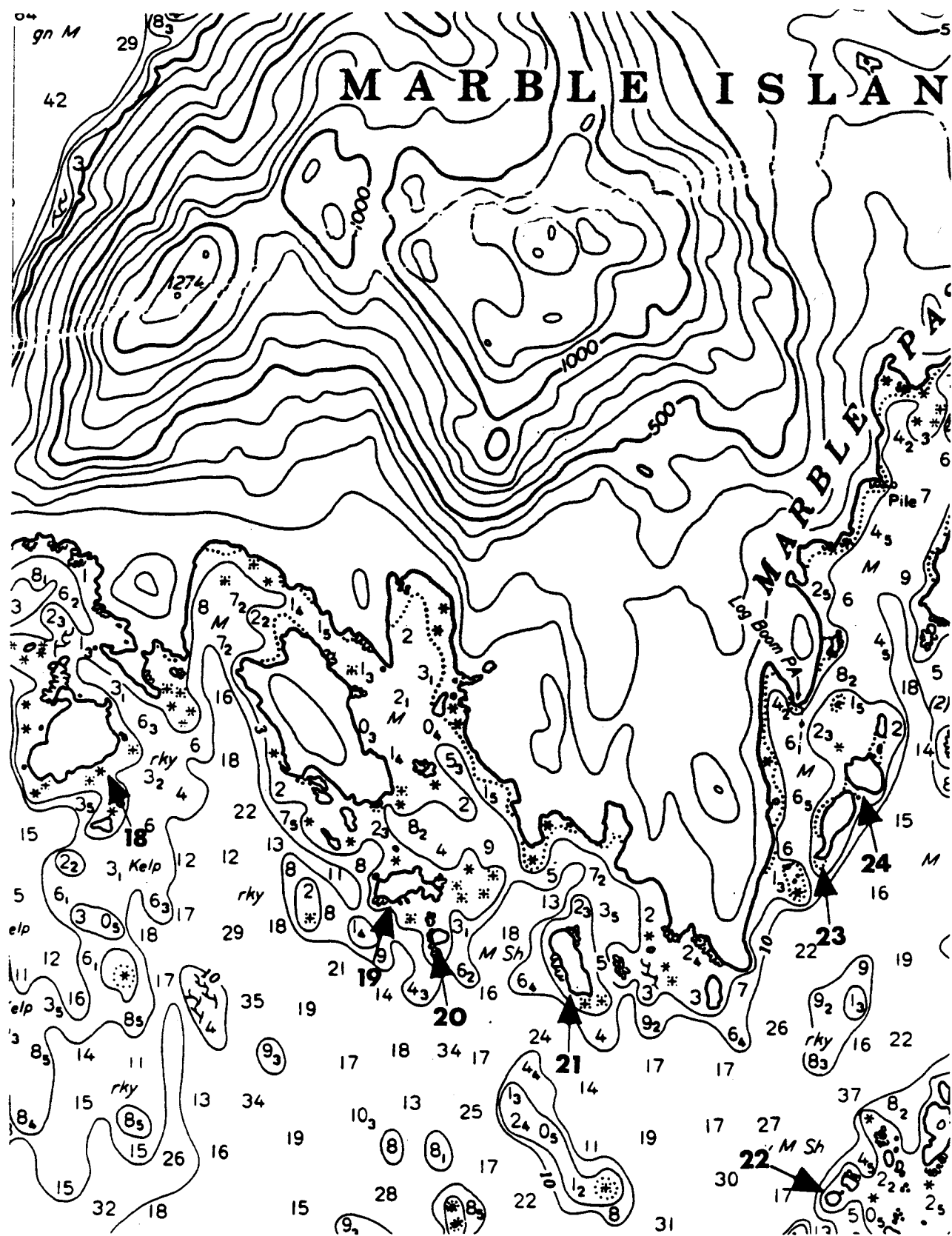
Appendix A

Locations of 97 small islands sampled 1989-94, Sea Otter Sound

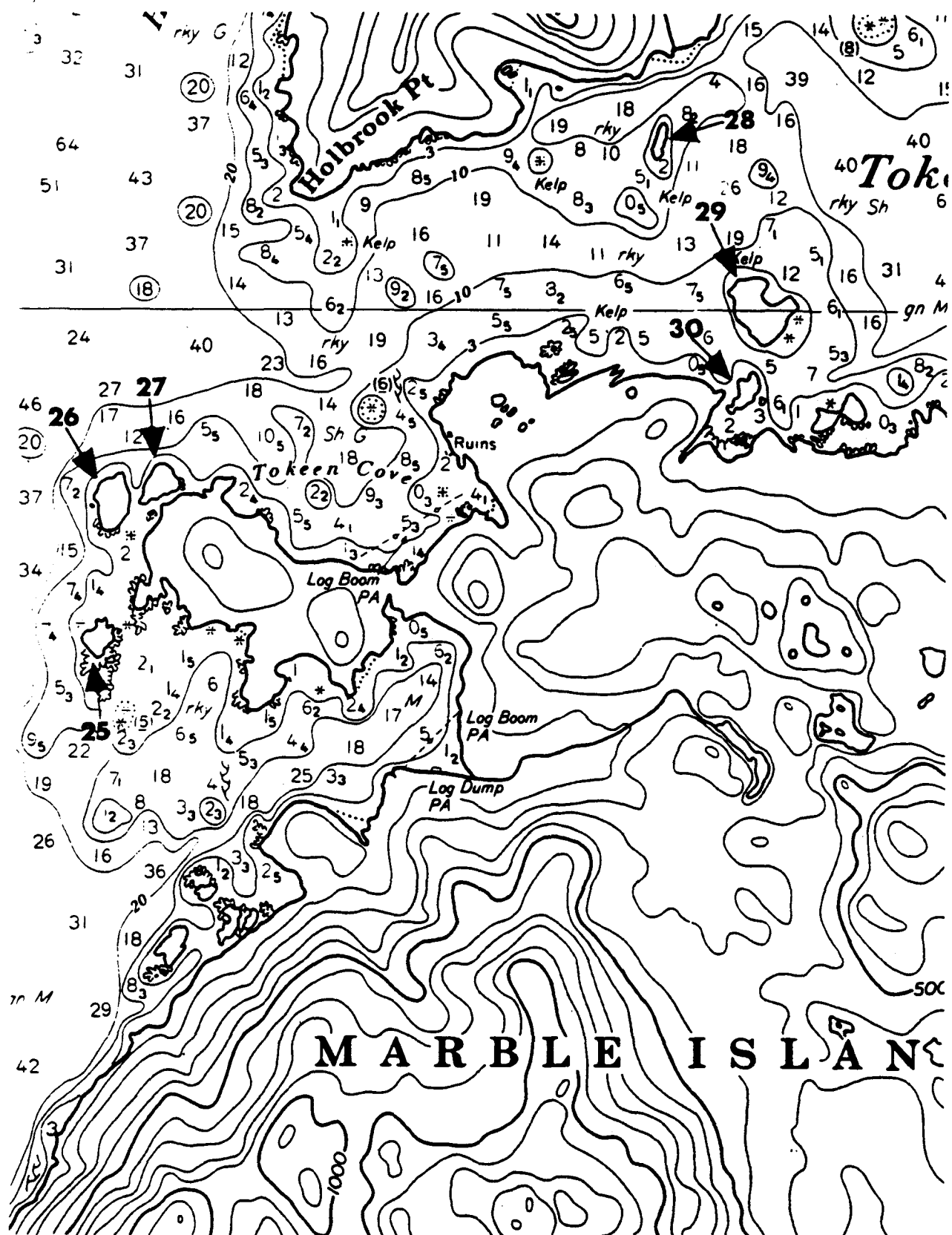
Appendix A. Location of sample islands 1-17.



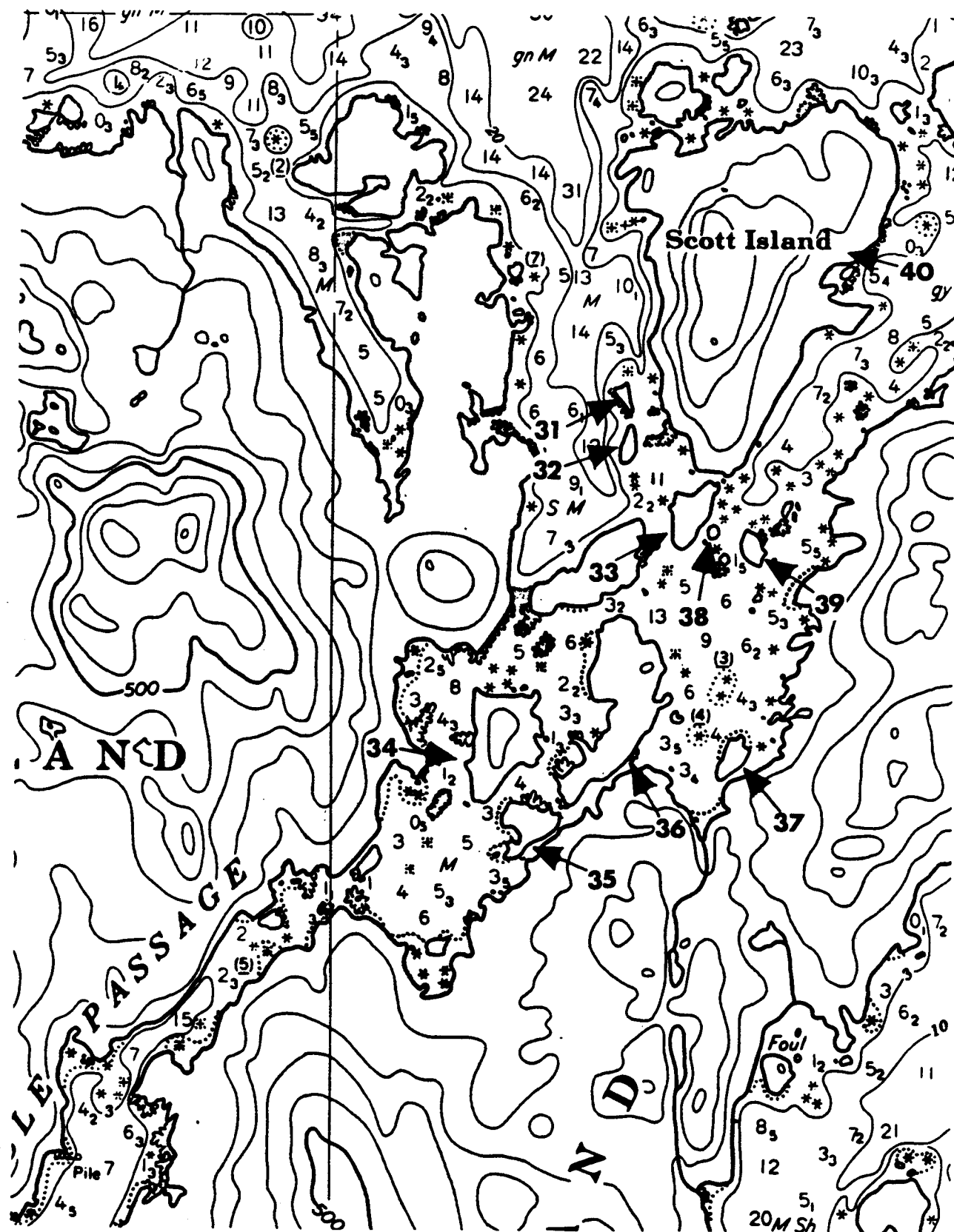
Appendix A. Location of sample islands 18-24.



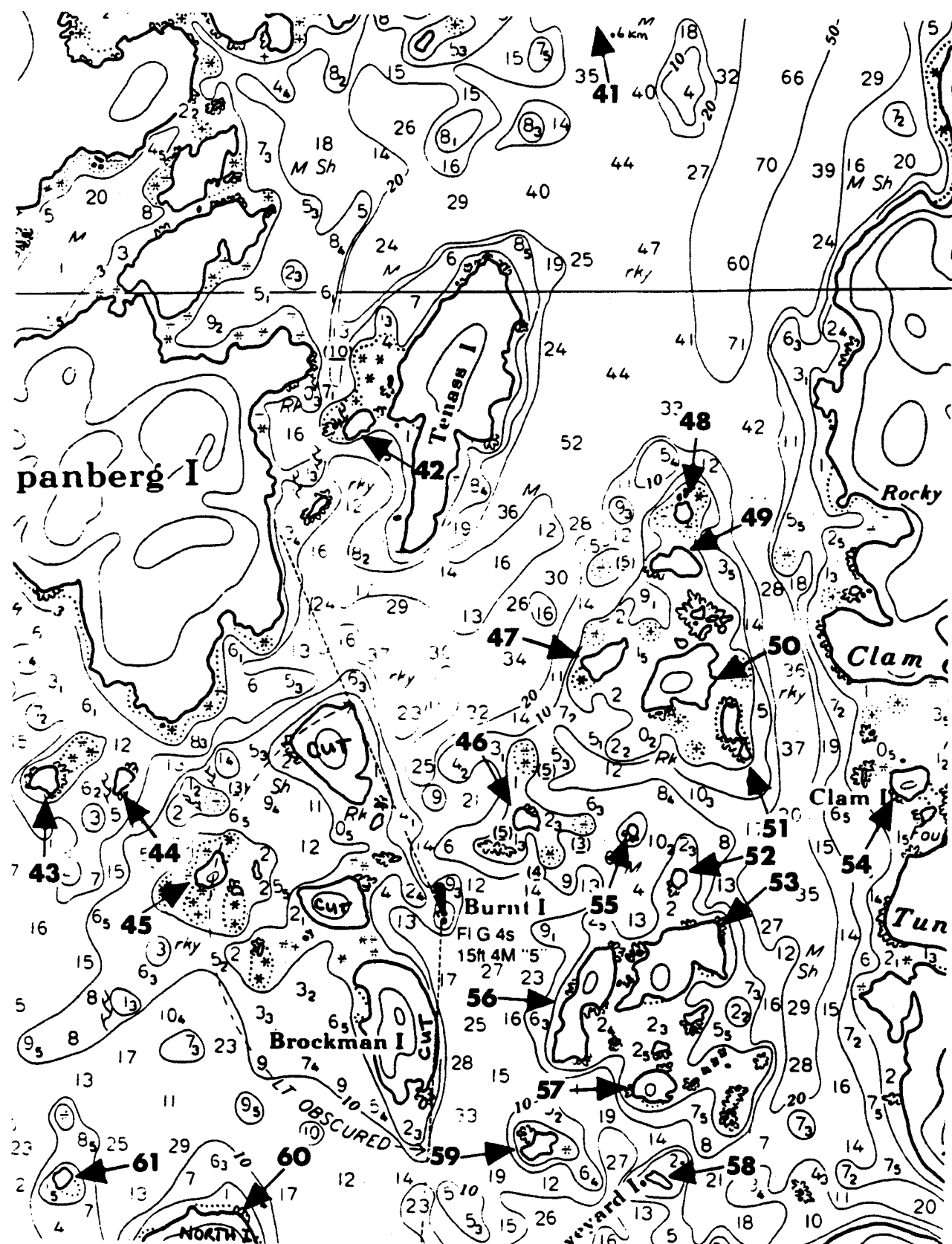
Appendix A. Location of sample islands 25-30.



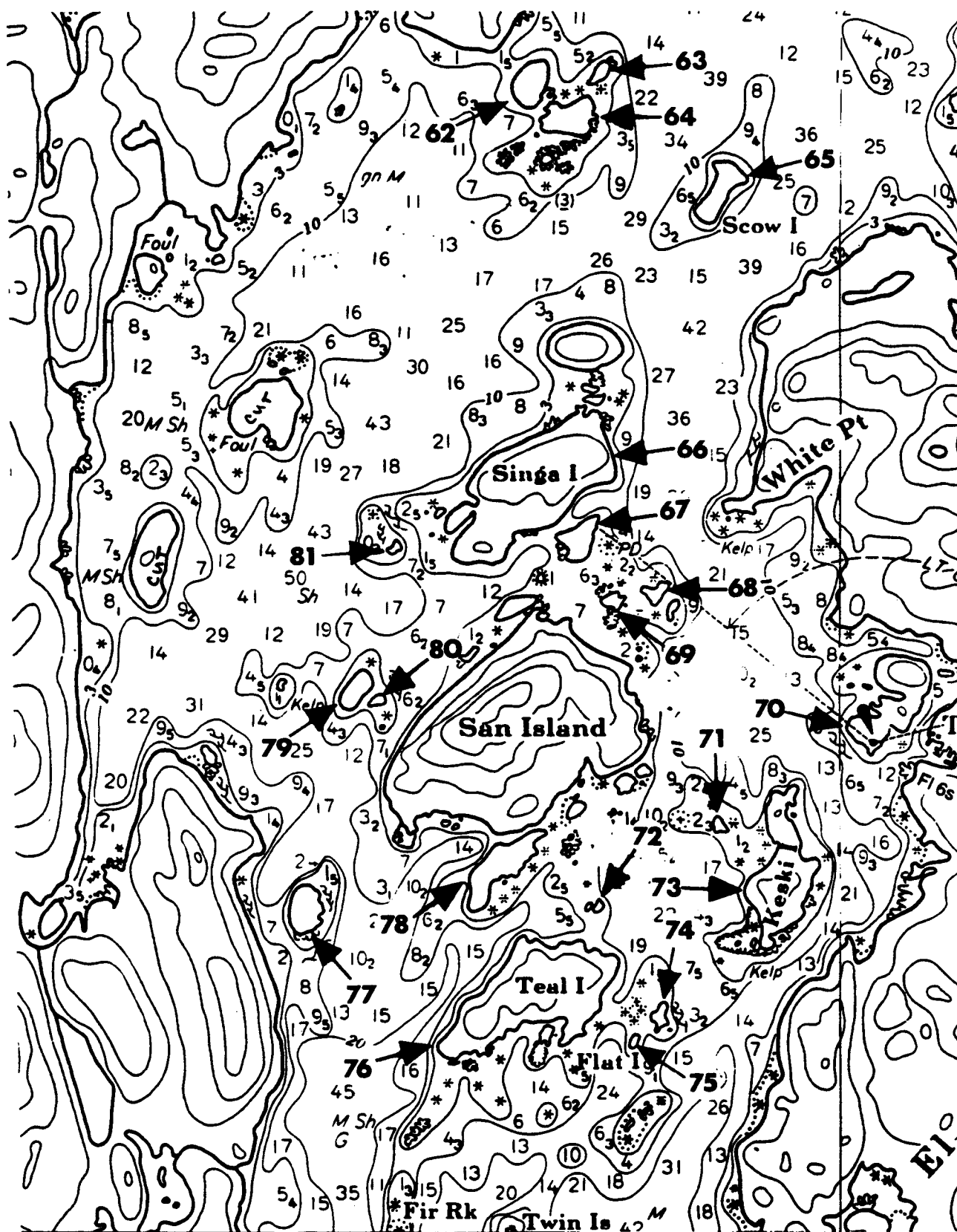
Appendix A. Location of sample islands 31-40.



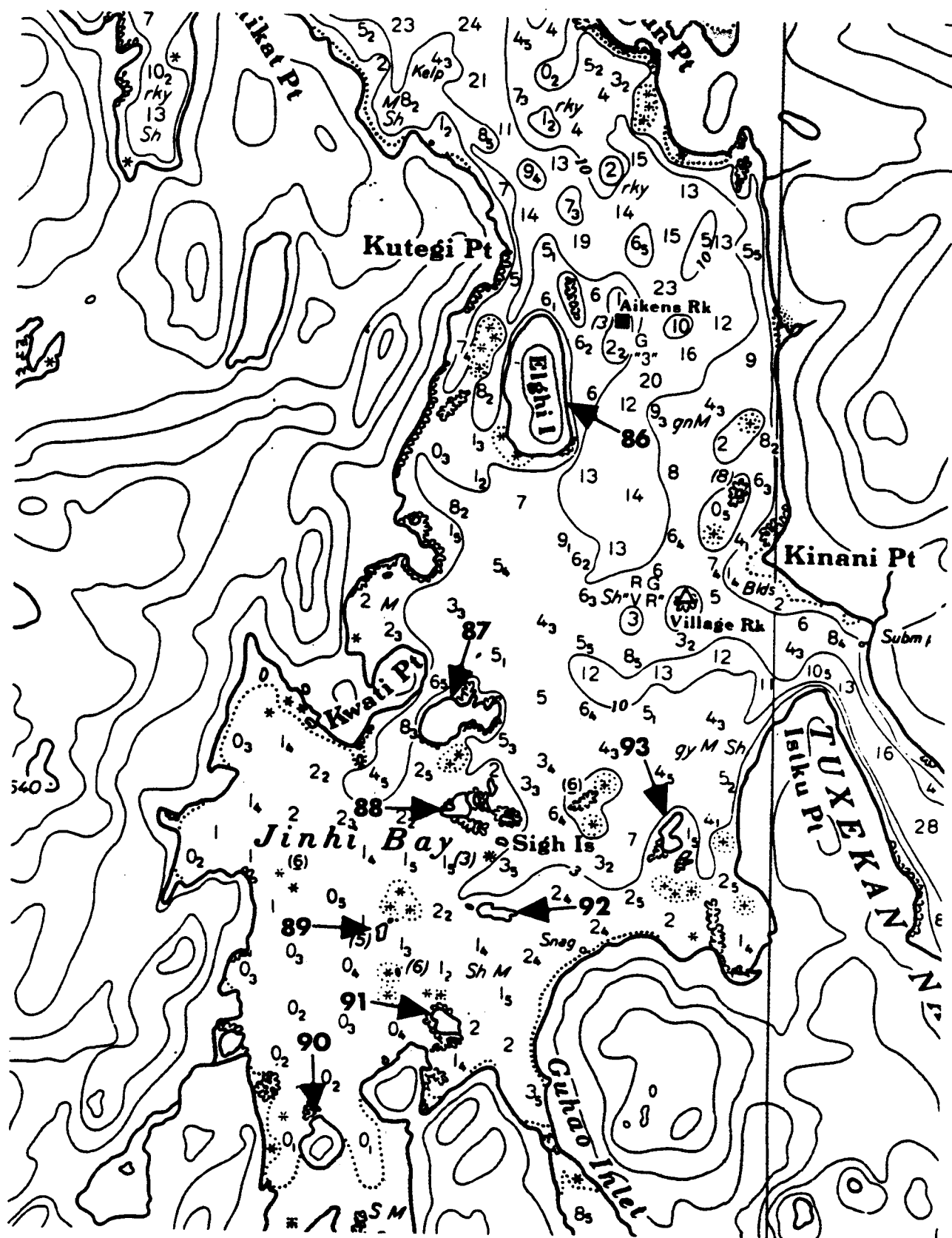
Appendix A. Location of sample islands 41-61.



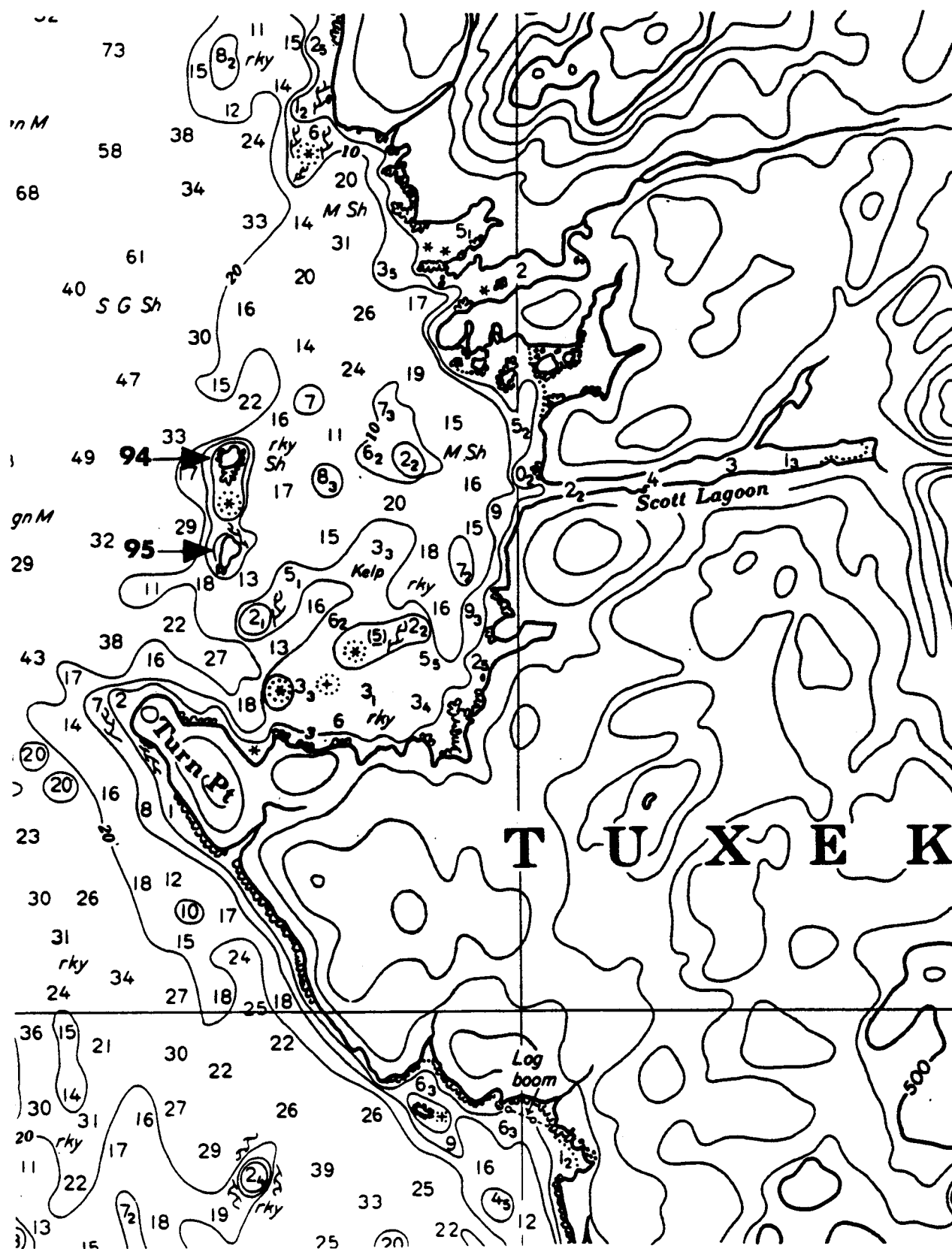
Appendix A. Location of sample islands 62-81.



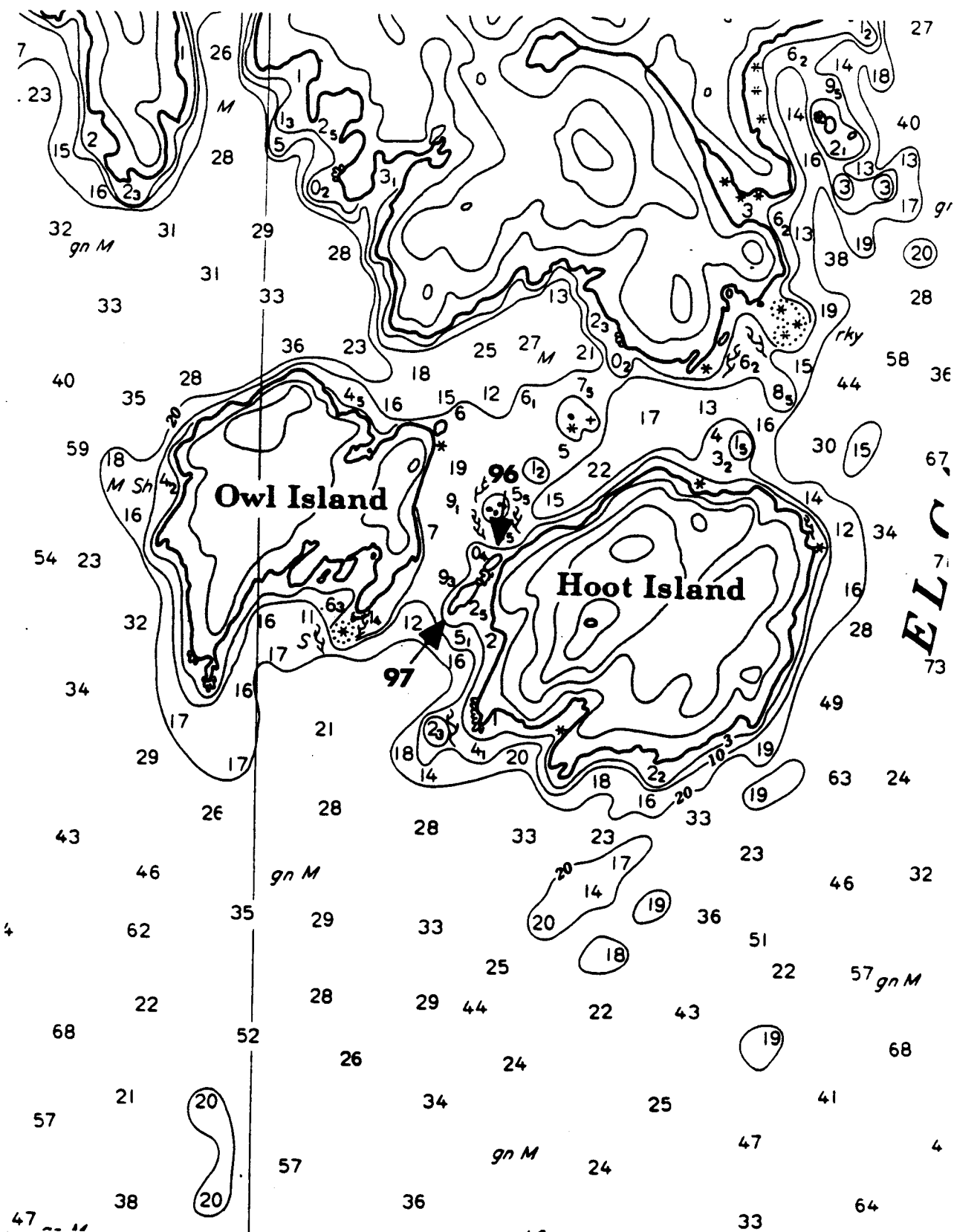
Appendix A. Location of sample islands 86-93.



Appendix A. Location of sample islands 94-95



Appendix A. Location of sample islands 96-97.



Appendix B

Deer Use and habitat attributes on 97 small islands, Sea Otter Sound

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	1	2	3	4	5	6	7	8	9	10
DEER USE										
Pellet-Groups/20 m2	1.0	6.9	8.1	3.6	3.5	1.5	7.0	4.0	3.4	5.4
Deer per Km2	16.5	113.3	133.5	59.1	58.5	24.4	115.2	65.9	56.6	89.3
% Browse Use	n.a.	93.0	35.2	73.2	20.5	21.3	35.0	103.7	211.8	492.6
SPATIAL ATTRIBUTES										
Island Size (Ha)	0.8	3.6	5.0	1.7	1.3	2.5	1.9	5.5	3.4	3.3
Effective Area (Ha)	0.8	177.9	177.9	133.8	133.8	133.8	8.7	47.8	13.6	13.6
TO ISLAND W/RES WOLVES										
No. Water Segments	11.0	12.0	11.0	9.0	9.0	9.0	9.0	10.0	11.0	11.0
Swimming Dist. (Km)	4.4	3.8	3.8	1.7	1.6	1.7	2.9	2.9	3.3	3.3
Overland Dist. (Km)	19.2	18.7	18.3	15.7	15.6	15.5	15.0	15.2	15.6	15.5
Total Dist. (Km)	23.6	22.5	22.1	17.4	17.2	17.2	17.9	18.1	18.9	18.8
OVERSTORY										
Basal Area (m2/Ha)	37.9	49.4	49.9	58.0	28.9	41.8	52.1	48.9	35.1	37.9
% Hemlock	0.0	12.2	34.5	36.5	7.1	23.8	29.9	55.3	50.5	36.2
% Spruce	100.0	86.7	39.5	36.5	32.1	33.3	32.1	14.9	10.3	20.0
% Cedar	0.0	1.1	25.9	27.0	60.7	42.9	38.1	29.8	39.3	43.8
SHRUBS (Kg/Ha)										
V. parvifolium	0.0	208.8	210.4	83.4	157.7	68.5	124.1	66.1	62.3	171.5
V. alaskensis	0.0	3.7	17.4	0.7	8.0	31.9	35.0	2.0	48.0	3.6
Herb-Layer Vacc.	0.0	1.2	18.9	3.8	4.5	2.2	3.9	5.4	3.2	2.7
M. ferruginea	0.0	0.0	0.6	76.9	54.8	36.2	5.2	2.4	15.7	56.3
G. shallon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.0	0.3	43.9	39.1	58.1	12.0	5.8	3.7	0.8	0.6
R. pedatus	0.0	0.1	7.3	1.1	0.0	0.0	0.1	1.2	0.0	0.0
T. trifoliata	0.0	4.2	12.0	5.0	7.1	1.1	0.2	0.9	0.2	1.2
C. asplenifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M. uniflora	0.1	0.1	1.3	0.3	0.0	0.1	0.4	0.9	0.4	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	169.3	68.7	1.4	22.6	51.5	103.4	3.1	2.3	2.9	0.5
P. alata	0.0	26.3	8.3	10.7	14.1	21.5	1.4	0.7	0.2	2.4
Streptopus spp.	0.0	3.3	10.7	27.4	3.4	18.1	0.3	0.0	0.0	0.1
Listera spp.	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.2	0.1	0.6
FERNS (Kg/Ha)										
G. dryopteris	0.0	1.3	0.0	14.3	0.0	0.0	0.0	8.2	2.8	1.6
D. dilatata	0.0	3.3	2.9	0.0	0.0	0.0	0.1	0.0	0.1	4.4

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	11	12	13	14	15	16	17	18	19	20
DEER USE										
Pellet-Groups/20 m2	2.4	5.1	2.6	0.0	2.0	2.7	5.6	1.2	4.5	1.0
Deer per Km2	40.4	84.3	43.4	0.0	32.7	45.0	92.6	20.2	73.8	16.5
% Browse Use	62.7	50.2	16.6	0.0	6.0	19.5	2.2	5.7	71.7	2.2
SPATIAL ATTRIBUTES										
Island Size (Ha)	3.2	0.4	0.4	1.1	5.5	1.1	1.3	10.5	2.5	0.2
Effective Area (Ha)	4.1	4.1	4.1	11.5	47.8	47.8	47.8	11.8	29.3	2.7
TO ISLAND W/RES WOLVES										
No. Water Segments	2.0	12.0	3.0	7.0	6.0	5.0	6.0	5.0	5.0	5.0
Swimming Dist. (Km)	2.1	2.6	2.4	1.0	0.7	0.6	0.7	0.9	1.2	1.3
Overland Dist. (Km)	14.0	14.2	14.2	14.2	14.0	13.6	14.4	14.1	11.0	11.0
Total Dist. (Km)	16.1	16.8	16.6	15.2	14.7	14.2	15.1	15.0	12.2	12.3
OVERSTORY										
Basal Area (m2/Ha)	36.4	34.0	40.3	23.9	26.6	60.9	42.6	32.4	38.6	17.9
% Hemlock	45.3	26.1	25.0	36.0	20.8	47.1	8.3	61.4	38.2	33.3
% Spruce	30.2	73.9	50.0	12.0	5.0	1.0	14.6	22.8	42.6	66.7
% Cedar	24.5	0.0	25.0	52.0	74.3	51.9	77.1	15.7	19.1	0.0
SHRUBS (Kg/Ha)										
V. parvifolium	82.4	6.3	22.4	94.4	1.0	6.6	58.5	7.9	68.7	51.8
V. alaskensis	8.9	7.0	29.7	23.3	15.7	34.3	43.9	8.1	7.7	0.0
Herb-Layer Vacc.	2.7	0.0	0.4	1.8	2.8	2.6	2.2	1.9	5.2	0.2
M. ferruginea	15.2	36.1	16.9	41.0	0.0	7.1	34.5	2.4	45.6	0.0
G. shallon	15.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.8	0.0	0.0	34.2	0.1	0.0	0.2	0.0	6.2	32.0
R. pedatus	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
T. trifoliata	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
C. asplenifolia	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
M. uniflora	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.7	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	0.4	185.1	3.1	9.6	0.0	1.1	0.0	0.0	10.1	234.5
P. alata	0.0	5.6	0.0	0.4	0.1	0.0	0.7	0.0	0.5	2.3
Streptopus spp.	0.0	7.7	0.0	1.4	0.0	0.0	0.0	0.0	0.4	0.0
Listera spp.	0.0	0.3	0.0	0.0	0.2	0.2	0.4	0.0	0.3	0.0
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	5.8	0.0
D. dilatata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	21	22	23	24	25	26	27	28	29	30
DEER USE										
Pellet-Groups/20 m2	5.0	3.1	4.8	3.4	1.6	0.5	1.1	4.2	0.9	1.7
Deer per Km2	83.5	50.8	79.2	56.1	26.5	8.1	18.1	69.1	15.7	27.4
% Browse Use	37.3	10.0	7.4	10.1	1.4	25.0	65.3	122.9	1.2	7.8
SPATIAL ATTRIBUTES										
Island Size (Ha)	3.2	0.5	2.4	1.9	1.0	2.8	1.9	0.7	6.1	0.9
Effective Area (Ha)	3.4	7.8	4.7	4.7	1.0	4.8	4.8	0.7	11.5	11.5
TO ISLAND W/RES WOLVES										
No. Water Segments	5.0	5.0	6.0	5.0	5.0	5.0	5.0	1.0	6.0	5.0
Swimming Dist. (Km)	1.1	0.5	1.2	1.2	0.9	0.9	0.8	0.3	0.9	0.8
Overland Dist. (Km)	11.0	12.0	10.0	10.0	11.2	11.2	11.2	0.1	9.4	9.4
Total Dist. (Km)	12.1	12.5	11.2	11.2	12.1	12.1	12.0	0.4	10.3	10.2
OVERSTORY										
Basal Area (m2/Ha)	43.8	53.8	51.2	31.9	36.4	37.2	40.6	70.0	54.7	47.4
% Hemlock	21.3	18.4	23.4	62.5	6.7	59.0	59.9	28.4	49.6	45.4
% Spruce	35.2	23.7	8.2	6.7	93.3	40.4	15.0	40.2	17.3	17.6
% Cedar	43.4	57.9	68.4	30.8	0.0	0.6	25.2	31.4	33.1	37.0
SHRUBS (Kg/Ha)										
V. parvifolium	24.4	7.1	50.7	27.7	0.0	9.5	19.6	242.0	0.1	0.0
V. alaskensis	31.8	57.8	79.6	62.0	74.3	20.8	9.5	7.3	58.8	102.5
Herb-Layer Vacc.	7.4	1.7	2.1	2.9	4.2	3.1	0.4	6.1	2.8	0.8
M. ferruginea	12.2	21.4	80.3	21.3	0.0	0.0	0.0	0.0	0.0	51.5
G. shallon	0.0	5.5	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	3.4	2.3	2.0	1.9	2.1	3.3	0.4	0.1	0.2	1.5
R. pedatus	0.1	0.0	0.1	0.0	0.0	8.2	0.1	0.0	0.2	0.2
T. trifoliata	0.7	0.0	0.1	0.2	0.0	0.5	0.1	0.1	0.0	0.0
C. asplenifolia	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
M. uniflora	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	3.2	0.0	0.0	0.0	0.0	2.8	338.7	41.6	0.0	4.1
P. alata	0.6	0.0	0.0	0.2	0.0	0.2	0.0	8.9	0.0	0.0
Streptopus spp.	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
Listera spp.	0.3	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.1	0.8
FERNS (Kg/Ha)										
G. dryopteris	2.8	0.0	3.2	0.3	0.0	5.3	0.0	0.0	0.0	0.0
D. dilatata	0.0	0.0	0.0	6.9	0.0	0.0	0.0	0.0	0.0	0.0

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	31	32	33	34	35	36	37	38	39	40
DEER USE										
Pellet-Groups/20 m2	2.4	1.3	0.7	0.9	0.9	0.7	0.4	2.4	1.1	0.8
Deer per Km2	39.5	21.5	11.8	14.5	14.3	12.3	6.0	39.1	19.0	12.5
% Browse Use	19.8	25.0	23.6	4.9	1.2	5.5	2.3	8.4	9.0	51.3
SPATIAL ATTRIBUTES										
Island Size (Ha)	0.4	1.2	4.1	12.1	3.8	20.5	1.6	0.3	0.3	133.9
Effective Area (Ha)	151.6	151.6	151.6	36.5	36.5	37.6	22.8	150.6	150.6	151.6
TO ISLAND W/RES WOLVES										
No. Water Segments	4.0	3.0	3.0	4.0	4.0	3.0	3.0	4.0	3.0	2.0
Swimming Dist. (Km)	0.4	0.3	0.2	0.3	0.0	0.1	0.1	0.3	0.4	0.2
Overland Dist. (Km)	5.1	5.0	5.0	6.6	6.6	6.3	5.5	5.1	5.1	1.6
Total Dist. (Km)	5.5	5.3	5.2	6.9	6.6	6.4	5.6	5.4	5.5	1.8
OVERSTORY										
Basal Area (m2/Ha)	38.8	47.0	39.6	44.7	35.8	26.4	35.8	17.1	45.3	44.1
% Hemlock	42.0	26.7	51.1	60.3	34.8	40.4	42.1	12.5	35.2	50.6
% Spruce	14.0	17.8	13.3	6.7	5.5	6.0	0.0	12.5	5.6	10.5
% Cedar	44.0	55.6	35.6	33.0	59.8	53.6	57.9	75.0	59.3	38.9
SHRUBS (Kg/Ha)										
V. parvifolium	65.5	73.6	0.6	19.2	39.3	3.5	47.9	24.7	1.7	3.8
V. alaskensis	205.3	69.6	22.5	55.5	94.4	78.1	46.4	37.0	14.8	57.2
Herb-Layer Vacc.	1.2	4.8	2.0	2.7	2.9	2.9	2.0	3.6	0.4	3.0
M. ferruginea	43.0	34.1	0.0	0.0	23.6	11.0	45.7	36.9	9.5	0.0
G. shallon	0.0	0.0	0.3	0.0	20.2	57.6	334.3	9.2	0.0	42.4
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	29.1	0.6	0.3	1.9	39.6	8.7	7.9	12.6	1.9	6.1
R. pedatus	2.1	0.3	0.0	2.3	6.6	1.1	2.8	1.2	0.2	5.2
T. trifoliata	0.0	0.1	0.1	1.7	0.8	0.0	0.0	0.0	0.2	5.6
C. asplenifolia	0.0	0.0	0.0	0.0	10.4	0.2	0.0	0.0	0.0	1.3
M. uniflora	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	1.6	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.0	0.0
P. alata	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Streptopus spp.	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Listera spp.	0.1	0.0	0.3	0.2	0.0	0.3	0.3	0.5	0.0	0.2
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	0.7	12.9	7.3	0.1	0.0	0.0	0.0	2.8
D. dilatata	0.0	0.0	0.2	0.1	1.4	0.0	0.0	0.0	6.2	0.6

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	41	42	43	44	45	46	47	48	49	50
DEER USE										
Pellet-Groups/20 m ²	3.4	2.5	1.7	2.2	1.3	1.0	5.4	2.4	3.4	2.0
Deer per Km ²	56.7	41.3	28.8	37.0	21.9	16.5	89.4	40.0	56.4	32.9
% Browse Use	8.5	2.4	28.2	20.0	12.3	5.4	45.7	53.4	192.8	27.5
SPATIAL ATTRIBUTES										
Island Size (Ha)	1.6	0.8	1.3	0.4	1.4	0.6	1.8	0.3	1.8	6.5
Effective Area (Ha)	1.6	41.4	1.7	1.7	6.4	0.6	10.6	2.1	10.6	10.6
TO ISLAND W/RES WOLVES										
No. Water Segments	1.0	2.0	2.0	2.0	3.0	6.0	4.0	5.0	4.0	3.0
Swimming Dist. (Km)	0.1	0.3	0.5	0.3	0.8	2.0	1.0	1.9	1.2	0.7
Overland Dist. (Km)	0.1	3.4	2.8	3.5	3.6	2.1	1.7	2.2	2.1	1.0
Total Dist. (Km)	0.2	3.7	3.3	3.8	4.4	4.1	2.7	4.1	3.3	1.7
OVERSTORY										
Basal Area (m ² /Ha)	65.0	47.4	45.5	68.1	43.9	42.2	49.4	43.5	42.3	45.1
% Hemlock	41.1	55.0	57.9	36.8	67.4	60.6	46.9	41.7	32.4	53.6
% Spruce	6.8	10.0	18.7	11.8	10.4	30.3	3.1	13.9	8.0	8.8
% Cedar	52.1	35.0	23.4	51.5	22.2	9.1	50.0	44.4	59.7	37.5
SHRUBS (Kg/Ha)										
V. parvifolium	0.6	0.0	34.0	73.5	123.6	140.2	48.6	12.5	16.8	39.4
V. alaskensis	69.6	35.0	4.6	6.4	108.9	36.9	26.2	14.6	37.5	18.9
Herb-Layer Vacc.	2.7	1.1	8.9	19.5	0.4	4.0	7.1	4.4	14.1	14.4
M. ferruginea	42.4	22.7	1.0	42.5	77.9	18.5	66.1	0.0	3.2	8.6
G. shallon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.0	2.6	0.9	1.6	0.0	0.0	1.6	0.1	4.4	0.3
R. pedatus	0.1	0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.0
T. trifoliata	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
C. asplenifolia	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
M. uniflora	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.3
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	0.0	0.0	167.3	0.1	0.0	6.0	0.0	0.1	0.4	0.0
P. alata	0.0	0.0	1.7	13.8	0.0	0.7	0.0	0.0	0.0	0.0
Streptopus spp.	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Listera spp.	0.1	0.0	0.2	0.3	0.0	0.0	0.4	0.0	0.7	0.2
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	8.0	0.0	0.0	0.1	0.0	0.0	1.6	0.2
D. dilatata	0.0	0.0	3.1	0.0	0.0	0.0	0.0	0.0	5.1	0.0

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	51	52	53	54	55	56	57	58	59	60
DEER USE										
Pellet-Groups/20 m2	1.9	0.1	1.4	0.9	0.8	1.8	1.9	1.1	3.5	0.8
Deer per Km2	30.9	1.5	22.5	14.9	12.7	28.9	31.7	18.2	58.6	14.0
% Browse Use	8.8	4.6	17.0	9.3	70.6	17.9	19.0	2.4	15.5	29.7
SPATIAL ATTRIBUTES										
Island Size (Ha)	0.9	0.4	9.8	1.4	0.2	7.0	1.6	0.4	0.9	75.8
Effective Area (Ha)	7.4	17.4	18.7	1.5	17.4	18.7	18.7	0.4	9.6	76.0
TO ISLAND W/RES WOLVES										
No. Water Segments	2.0	4.0	3.0	1.0	5.0	3.0	2.0	1.0	2.0	3.0
Swimming Dist. (Km)	0.8	1.4	1.2	0.1	1.6	1.1	0.9	0.5	0.9	0.8
Overland Dist. (Km)	1.2	1.8	1.4	0.1	1.8	1.1	1.0	0.5	1.0	19.1
Total Dist. (Km)	2.0	3.2	2.6	0.2	3.4	2.2	1.9	1.0	1.9	19.9
OVERSTORY										
Basal Area (m2/Ha)	50.3	59.7	37.3	35.8	26.9	37.0	30.9	22.0	40.1	19.0
% Hemlock	28.3	24.1	49.7	46.3	37.5	43.6	60.2	16.3	61.5	34.9
% Spruce	19.5	15.5	18.4	28.0	15.6	8.0	15.0	27.9	19.7	4.0
% Cedar	52.2	60.3	32.0	25.6	46.9	48.4	24.8	55.8	18.9	61.1
SHRUBS (Kg/Ha)										
V. parvifolium	54.8	17.7	20.6	7.9	193.9	70.9	70.8	45.1	47.0	0.7
V. alaskensis	3.5	77.7	25.1	7.7	28.8	65.5	45.9	22.7	53.7	23.1
Herb-Layer Vacc.	6.5	3.7	11.3	1.8	8.6	6.5	4.5	0.0	4.4	0.
M. ferruginea	1.4	127.2	3.6	0.0	0.0	0.2	0.0	80.7	19.0	0.
G. shallon	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	596.3
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.4	1.4	1.4	0.1	4.4	2.6	1.3	0.9	0.6	8.6
R. pedatus	0.2	0.0	0.6	0.0	0.5	0.6	0.2	0.0	0.0	1.6
T. trifoliata	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.
C. asplenifolia	0.0	0.0	0.2	0.0	0.0	0.3	0.1	0.0	0.0	1.3
M. uniflora	0.1	0.0	0.2	0.5	0.0	0.2	0.1	0.0	0.0	0.
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	0.0	0.0	0.0	0.1	18.7	0.0	0.0	0.0	0.0	0.
P. alata	0.7	0.0	0.0	0.2	5.2	0.0	0.7	0.0	0.1	0.
Streptopus spp.	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.
Listera spp.	0.2	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	0.
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	0.3	10.3	0.0	1.8	1.3	0.0	0.0	0.
D. dilatata	0.0	0.0	0.1	1.8	0.0	0.0	0.0	0.0	0.0	0.

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	61	62	63	64	65	66	67	68	69	70
DEER USE										
Pellet-Groups/20 m2	0.0	1.2	3.5	0.7	0.9	1.0	2.2	3.8	3.7	0.9
Deer per Km2	0.0	19.5	57.5	11.6	15.0	15.9	35.7	62.5	61.8	15.4
% Browse Use	1.3	9.4	59.7	4.2	47.4	66.1	5.3	6.5	46.7	4.6
SPATIAL ATTRIBUTES										
Island Size (Ha)	0.8	3.2	0.8	4.2	3.5	30.4	2.8	1.0	0.9	2.1
Effective Area (Ha)	0.8	9.4	9.4	9.4	3.5	111.7	111.7	112.9	111.7	8.9
TO ISLAND W/RES WOLVES										
No. Water Segments	4.0	3.0	4.0	4.0	3.0	3.0	4.0	5.0	5.0	3.0
Swimming Dist. (Km)	1.3	0.2	0.3	0.2	1.1	1.1	1.1	1.4	1.2	1.6
Overland Dist. (Km)	19.5	5.1	5.2	5.2	19.3	18.8	19.2	19.3	19.3	17.2
Total Dist. (Km)	20.8	5.3	5.5	5.4	20.4	19.9	20.3	20.7	20.5	18.8
OVERSTORY										
Basal Area (m2/Ha)	37.5	31.9	59.9	41.8	46.1	12.1	37.5	38.5	32.6	34.6
% Hemlock	63.3	56.5	21.2	67.8	40.7	42.4	32.5	50.8	20.7	42.7
% Spruce	10.2	21.0	9.1	6.7	1.9	3.1	4.0	9.2	20.7	1.9
% Cedar	26.5	22.6	69.7	25.6	57.4	54.5	63.6	40.0	58.6	55.5
SHRUBS (Kg/Ha)										
V. parvifolium	43.3	4.9	0.9	0.0	10.4	4.4	51.0	72.3	84.4	0.8
V. alaskensis	44.5	109.6	22.8	292.8	22.0	15.6	56.1	45.2	34.1	74.5
Herb-Layer Vacc.	0.2	1.8	1.2	miss.	12.5	3.7	3.2	3.3	3.2	1.3
M. ferruginea	61.9	36.3	17.8	miss.	2.9	1.6	28.8	29.2	2.6	11.1
G. shallon	208.0	0.0	523.6	0.0	0.0	160.9	19.6	25.1	0.0	22.6
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.0	0.9	0.4	0.5	2.0	1.6	1.6	3.0	7.2	2.7
R. pedatus	0.0	0.0	0.0	0.0	0.0	0.6	1.1	0.0	0.0	0.0
T. trifoliata	0.0	0.0	0.0	miss.	0.0	0.2	0.0	0.1	0.0	0.1
C. asplenifolia	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
M. uniflora	0.0	0.0	0.0	miss.	0.0	0.0	0.0	0.0	0.0	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	1.5	0.0	0.0	miss.	0.0	0.0	0.0	0.0	0.0	0.0
P. alata	0.4	0.0	0.0	miss.	0.0	0.0	0.0	0.0	0.2	0.0
Streptopus spp.	0.0	0.0	0.0	miss.	0.0	0.0	0.0	0.0	0.0	0.0
Listera spp.	0.0	0.0	0.0	miss.	0.9	0.0	0.1	0.0	0.0	0.0
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	0.0	miss.	0.0	0.2	1.2	5.1	0.0	0.0
D. dilatata	0.0	0.4	0.0	miss.	0.3	0.0	0.0	0.0	0.0	0.6

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND									
	71	72	73	74	75	76	77	78	79	80
DEER USE										
Pellet-Groups/20 m2	0.4	4.8	1.4	1.3	3.2	0.8	1.9	2.9	1.3	2.4
Deer per Km2	5.9	79.1	23.2	21.1	52.2	13.0	31.5	48.5	22.2	39.1
% Browse Use	1.3	7.2	19.4	39.5	13.1	20.4	7.2	17.6	26.9	29.9
SPATIAL ATTRIBUTES										
Island Size (Ha)	0.4	0.4	11.3	0.7	0.4	24.4	3.0	5.3	1.5	0.4
Effective Area (Ha)	12.5	81.6	12.5	25.7	25.7	81.6	3.0	81.6	77.5	77.5
TO ISLAND W/RES WOLVES										
No. Water Segments	4.0	5.0	3.0	3.0	4.0	4.0	3.0	5.0	6.0	5.0
Swimming Dist. (Km)	1.0	1.5	0.8	1.1	1.2	1.4	0.2	1.3	1.5	1.4
Overland Dist. (Km)	16.1	16.0	15.8	15.6	15.6	15.7	11.3	20.8	20.5	20.6
Total Dist. (Km)	17.1	17.5	16.6	16.7	16.8	17.0	11.5	22.1	22.0	22.0
OVERSTORY										
Basal Area (m2/Ha)	44.8	20.9	42.0	47.0	29.9	23.6	35.8	41.4	48.3	46.3
% Hemlock	52.5	86.7	53.6	40.0	28.7	59.9	64.2	46.8	63.7	28.9
% Spruce	13.6	13.3	18.5	11.7	20.2	16.6	8.8	4.2	14.2	0.0
% Cedar	33.9	0.0	27.9	48.3	51.1	23.5	27.0	48.9	22.1	71.1
SHRUBS (Kg/Ha)										
V. parvifolium	58.3	52.9	18.5	83.5	88.9	2.1	1.8	17.3	9.4	28.7
V. alaskensis	57.7	77.7	42.2	113.9	106.7	8.8	20.3	37.7	17.5	27.2
Herb-Layer Vacc.	27.1	5.5	4.9	1.0	4.7	2.4	5.8	3.5	9.9	2.7
M. ferruginea	0.0	55.7	0.0	0.0	0.0	0.0	0.0	33.5	10.3	92.3
G. shallon	0.0	0.0	0.0	0.0	18.7	0.1	0.0	25.2	0.0	1029.8
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.0	1.5	0.2	0.0	2.2	0.0	0.1	0.2	4.3	49.3
R. pedatus	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.4	0.0
T. trifoliata	0.0	0.0	0.4	0.0	0.0	0.1	0.0	0.0	0.1	0.0
C. asplenifolia	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
M. uniflora	0.0	1.6	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	5.8	0.5	0.3	0.0	0.8	0.0	0.0	0.0	0.1	3.8
P. alata	2.4	0.1	0.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0
Streptopus spp.	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Listera spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	9.1	0.0	0.0	3.8	0.2	1.8	0.3	0.0
D. dilatata	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0

(continued)

Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

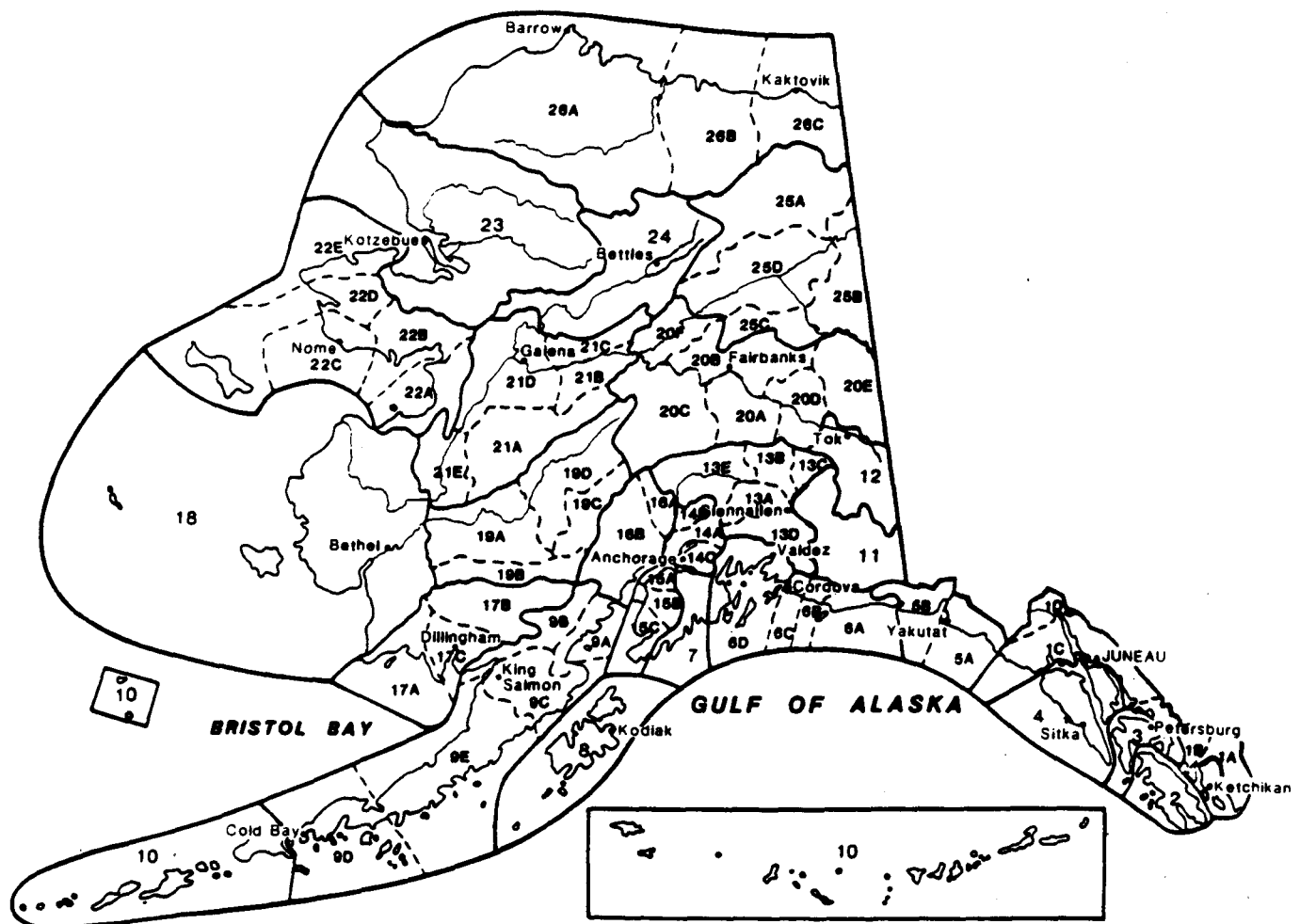
	ISLAND									
	81	82	83	84	85	86	87	88	89	90
DEER USE										
Pellet-Groups/20 m2	0.2	1.3	1.7	1.5	3.4	0.2	0.4	0.4	0.6	0.2
Deer per Km2	3.1	21.3	28.0	25.3	55.9	2.7	6.7	6.4	10.1	3.4
% Browse Use	0.0	12.2	129.4	48.5	25.6	4.4	0.0	0.0	20.5	0.5
SPATIAL ATTRIBUTES										
Island Size (Ha)	0.4	1.5	2.8	13.7	1.1	15.2	3.6	0.4	0.2	3.5
Effective Area (Ha)	32.2	20.6	123.6	15.0	1.6	15.3	4.4	4.4	0.2	3.5
TO ISLAND W/RES WOLVES										
No. Water Segments	4.0	2.0	3.0	3.0	2.0	2.0	2.0	3.0	3.0	2.0
Swimming Dist. (Km)	1.3	1.1	0.8	0.6	0.4	0.6	0.3	0.6	0.9	0.2
Overland Dist. (Km)	19.6	14.5	14.3	13.1	13.0	10.9	10.1	10.2	4.2	5.4
Total Dist. (Km)	20.9	15.6	15.0	13.7	13.4	11.5	10.4	10.8	5.1	5.6
OVERSTORY										
Basal Area (m2/Ha)	30.9	40.3	32.6	45.8	45.2	41.9	45.0	54.8	57.3	49.3
% Hemlock	63.0	51.8	64.3	55.8	61.8	82.7	61.0	42.1	12.1	65.5
% Spruce	11.1	10.5	7.8	18.1	7.3	6.1	7.1	16.4	29.8	4.1
% Cedar	25.9	37.7	27.8	26.2	30.9	11.2	31.9	41.4	58.1	30.5
SHRUBS (Kg/Ha)										
V. parvifolium	21.2	48.1	31.0	7.8	51.0	6.4	18.6	38.5	49.0	13.6
V. alaskensis	117.6	52.4	16.8	15.3	52.7	6.3	48.7	25.3	3.3	29.6
Herb-Layer Vacc.	1.8	3.8	5.3	2.1	4.3	0.6	0.8	1.4	0.0	1.3
M. ferruginea	0.0	0.0	0.0	0.0	0.0	6.2	25.9	37.5	0.0	0.0
G. shallon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EVERGREEN FORBS (Kg/Ha)										
C. canadensis	0.0	13.2	0.2	0.2	0.0	0.0	0.1	0.2	0.0	0.1
R. pedatus	0.0	0.0	0.2	1.1	0.5	0.0	0.0	0.0	0.0	0.0
T. trifoliata	0.0	0.0	0.1	0.8	1.2	0.2	0.0	0.0	0.0	0.0
C. asplenifolia	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
M. uniflora	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
DECIDUOUS FORBS (Kg/Ha)										
M. dilatatum	5.6	0.0	0.0	0.7	0.2	0.0	0.0	0.0	21.4	0.0
P. alata	0.0	0.0	0.0	0.1	1.0	0.0	0.0	0.0	4.6	0.0
Streptopus spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Listera spp.	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
FERNS (Kg/Ha)										
G. dryopteris	0.0	0.0	1.5	11.3	9.5	0.3	0.9	1.8	0.0	0.0
D. dilatata	0.0	0.0	6.5	0.3	0.6	0.1	0.0	0.0	0.0	0.7

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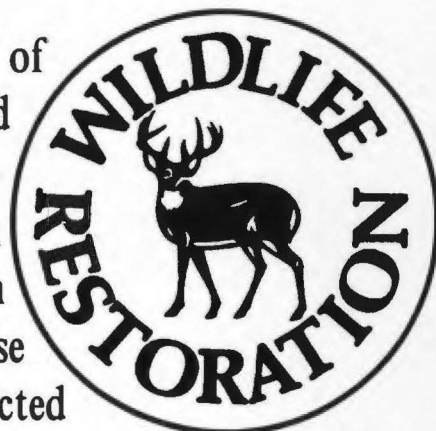
Appendix B. DEER USE AND HABITAT ATTRIBUTES ON 97 ISLANDS, SEA OTTER SOUND

	ISLAND						
	91	92	93	94	95	96	97
DEER USE							
Pellet-Groups/20 m2	0.6	0.4	0.1	0.0	0.0	6.2	4.8
Deer per Km2	9.9	6.4	0.9	0.0	0.0	101.8	79.5
% Browse Use	39.1	28.5	miss.	0.0	0.0	41.9	12.6
SPATIAL ATTRIBUTES							
Island Size (Ha)	2.0	0.2	0.2	0.7	0.5	0.4	0.7
Effective Area (Ha)	2.0	1.1	0.4	0.7	1.6	240.3	240.3
TO ISLAND W/RES WOLVES							
No. Water Segments	2.0	2.0	2.0	3.0	2.0	5.0	4.0
Swimming Dist. (Km)	0.4	0.6	0.5	1.0	1.3	0.7	0.6
Overland Dist. (Km)	4.1	2.3	1.1	9.6	9.5	14.6	14.6
Total Dist. (Km)	4.5	2.9	1.6	10.6	10.8	15.3	15.2
OVERSTORY							
Basal Area (m2/Ha)	45.2	68.4	32.5	38.4	52.9	42.1	43.1
% Hemlock	67.1	30.9	50.0	18.2	27.0	31.4	46.9
% Spruce	6.9	17.5	8.3	45.5	27.0	23.3	16.7
% Cedar	26.0	51.5	41.7	36.4	45.9	45.3	36.5
SHRUBS (Kg/Ha)							
V. parvifolium	55.3	58.2	miss.	55.6	20.8	0.0	22.8
V. alaskensis	24.2	2.1	miss.	7.8	2.6	20.8	55.9
Herb-Layer Vacc.	1.5	1.2	0.8	0.9	1.5	3.3	2.5
M. ferruginea	22.6	48.3	9.6	0.0	10.0	5.0	27.8
G. shallon	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EVERGREEN FORBS (Kg/Ha)							
C. canadensis	0.0	0.0	0.9	16.5	0.5	0.8	12.6
R. pedatus	0.8	0.0	0.1	0.1	0.0	0.2	9.1
T. trifoliata	0.1	0.0	0.0	0.0	0.0	0.3	0.2
C. asplenifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M. uniflora	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DECIDUOUS FORBS (Kg/Ha)							
M. dilatatum	1.0	0.3	1.9	92.9	43.2	0.1	0.0
P. alata	0.0	0.1	0.3	0.0	13.5	0.4	1.1
Streptopus spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Listera spp.	0.0	0.0	0.3	0.0	0.0	0.2	0.2
FERNS (Kg/Ha)							
G. dryopteris	1.3	0.0	0.0	0.0	2.3	0.0	14.4
D. dilatata	1.6	0.0	0.0	0.0	0.0	0.0	0.0

Alaska's Game Management Units



The Federal Aid in Wildlife Restoration Program consists of funds from a 10% to 11% manufacturer's excise tax collected from the sales of handguns, sporting rifles, shotguns, ammunition, and archery equipment. The Federal Aid program distributes funds to states using a formula based on each state's geographic area and number of paid hunting license holders. Alaska receives a maximum of 5% of revenues collected each year. The Alaska Department of Fish and Game uses its funds to help restore, conserve, and manage wild birds and mammals. These funds are also used to educate hunters to develop skills and attitudes for responsible hunting. Federal Aid funds paid for 75% of this study.



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If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

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