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Effects of Forest Fragmentation on Deer in Southeast Alaska

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SUMMARY

As clear-cut logging causes residual stands of old-growth forest to become smaller and more insular, their value to Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in winter is expected to decline. To test this hypothesis, the effects of habitat fragmentation are being studied in two areas, the first in Sea Otter Sound in southern southeast Alaska, and the second in Peril Strait in northern southeast Alaska. In the Sea Otter Sound study area, deer use, forage abundance, and forage quality are being measured on 112 islands which vary in size, shape, and insularity. In Peril Strait, these same parameters are being measured on figurative "islands" of old growth surrounded by even-aged clearcuts. The primary objective is to learn how spatial attributes of habitat affect their value to deer, and ultimately, use that knowledge to prescribe old-growth retention in intensively managed landscapes.

During spring, 1991, pellet-group density was measured on 35 islands in Sea Otter Sound. Ten new islands were sampled, including several of the larger islands in the study area. Plant dimension-biomass regressions were developed from samples collected in 1990 and 1991, and the availability and use of browse was examined as a complementary index of deer density. Other spatial habitat attributes, including island size, perimeter:area ratios, and indices of insularity were quantified.

From 1989 to the present, 2,860 pellet-group plots have been sampled on 112 islands in Sea Otter Sound. The islands sampled are mostly small (median 1.1 ha), with an average size of 116 ha. Deer are frequently seen swimming between islands, and probably inhabit the smaller islands (< 1 ha) for relatively short periods (days to weeks) before moving on to other islands. Based on pellet-group counts, deer densities on the islands range from 0 to 100 deer/km^2, with a mean density of 25 deer/km^2 (median = 12 deer/km^2). Pellet-group densities have varied annually, particularly on smaller islands where the

presence or absence of relatively few deer has a large affect on pellet-group densities. Repeated measurements are needed to accurately reflect long-term deer use on smaller islands.

Regression equations were developed to predict browse biomass available in winter (green twigs below 1.5 m) for each species of *Vaccinium*. Although the regressions were all significant ($P < 0.05$), the low r^2 values (0.17 - 0.34) reflect the highly variable growth forms of individual plants. The growth forms reflect localized growing conditions and intensity of browsing by deer. *Vaccinium* consumption or use can be calculated by measuring the terminal twig diameters of browsed stems and using regression equations to calculate total biomass consumed. For most management applications, however, acceptable regression estimates can be obtained by counting the number of browsed twigs and estimating an average browsed twig diameter for each plant. The mean terminal diameter of browsed twigs sampled on plots in Sea Otter Sound was 1.21 mm (SD = 0.63, N = 13,377).

Patterns of deer use observed in Sea Otter Sound are influenced by a combination of factors, including the relative abundance of certain plant species, forage quality, and the accessibility of small islands to predators like the wolf (*Canis lupus ligoni*) and black bear (*Ursus americanus*). Although predators are physically capable of swimming to all islands, that likelihood diminishes with increased swimming distance and decreased island size. Deer are generally found at the highest densities on islands which are relatively isolated from the larger islands and their resident predators. Deer numbers also tend to be higher on islands with an abundant understory, particularly red huckleberry (*Vaccinium parvifolium*), bunchberry (*Cornus canadensis*) and five-leaf bramble (*Rubus pedatus*). Deer show a strong preference for *V. parvifolium* over other *Vaccinium* species. This may be attributed to its higher nutritional quality, including lower levels of fiber and lignin, and higher levels of protein.

In theory, deer will occupy habitat which maximizes their ability to survive and reproduce. This requires that individual deer find adequate food resources to survive the winter, while minimizing the risk of being killed by wolves. As more deer move onto food-rich, secure islands, the amount of food available to each deer declines. When the risk of starvation outweighs the risk of predation, individual deer will move to new islands, accepting increased predation risk in exchange for more abundant or higher quality food. Eventually, equilibrium is established -- one that balances deer density, per capita forage availability, and predation risk to maximize overall deer survival. Deer in this study appear to select habitat consistent with these principles; however, data are still incomplete for many islands. Additional data on forage availability, deer density, and predation risk should be gathered before these interactions are quantified.

Although small islands of old growth surrounded by saltwater may provide security from predators, patches of old growth surrounded by clearcuts may not provide that same security. Logging roads are readily travelled by both wolves and bears, and these roads

usually connect residual old growth blocks. Predators are probably able to exploit small patches of old growth more efficiently than large patches, although this hypothesis has not yet been tested.

On Admiralty, Baranof, and Chichagof islands, where wolves and black bears are absent, optimal patch size is a function of forage availability in the old-growth patch and surrounding second-growth stand. The relationship between deer use and habitat fragmentation, in the absence of significant predators, was examined on a study area on the north shore of Peril Strait, Chichagof Island. Measurements of deer use, browse availability, browse consumption, and overwinter mortality were gathered in a 150 ha fragmented block (33% old growth, 67% clearcut), and a nearby 100 ha unfragmented block (100% old growth).

The clearcut portion of the fragmented block was 16 years old, and browse production was at its peak. The post-winter biomass of available *Vaccinium* was 136.8 kg/ha in the fragmented block, and 7.7 kg/ha in the unfragmented block. Over-winter consumption averaged 71.1 kg/ha in the fragmented block, and 9.8 kg/ha in the unfragmented block. Although far more *Vaccinium* was available and consumed in the fragmented block, pellet-group density in the fragmented block (49 deer/km^2) and the unfragmented block (55 deer/km^2) were not significantly different. Overwinter mortality as determined from counts of deer carcasses was nearly 2 times greater in fragmented habitat than in unfragmented habitat (10.0 and 5.6 carcasses per km of coastline).

There is far more *Vaccinium* available, and more consumed, in early clearcuts than in old growth, even though deer densities in the clearcut block and the old-growth block are approximately equal. Over-winter mortality was nearly twice as high in fragmented habitat as in unfragmented habitat. Deer which inhabit fragmented habitat appear to have a relatively low-quality diet, high energy costs, and consequently, increased mortality. In contrast, deer in the unfragmented, old-growth block presumably had greater access to a more nutritious diet, including evergreen forbs and arboreal lichens, in an environment where the energetic costs of locomotion are lower. Habitats which provide nutritious forage, even in limited quantities, appear superior to habitats that provide unlimited quantities of low-quality forage. These preliminary conclusions should be verified with additional data documenting snow depths, winter forage availability, and forage quality on this and other paired sites in southeast Alaska.

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

CONTENTS

INTRODUCTION

Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) are expected to decline in southeast Alaska as 60-80 km^2 of old-growth forest, much of it important deer winter range, are logged on federal, state, and private lands each year (Wallmo and Schoen 1980, Fagen 1988). On federal lands alone, 1,620 km^2 of old growth have been logged to date, with 8,500 km^2 scheduled for eventual harvest. This level of logging will remove, on the average, over half of the commercial old growth in all entered drainages, and up to 98% of the commercial old-growth in the most heavily logged drainages (Schoen et al. 1985).

Much of this logging activity is concentrated along the lower slopes of steep hillsides, potentially restricting elevational movement by deer during winter (Schoen and Kirchhoff 1985). As residual patches of old growth shrink in size and become more insular, their value to deer is expected to decline. In southeast Alaska, Samson et al. (1989) point out the need for landscape-level planning, and offer examples of cutting patterns that minimize fragmentation and loss of important wildlife habitat. The primary objective of this research is to learn how spatial attributes of habitat affect their value to deer, and ultimately, use that knowledge to prescribe old-growth retention in intensively managed landscapes.

BACKGROUND

Habitat fragmentation traditionally has not been a concern of wildlife managers. Many popular game species, deer included, are assumed to benefit from increased "edge," and managers in the past have tried to maximize habitat interspersion, juxtaposition, and "fragmentation" to wildlife's advantage (Leopold 1933, Brown 1961). Biologists today, however, find natural ecosystems shrinking rapidly, and many wildlife species seriously threatened. Many long-standing tenets of game management, particularly those which promote the value of early successional forest stages and edge, are being critically reevaluated (Schoen et al. 1981, Kirchhoff et al. 1983, Reese and Ratti 1988).

Recent concerns about habitat fragmentation are based on island biogeographic theory (MacArthur and Wilson 1967), which postulates that the species richness of an island is controlled by an equilibrium between immigration and emigration. Extensive empirical data show that the number of species typically increase with increasing island area (the "area effect"), and decrease with increasing insularity of islands (the "distance effect"). By extension, these same principles were found applicable to habitat fragments or "islands" in a terrestrial setting, such as woodland patches surrounded by agricultural lands (Burgess and Sharpe 1981, Brown and Gibson 1983). These principles apply, hypothetically, to old-growth reserves surrounded by clearcuts as well (Harris 1984, Rosenburg and Raphael 1986).

In one of the few published studies of island biogeography and deer, Picton and Mackie (1980) found that mule deer (*O. h. hemionus*) populations on large montane islands in Montana had lower turnover rates than populations inhabiting small islands. The results suggest that a single large reserve provides higher-quality habitat than several small reserves of the same total area. In southeast Alaska, biologists have measured higher deer mortality in old-growth retention areas isolated by clearcuts than in nearby extensive old growth (Schoen et al. 1979, ADF&G unpubl. data). These observations also suggest large reserves provide higher-quality habitat. Although neither study measured deer survival or population density directly, the results indicate a relationship between habitat quality and patch size, shape, and location.

Identifying specific attributes of high-quality habitat assumes one can objectively and reliably measure habitat quality. Fagen (1988) assumed that habitat quality was positively correlated with deer density, at least during limiting seasons or years. In this study, deer density is determined by measuring both fecal pellet-group density (Neff 1968) and browse utilization (Shafer 1963, Pitt and Schwab 1988) in various habitat patches. Both techniques measure persistent indicators of deer presence, not deer themselves, so density estimates reflect cumulative use over a relatively long period of time. In southeast Alaska, fecal deer pellets last for 7-11 months depending on rainfall, temperature, and exposure (Fisch 1979, Rose 1982, Kirchhoff 1990). Browsed twigs can persist in a green condition for over 3 years, depending on the plant species, season of browsing, and severity of browsing (ADF&G, unpubl. data).

Despite known limitations, pellet-group counts remain the best method available to assess relative deer numbers in southeast Alaska (Kirchhoff and Pitcher 1988, Kirchhoff 1989, 1990). With resident deer, pellet-group counts and browse surveys probably provide a reasonably good indicator of the amount of year-round use (e.g., average deer density) a habitat receives. Using standard pellet-group sampling techniques on a small island with a known-size resident deer population, Kirchhoff (1990) found that the mean deer density in deer/km^2 is equivalent to the mean pellet-group density per 20 m^2 plot times 12.

Inventories of browse production and utilization can provide complementary information on carrying capacity and population density of certain habitats for deer (Anderson et al. 1972, Telfer 1981). Inventory methods range from reconnaissance techniques to weight estimates, to clip-and-weigh methods. Reconnaissance estimates are rapid, but are hindered by observer and statistical bias. Clip-and-weigh methods (Schwan and Swift 1941) yield highly accurate results, but are costly, tedious and destructive (Lyon 1970). The twig-count method (Shafer 1963) used in this study has several important advantages. It is as accurate as the clip-and-weigh method, about as fast as the weight estimation method, and because the results are counts, not estimates, data can be analyzed statistically (Shafer 1963).

The twig-count method converts counts of browsed twigs to weight of browse consumed by using an average weight per twig for each species. The relationship is developed by clipping a wide sample of twigs and regressing biomass as a function of basal twig diameter (Shafer 1963, Telfer 1969). However, as Pitt and Schwab (1990) noted, correlations among shrub dimensions and browse production and use may vary highly depending on (1) time of year the twigs are collected (Potvin 1981), (2) geographical location (Basile and Hutchings 1966), (3) site conditions at time of sampling (Peek et al. 1971), (4) portion of crown from which the sample is collected (Lyon 1970) and (5) age of twig (Telfer 1969). Variability with respect to site and stand age has also been demonstrated in southeast Alaska (Alaback 1986, 1987).

STUDY AREAS

Sea Otter Sound. The initial phase of the study focuses on biogeographic relationships between deer and habitat on true islands. Sea Otter Sound, in southern Southeast Alaska (Figure 1) contains hundreds of small Islands ranging in size from less than 1 ha to > 1000 ha. Topographic and vegetative characteristics are similar on most islands, but island size, shape, and remoteness vary widely. In the 1960s and 1970s, extensive clearcutting occurred on larger islands within the Sound (Tuxekan, Marble, Orr, Hoot, Owl, Eagle, and Whitecliff); however, most of the smaller islands (< 20 ha) are unlogged. The study area includes some of the most productive forest soils in southeast Alaska. The unlogged small islands are uniformly covered with commercial quality old-growth forest composed of western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), and red cedar (*Thuja plicata*). The predominant forest plant associations are hemlock/blueberry (*Vaccinium* spp.) and red cedar/blueberry types (DeMeo 1989). Deer, wolves (*Canis lupus ligoni*) and black bear (*Ursus americanus*) occur throughout the study area. Human population and attendant hunting and trapping pressure in the study area are low.

Peril Strait. The second phase of the study focuses on the effects of habitat fragmentation caused by clearcut logging. The study area is located near Lindenberg Head on Chichagof Island, in northern southeast Alaska (Figure 2). Within the study area, data were collected in two separate sites. The first site is 150 ha in size, and includes a 100 ha area that was logged in 1975. A narrow fringe of timber was left along the beach, and a small (approximately 28 ha) island of old growth was left in the middle of the clearcut. The old-growth island was originally connected to the beach fringe timber by a narrow strip of trees in the southwest corner, but that strip has since blown down. The second site, located 4.8 km to the east, is approximately 100 ha in size. It has not been logged and is covered with mid-volume, hemlock-spruce old growth. Both sites extend from the beach to 180 m elevation, and share similar slope, aspect and soil conditions.

METHODS

From 17-26 April 1989, deer use and selected habitat attributes were measured on 35 islands in Sea Otter Sound. Twenty-five of these had data collected from them in previous years as well (Kirchhoff 1990). Ten were new islands, including several of the larger Islands in the study area (Tuxekan, Marble, Orr, El Capitan, and Scott). All islands were given sequential identification numbers and their location recorded on a 1:40,000 scale nautical chart (on file, ADF&G, Douglas). Field work was conducted from a base camp at New Tokeen on El Capitan Island with the assistance of unpaid field volunteers as well as staff from ADF&G and USFS.

On each island transect lines were established from convenient landing points on the beach, and oriented to achieve maximum coverage of the island. On small islands, transects were usually run across the entire island, and a 2nd transect established along a return, parallel course. On large islands, transects were run in one direction only from each starting point. Following a strict compass bearing, a series of 1 x 20 m plots were established end to end, running across the island (Figure 3). Each 1 x 20 m plot was carefully searched for fecal pellet-groups. A pellet group was counted if the majority of pellets fell within 0.5 m of the survey cable. All groups, regardless of size or age, were counted.

Overstory attributes were measured with reference to a 20 m x 20 m quadrat (0.04 ha) bisected by the pellet-group plot (figure 3). Basal area of overstory trees > 15 cm dbh were measured with a 40 factor prism using variable plot sampling (Dilworth and Bell 1971, Forest Service 1979). For each quadrat, forest plant association (DeMeo 1989), and net inventory volume class (Forest Service 1978) were also recorded (Figure 3).

Understory attributes were measured on a circular 2 m^2 plot randomly located within each quadrat. The plot center was established by blindly throwing a 284 gm plumb bob over the shoulder (figure 3). The number of *vaccinium* stems rooted in each plot were counted, and a subsample of 5-10 stems randomly selected for measurement. For each stem selected, the species, minimum basal diameter, plant length, number of browsed twigs, and browse utilization category were recorded (figure 4).

Pellet-group and vegetative data were aggregated by island, with results (mean and SD for each variable) written to a separate file. Mean net inventory volume, mean percent cover, and mean browse utilization were computed using the midpoints of the volume, cover class, and browse use categories respectively. The age class and forest plant association reflected the most common category on each island.

In order to generate plant dimension/biomass regressions, a subsample of plants (N=189) was selected for further measurement. Samples of all 3 *Vaccinium* species were selected to represent the range of observed conditions, including small to very large plants, and plants showing light to very heavy browsing. For each plant all green stems within 1.5 m of the ground (i.e., that available to deer during winter), were clipped and saved. The samples were frozen, oven-dried at 45 degrees C for 24-48 hrs., and weighed to 0.001 gms. Thirty-three plant samples were sent to a laboratory at Washington State University where their chemical composition and nutritive value will be analyzed.

Field work in the Peril Strait area was conducted from 6-14 May 1991, and was supported by the 65' motor vessel Princeton Hall. Data collection methods were the same on the Sea Otter Sound and Peril Strait study areas.

RESULTS AND DISCUSSION

Sea Otter Sound

During 1991, pellet-group and vegetation data were collected on 35 Islands in Sea Otter Sound. The 112 islands sampled since spring 1989 range in size from 0.10 ha to 7,509 ha, and average 116 ha. Most islands are small (median 1.1 ha). Twenty-five islands have been sampled over 3 years, 61 over 2 years, and 26 for 1 year. Summary statistics showing the mean pellet-group density per plot on each island are given in Table 1. Pellet-group densities can be converted to the equivalent deer per km^2 by multiplying these numbers by 12 (Kirchhoff 1990).

Deer use has varied considerably from year to year on some islands, particularly smaller ones where the comings and goings of individual deer have a large affect on pellet-group density. This variability is, in part, because of chance deer movements. For example, in 1989, Island 10 was uninhabited by deer. From the condition of the vegetation, it was clear that deer had been absent from the island for at least several years. By 1990, however, at least 1 deer had discovered the island, and by 1991, the condition of the vegetation and the pellet-group density reflected very heavy use. Similar cycles probably occur naturally on other small islands as well.

Local residents have described the past practice of hunters running dogs across small islands and mimicking the howls of wolves. This causes deer to immediately flee the island, where, in the water, they are easily dispatched by hunters in skiffs. Although wolves do not announce their arrival so boldly, once deer realize wolves are on the island, their natural reaction is probably to leave. The more remote the island, the more infrequently it will be visited by wolves. Likewise, once deer are forced off a remote island, it may take some time for deer to reestablish and reach high densities. By monitoring deer use on many islands, over a time frame of 3-5 years, this natural spatial and temporal variability is minimized.

To characterize the amount of browse available to deer, regression equations had to be developed relating the available food per plant to easily measured plant dimensions, such as basal diameter, plant height, and/or crown diameter. Although predictive equations have been generated at various sites in southeast Alaska (Alaback 1986, Yarie and Mead 1989, Kirchhoff 1990), these yield the stem, leaf, or current annual growth fractions of the entire plant. When dealing with tall species, particularly *V. parvifolium* and *V. alaskensis*, much of the biomass on large plants is unavailable to deer. In 1991, 20% of the plants sampled had no biomass available because of their large size.

Another factor that warrants consideration is the effect the deer themselves have on the amount of browse available. In areas where deer density is high, moderate browsing can stimulate twig growth and keep the plants from growing beyond the deer's reach. Under very high browsing pressure, however, plants die back and often become stunted. Plants with relatively large basal diameters may produce very little available browse because they are either overbrowsed and stunted, or underbrowsed and out of reach.

In Sea Otter Sound, plant samples were collected from various islands having densities of 0 to 100 deer per km^2. Regression equations were calculated on all plants that had browse available. Plants which because of their large size had no browse available were excluded. Multiple regression equations were generated for each species individually, for *V. ovalifolium* and *V. alaskensis* combined (because they can be difficult to separate in the field), and for all 3 species combined (figures 5-9). Although the regressions were significant ($P < 0.05$), the r^2 values were relatively low (0.17-0.34). These regression equations should be considered preliminary. Additional plant samples will be collected next summer and new regression equations calculated.

Water contributes significantly to the weight of plants, and the water content of most plants varies seasonally. To standardize samples before weighing, plants are normally placed in a convection oven at 40-70 degrees C for 24-48 hours to bring their water content to zero. This can be a time consuming job, particularly if the plant samples are large and the oven is small. Fifteen of the plant samples collected (green stems) were taken from the freezer and weighed to the nearest 0.001 gm. The samples were then placed in small paper lunch bags, left at room temperature (approx 75 F) for 48 hours, and again weighed. The samples were next dried in a convection oven (45 C for 48 hours) and weighed again. After air drying, the samples averaged 52% (SD=0.10) of their original weight. Oven drying reduced their weight by only 4% more (X=48%, SD-0.07).

For some purposes, air drying plant samples will yield very acceptable results. Certainly, when regression equations are generated from biomass, data as inherently variable as that in Figures 5-9, the precision gained by oven drying versus air drying samples is insignificant. The recommended time spent air drying samples will depend on the size of the sample, its moisture content, and ambient air temperature and humidity. While air drying, the weight of a few samples should be checked daily. When the weight of this subsample no longer declines, the rest of the samples should be weighed. A subsample should be oven dried to indicate how much moisture remained in the air dried samples.

Deer exhibit a strong preference for twigs of *V. parvifolium* over *V. Alaskensis* or *V. ovalifolium.* Of 1,360 plants measured during 1991 in Sea Otter Sound, 48% of the available twigs on *V. parvifolium* were browsed versus 26% for the other species (Table 2). The strong preference by deer for this particular species has been noted in the Pacific Northwest and British Columbia as well, but there appear to be no published explanations for this preference (R. Ellis, pers. comm.).

In 1990, 10 plant samples were collected from 5 islands in Sea Otter Sound and sent to the Wildlife Habitat Laboratory at Washington State University for nutritional analysis. Each sample represented the combined available biomass (green twigs below 1.5 m) of 10-25 plants of a single species from a single island. *Vaccinium parvifolium* had a slightly higher crude protein content, and lower fiber and lignin content than the other species (Table 3). Differences in browse quality were evident from island to island, however, significance testing was not possible given the low sample sizes. An additional 33 plant samples collected this spring were sent to Washington State University for analysis. Those results will be presented in the next progress report.

Patterns of deer use among the islands appear to be controlled by a combination of factors, including the relative abundance of certain plant species, forage quality, and the accessibility of individual islands to predators such as wolf and black bear. Although predators are physically capable of swimming to all islands (as evidenced by wolf scat), that likelihood diminishes with increased swimming distance and decreased island size. Deer are generally found at the highest densities on islands which are relatively isolated from the larger islands and their resident predators. Deer numbers also tend to be higher on islands with an abundant understory, particularly of red huckleberry (*Vaccinium parvifolium*), bunchberry (*Cornus canadensis*) and five-leaf bramble (*Rubus pedatus*).

In theory, deer will occupy habitat which maximizes their ability to survive and reproduce. This requires that individual deer find adequate food resources to survive the winter, while minimizing the risk of being killed by wolves. As more deer move onto food-rich, secure islands, the amount of food available to each deer declines. When the risk of starvation outweighs the risk of predation, individual deer will move to new islands, accepting increased predation risk in exchange for more abundant or higher quality food. Eventually, an equilibrium condition is established -- one that balances deer density, per capita forage availability/quality, and predation risk to maximize overall deer survival. Deer in this study appear to select habitat consistent with these principles; however, data are still incomplete for many islands. Additional data on forage availability, forage quality, deer density, and predation risk will be gathered before these interactions are quantified.

Peril Strait

Deer use, forage production, and forage consumption were measured in a fragmented block and in an adjacent unfragmented block of forest on Chichagof Island in Peril Strait. Available biomass of *Vaccinium* was calculated by applying basal diameter measurements from 322 vegetation plots to the appropriate regression equations (Figures 5-7). The results showed *Vaccinium* browse to be 17 times more abundant in the fragmented block, averaging 136.8 kg/ha compared to 7.7 kg/ha in the unfragmented block (table 4). *Vaccinium* appeared to be near it's peak in this 16-year-old clearcut (Alaback 1982), and heavy browsing by deer had kept most of the biomass from growing out of reach. Only a small proportion (< 10%) of the clearcut had closed over and lost its understory. In the unfragmented block, most of the *Vaccinium* was very short (< 12") and heavily browsed. Mature forbs were rare in old growth habitat in both blocks, reflecting heavy use by deer during winter.

Consumption of *Vaccinium* browse was calculated by extrapolating counts of browsed twigs on sample plots to numbers of browsed twigs over the entire area, and assuming a dry weight of 0.15 g per browsed twig. The dry weight was calculated from the mean green weight of 1,825 twigs collected in 1990 (0.25 g, Kirchhoff 1990), times a factor of 0.4 to yield dry weight. The results reveal an over-winter consumption of 71.1 kg/ha in the fragmented block, and 9.8 kg/ha in the unfragmented block (table 5).

Deer use on the fragmented and unfragmented blocks was estimated from pellet-group density (359 plots) and percent browse utilization (891 plants). The pellet-group data indicate slightly more deer use in the unfragmented block (Table 6), although the difference is not significant (M-W test, p=0.27). The highest use occurred in the old-growth habitat, within the fragmented block. This may reflect the fact that the deer which regularly forage in the clearcut often move into old growth during inclement winter weather (Yeo 1991, in press).

Browse reconnaissance surveys are sometimes used as an index of deer abundance (Telfer 1981). Biologists estimate the percent utilization of woody browse plants, and assume that the higher the percent utilization, the higher the deer density. In Peril Strait, percent browse utilization was 40% higher in the unfragmented old-growth block, than in the fragmented block (Table 7). Clearly, it would be wrong to conclude that the unfragmented block therefore had higher deer use. In this case, percent utilization is poorly correlated with pellet-group density because so much *Vaccinium* is available in the clearcut. These data illustrate the importance of calculating the availability of browse, as well as its relative use, when interpreting browse utilization data.

Deer mortality was estimated by searching for carcasses of winter-killed deer. Below each block, a 3-person team thoroughly searched the beach edge and adjoining forest (inland to 75 m) for a distance of 3.2 km. The mortality transect for "fragmented" forest was located below large clearcuts, and included the fragmented study block. The other mortality transect was below continuous old growth and included the unfragmented block. Searchers found nearly 2 times as many deer carcasses on the transect below clearcuts as the transect below continuous old growth (10.0 and 5.9 carcasses per km of coastline). Counts were extremely high compared to the 1-2 deer/km^2 typically counted on mortality transects in the region (ADF&G, unpubl. data). Although this may be partially attributed to very high deer densities in this area, I believe it is largely a result of more thorough searching.

The results clearly show that there is far more *Vaccinium* available, and more consumed, in early clearcuts than in old growth. Yet, deer densities in the clearcut block and the old-growth block are about equal. Moreover, a greater percentage of deer in the old-growth block are apparently surviving. Despite the abundance of forage produced in the young clearcut, deer there may be suffering increased nutritional and energetic stress. Several factors contribute to this stress. Snow depths, which can be 3 times greater in openings than in old growth (Kirchhoff et al. 1987), and logging slash increase the energetic cost of locomotion in clearcuts (Parker et al. 1984). Increased snow accumulation also buries the nutritious herb-layer plants, and results in a low-quality diet (Schoen et al. 1984, Hanley and McKendrick 1985). Even if the diets in the two blocks were the same, plants grown in open clearcuts have relatively high levels of tannins and other phenolics which can lower protein availability and digestibility (Hanley et al. 1987, 1989, VanHorne et al. 1988).

Both the quantity and quality of forage are important to estimation of deer carrying capacity (Hanley et al. 1989). If young clearcuts stayed young clearcuts forever, there presumably would be some combination of old growth and clearcut that would sustain more deer than either habitat type alone. In the Peril Strait study site, 25% of the fragmented block was retained in old growth. Based on the high winter mortality in this block, I conclude that this percentage of old-growth does not optimally meet the requirements of deer. Just what the optimal mix of old-growth and clearcut might be will depend on the productivity of the clearcut and site-specific snow conditions. These preliminary conclusions should be verified with additional data documenting snow depths, winter forage availability, and forage quality on this and other paired sites in southeast Alaska.

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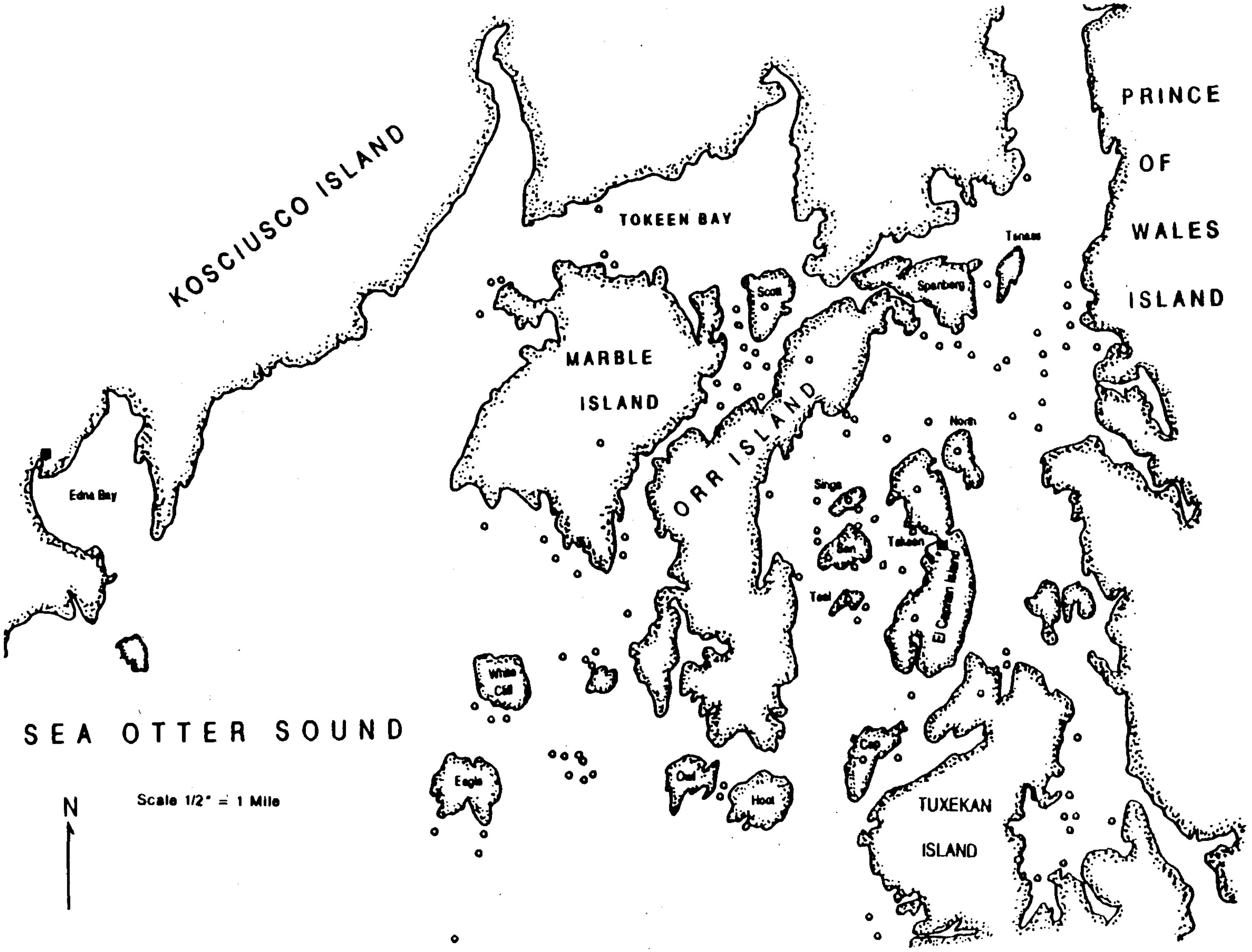

Figure 1. Study Area in Sea Otter Sound, southeast Alaska. For clarity, small islands have not been drawn. Circles represent location of islands sampled in this study.

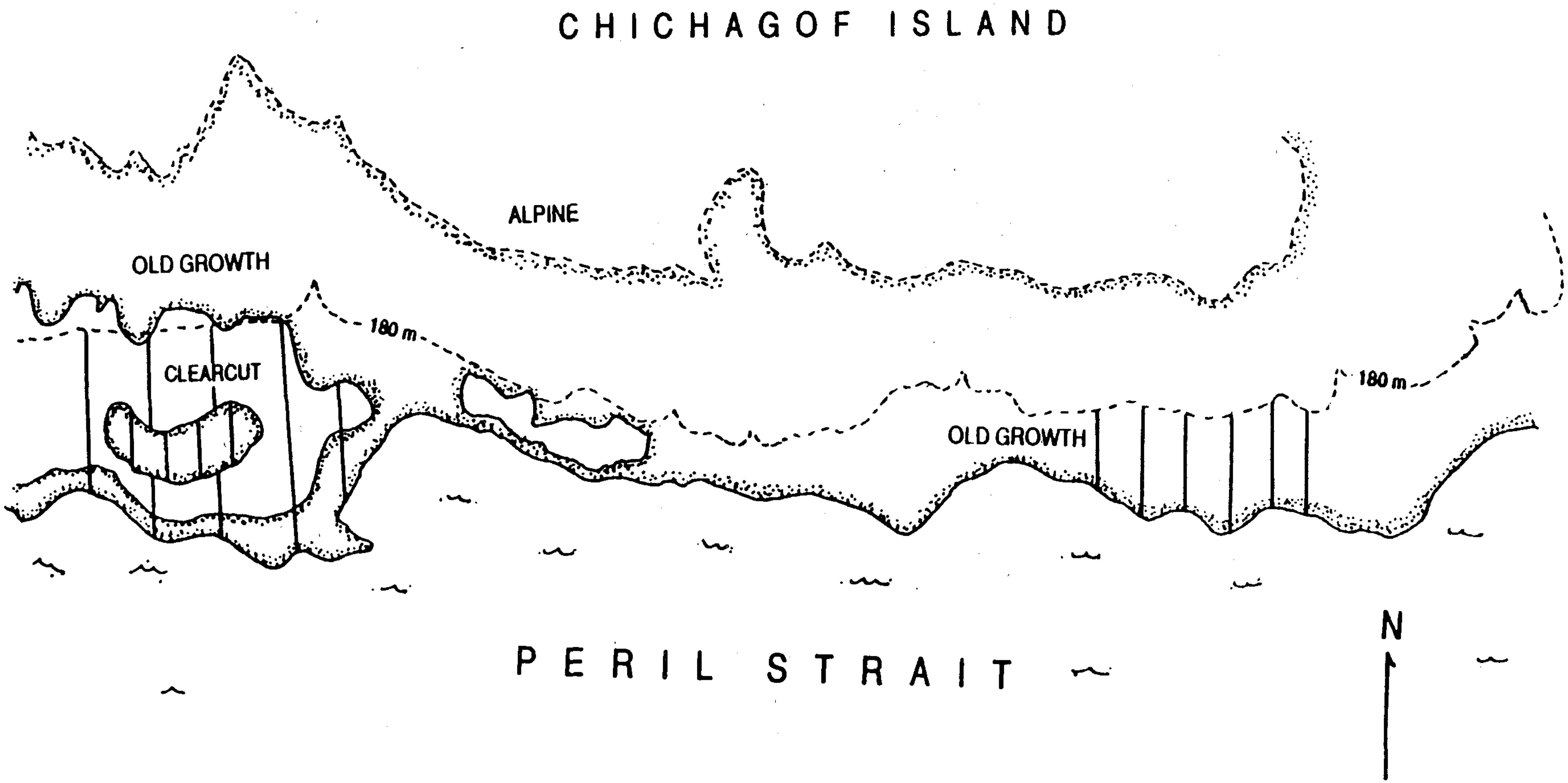

Figure 2. Peril Strait study area, Chichagof Island, southeast Alaska.

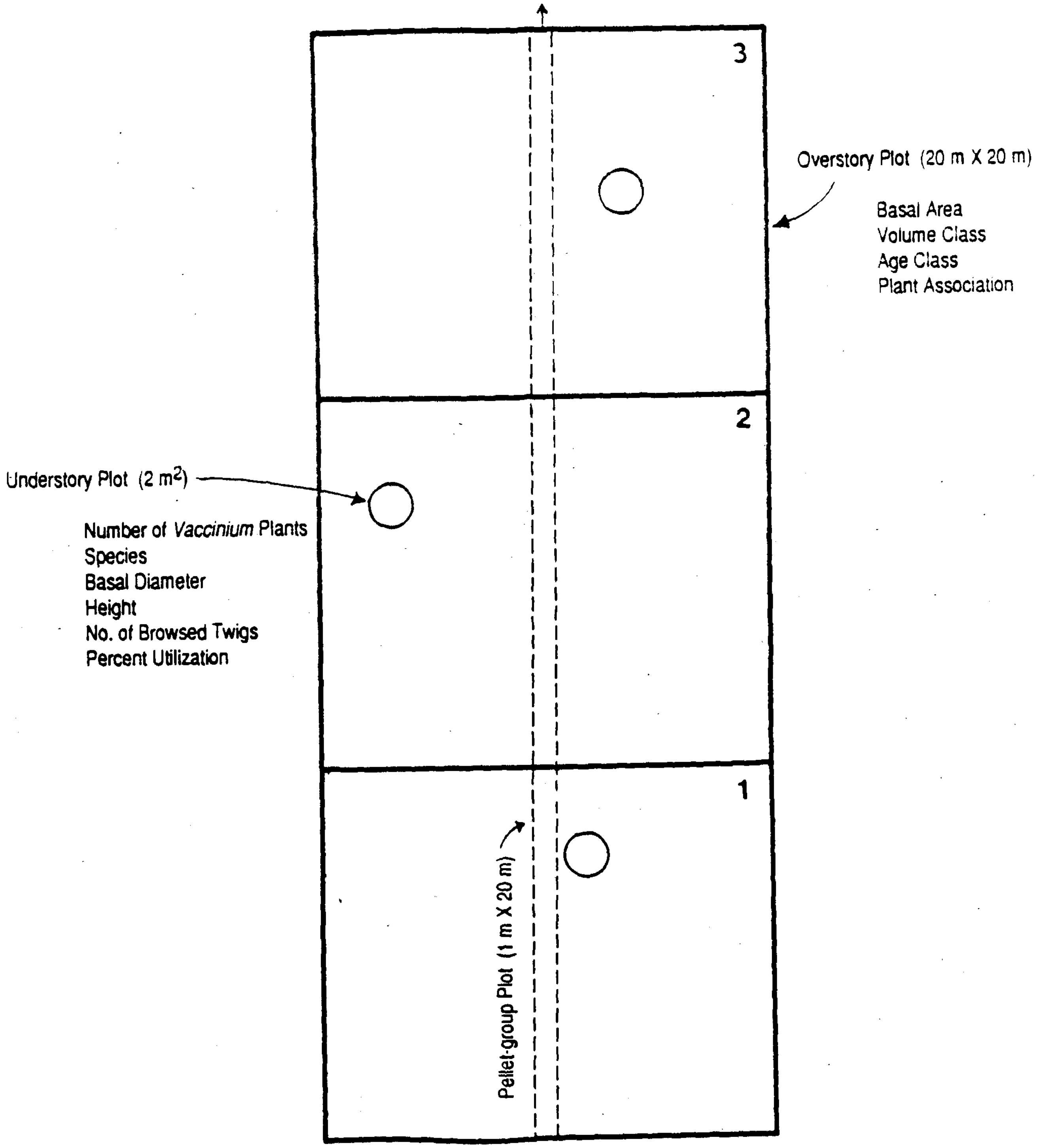

Figure 3. Sampling design for measuring overstory characteristics, understory abundance, browse utilization, and pellet-group density on both study areas.

DATA KEY

Plot: Number consecutively for each island (or block).

Ced/Hem/Spr: Number of cedar, hemlock and spruce that are counted "in".

Vol: Volume/age class

1 = secondgrowth 6-25 years old
2 = poletimber 26-75 years old
3 = non CFL (< 8 mbf/ac)
4 = low volume Old Growth (8-20 mbf/ac)
5 = mid-volume Old Growth (20-30 mbf/ac)
6 = high-volume Old Growth (30-50 mbf/ac)
7 = very high-volume Old Growth (50+ mbf/ac)

PA: Plant Association (from key, DeMeo 1989)

PG: Pellet-group count

X: The fraction of all rooted stems measured in the plot.

N: Number of stem being measured (measure 5-10/plot if available)

Sp: Vaccinium species (in alphabetical order)

1 = V. alaskensis
2 = V. ovalifolium
3 = V. parvifolium

BD: Basal diameter of stem, just above moss, to nearest 0.1 mm.

Ht: Total plant height, (length of leaning).

Count: Total number of browsed twigs. (estimate beyond 100th count)

Use: Estimated percent of green twigs below 5' that are browsed.

1 = <2%
2 = 2-20
3 = 21-50%
4 = 51-80%
5 = >80%

Sample No.: Island-Plot-N of stem destructively sampled.

Wet weight: Total weight to nearest 0.1 gram, in camp.

Birds: Names of birds heard/seen on plot (first 2 letters each name).

Comments: Other pertinent observations

Island ______ Month ____ Day ____ Year ____

Plot	Ced	Hem	Spr	Vol	PA	PG	X	N	Sp	BD	Ht	Count	Use
								1					
Sample No. ______-____-____ (Isl-Plot-N)								2					
								3					
Wet wt. ________ Dry wt. ________								4					
Birds:								5					
								6					
								7					
Comments:								8					
								9					
								10					

Plot	Ced	Hem	Spr	Vol	PA	PG	X	N	Sp	BD	Ht	Count	Use
								1					
Sample No. ______-____-____ (Isl-Plot-N)								2					
								3					
Wet wt. ________ Dry wt. ________								4					
Birds:								5					
								6					
								7					
Comments:								8					
								9					
								10					

Plot	Ced	Hem	Spr	Vol	PA	PG	X	N	Sp	BD	Ht	Count	Use
								1					
Sample No. ______-____-____ (Isl-Plot-N)								2					
								3					
Wet wt. ________ Dry wt. ________								4					
Birds:								5					
								6					
								7					
Comments:								8					
								9					
								10					

Figure 4. Data key and field form used on both study areas

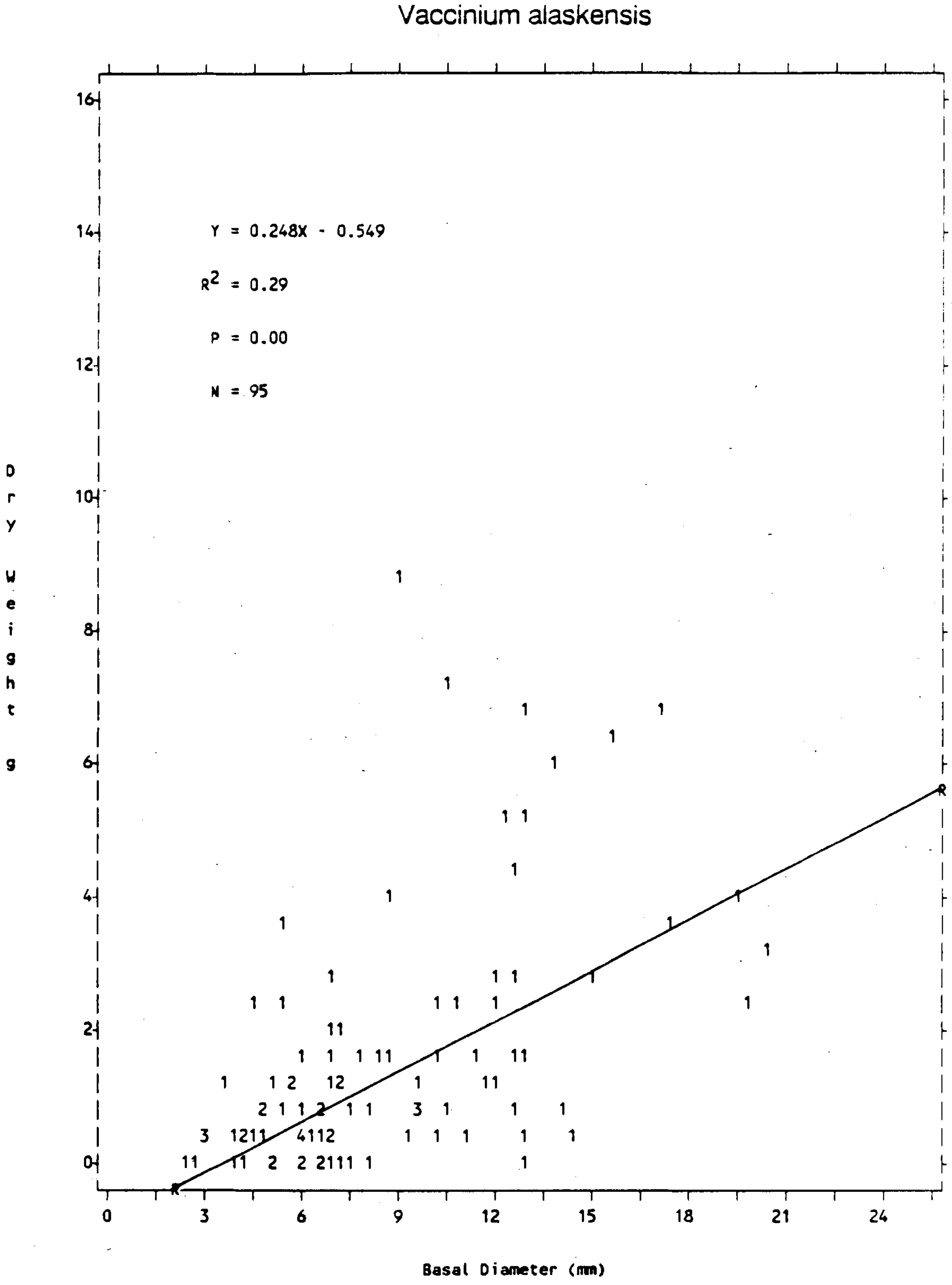

Figure 5. Biomass of available *V. alaskensis* browse as a function of basal diameter, Sea Otter Sound.

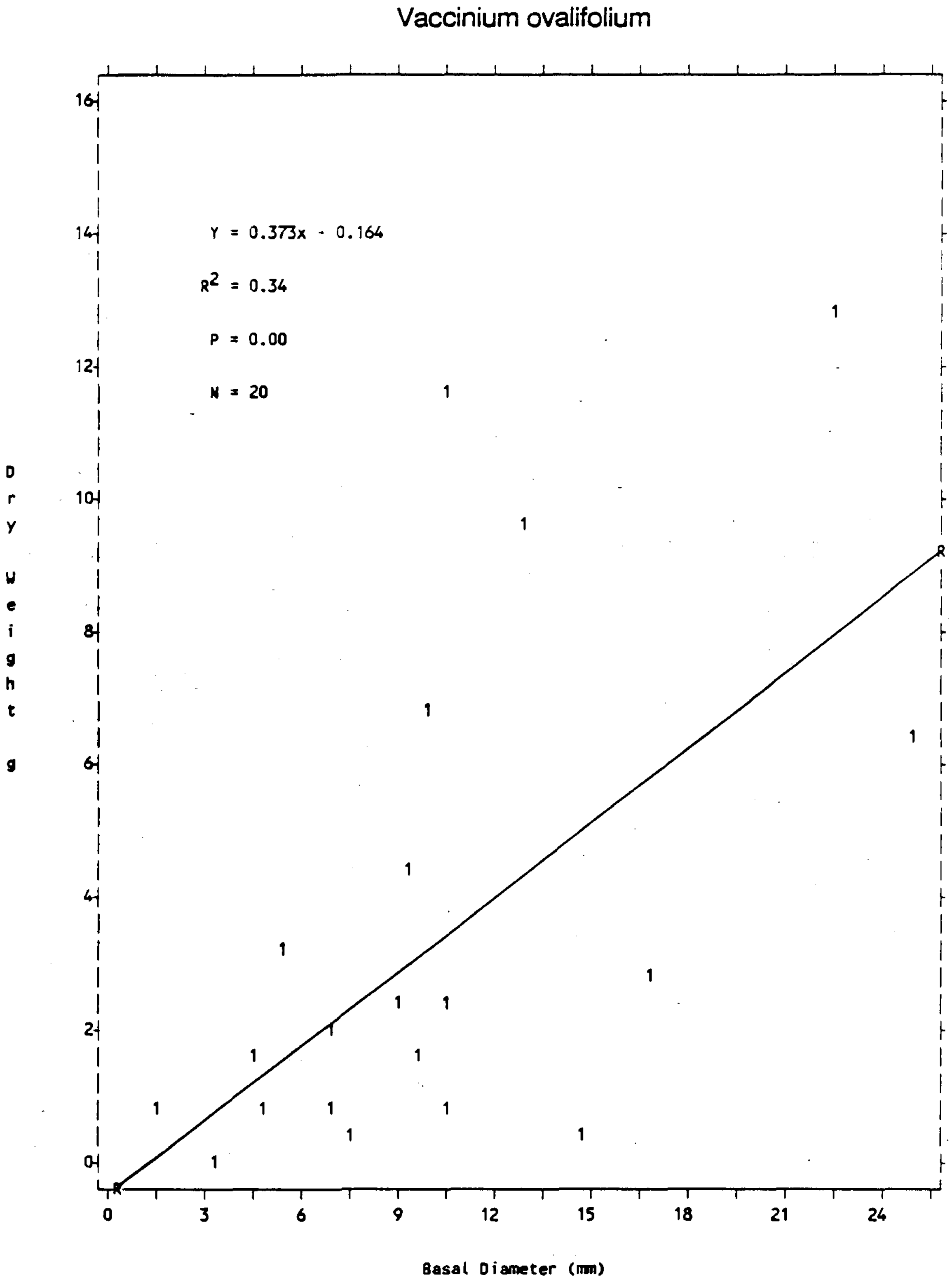

Figure 6. Biomass of available *V. ovalifolium* browse as a function of basal diameter, Sea Otter Sound.

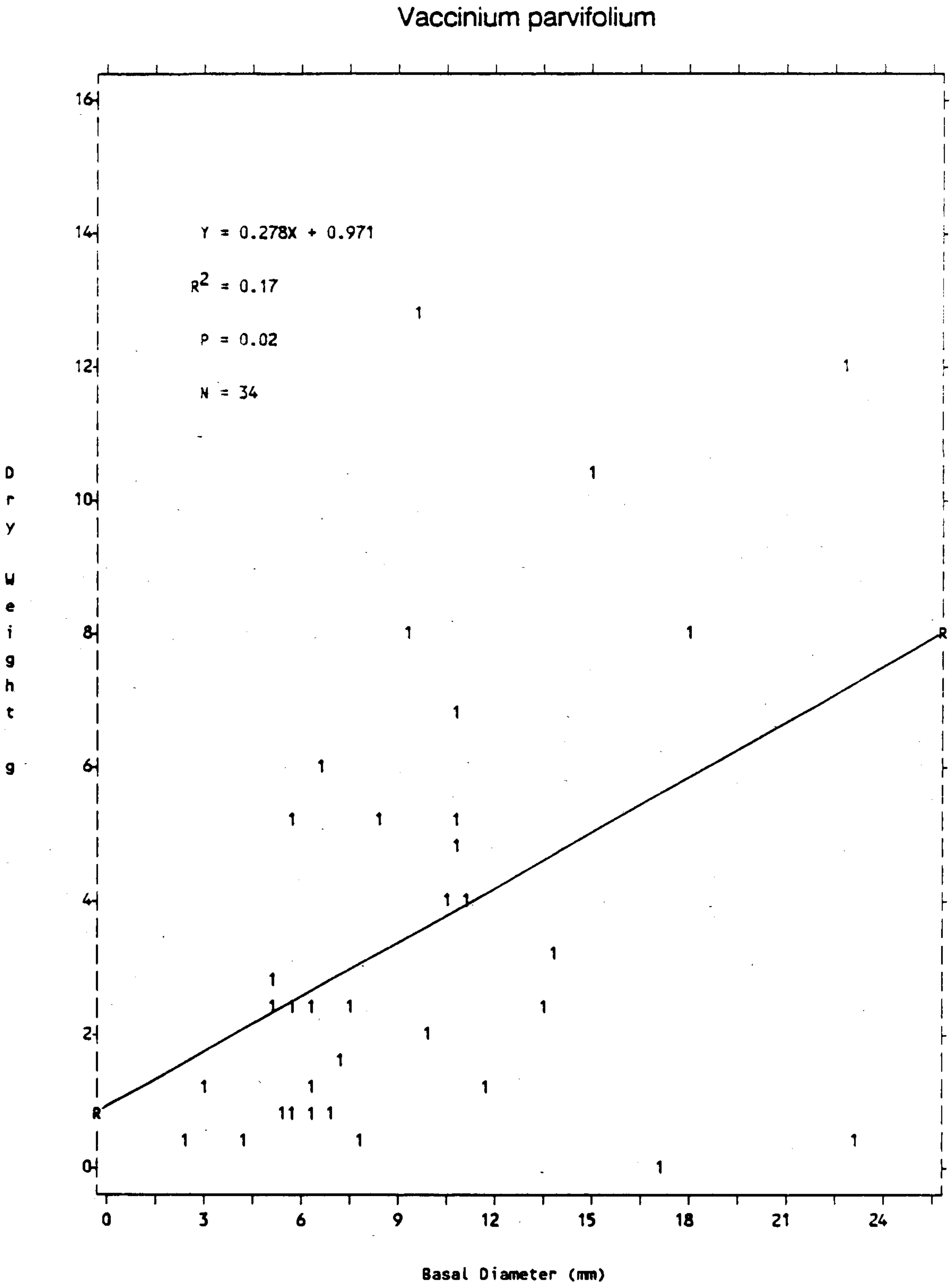

Figure 7. Biomass of available *V. parvifolium* browse as a function of basal diameter, Sea Otter Sound.

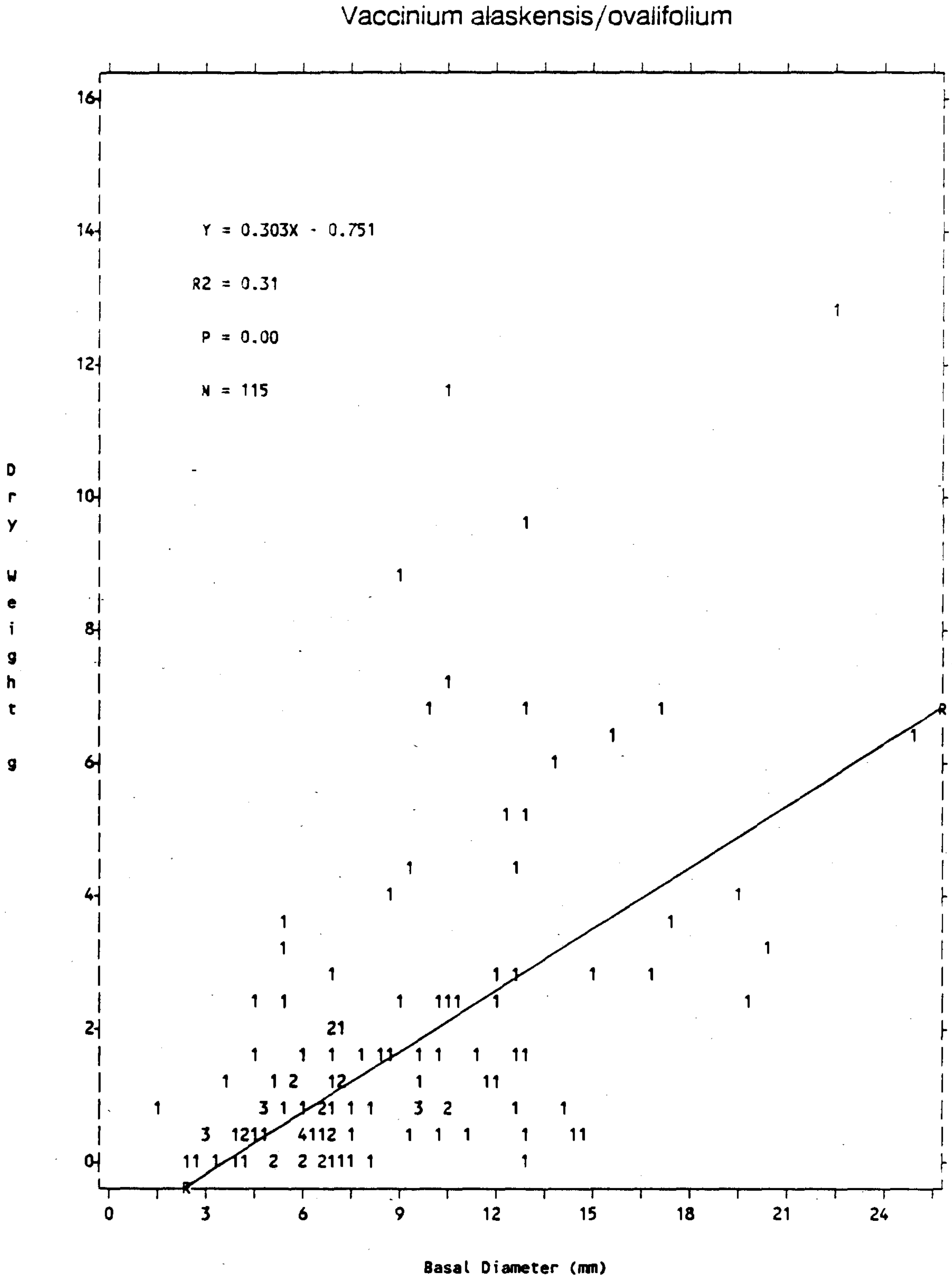

Figure 8. Biomass of available *V. alaskensis/ovalifolium* browse as a function of basal diameter, Sea Otter Sound.

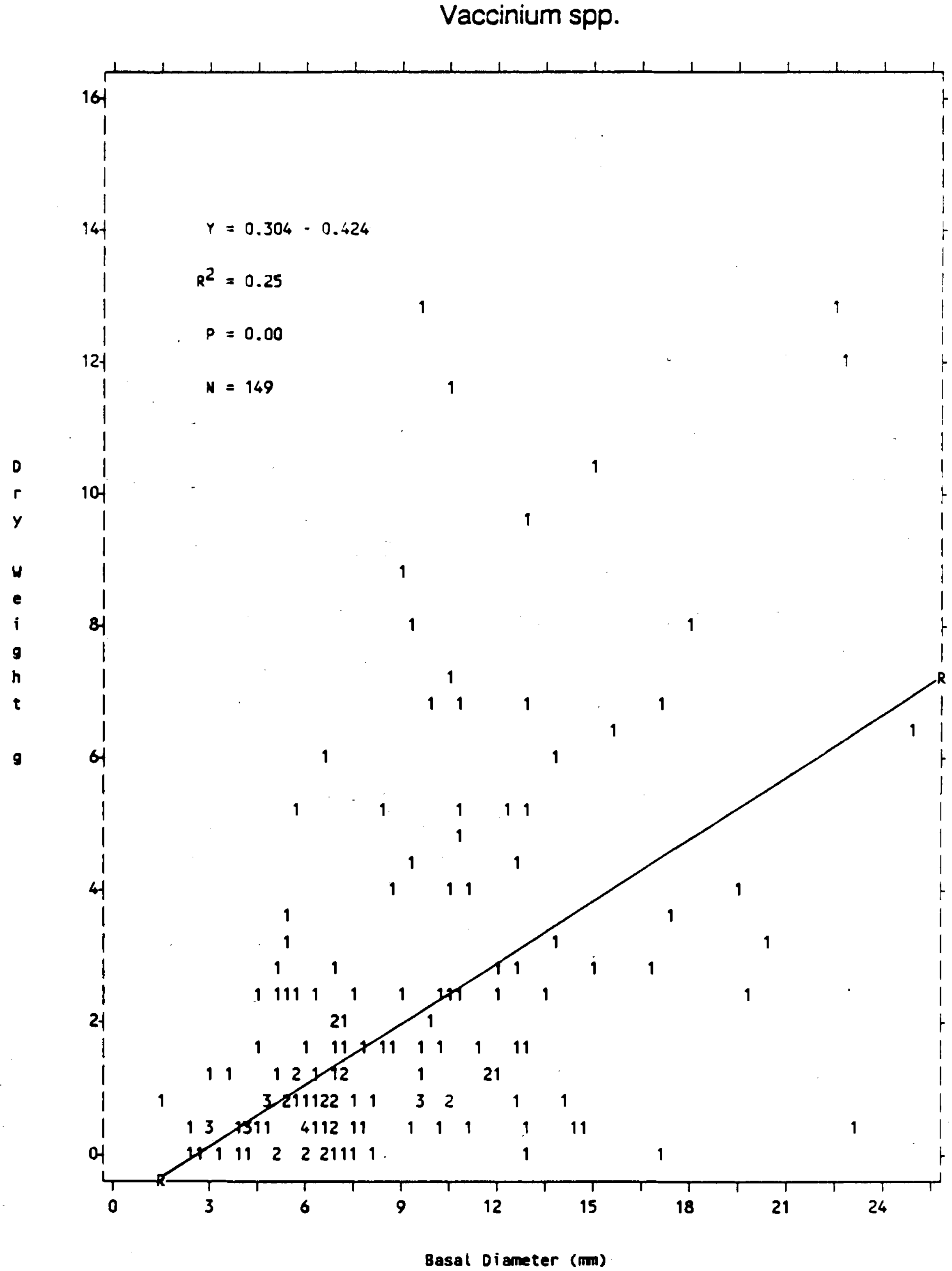
Vaccinium spp.

Figure 9. Biomass of available *Vaccinium* browse as a function of basal diameter, Sea Otter Sound.

Table 1. Pellet-group summary statistics (mean pellets/plot, standard error, and n) for 112 islands sampled in Sea Otter Sound, Spring, 1989-91.

Pellet-Group Summary Statistics

Island	1989	1990	1991	3-Year Average
1.00				
X	1.4	0.7	.	1.1
SE	0.7	0.3	.	0.4
N	10	9		19
2.00				
X	3.2	1.3	.	2.5
SE	0.6	0.4	.	0.4
N	20	11		31
3.00				
X	0.0	0.0	0.0	0.0
SE	0.0	0.0	0.0	0.0
N	3	7	6	16
4.00				
X	2.0	1.0	.	1.5
SE	.	.	.	0.5
N	1	1		2
5.00				
X	1.8	1.1	.	1.4
SE	0.4	0.2	.	0.2
N	13	14		27
6.00				
X	0.2	1.3	.	1.0
SE	0.2	0.3	.	0.3
N	6	15		21
7.00				
X	.	1.1	.	1.1
SE	.	0.6	.	0.6
N		7		7
8.00				
X	2.2	0.4	.	1.3
SE	0.4	0.2	.	0.3
N	14	14		28

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
9.00				
X	4.6	12.2	5.7	7.2
SE	0.9	1.4	1.0	0.8
N	10	9	14	33
10.00				
X	0.0	1.5	3.6	1.7
SE	0.0	0.6	0.8	0.4
N	10	8	10	28
11.00				
X	.	4.3	.	4.3
SE	.	1.2	.	1.2
N		8		8
12.00				
X	1.7	4.8	.	3.4
SE	0.3	2.1	.	1.3
N	3	4		7
13.00				
X	2.9	2.5	.	2.7
SE	0.7	0.7	.	0.5
N	8	6		14
14.00				
X	0.5	1.3	.	0.9
SE	0.2	0.4	.	0.2
N	14	14		28
15.00				
X	0.0	0.0	.	0.0
SE	0.0	0.0	.	0.0
N	3	4		7
16.00				
X	0.0	0.0	.	0.0
SE	0.0	0.0	.	0.0
N	6	5		11

(continued)

Table 1. (continued).

Island	1989	1990	1991	3-Year Average
17.00				
X	2.4	5.3	1.0	3.4
SE	1.1	1.3	0.6	0.8
N	5	10	6	21
18.00				
X	0.0	1.8	.	0.8
SE	0.0	0.7	.	0.4
N	8	6		14
19.00				
X	0.2	4.6	0.5	2.3
SE	0.2	1.0	0.3	0.7
N	5	11	8	24
20.00				
X	0.9	3.7	4.4	1.8
SE	0.4	1.2	0.9	0.4
N	28	7	5	40
21.00				
X	2.5	2.5	.	2.5
SE	0.5	0.8	.	0.6
N	2	6		8
22.00				
X	1.7	1.3	0.7	1.4
SE	0.4	0.4	0.4	0.3
N	16	18	7	41
23.00				
X	0.7	0.8	0.3	0.7
SE	0.3	0.3	0.3	0.2
N	20	12	8	40
24.00				
X	2.3	1.3	.	1.7
SE	0.5	0.7	.	0.5
N	4	6		10

(continued)

Table 1. (continued).

Island	1989	1990	1991	3-Year Average
25.00				
X	0.8	0.2	.	0.4
SE	0.3	0.1	.	0.1
N	8	17		25
26.00				
X	4.9	5.0	.	4.9
SE	1.0	0.7	.	0.6
N	14	21		35
27.00				
X	1.3	1.3	.	1.3
SE	0.4	0.3	.	0.3
N	7	18		25
28.00				
X	4.0	3.3	.	3.5
SE	0.4	1.0	.	0.7
N	4	8		12
29.00				
X	1.1	1.3	0.7	1.1
SE	0.1	0.4	0.2	0.1
N	74	25	16	115
30.00				
X	1.3	0.8	.	1.1
SE	0.3	0.2	.	0.2
N	23	11		34
31.00				
X	3.5	4.3	.	4.1
SE	0.3	1.1	.	0.8
N	4	12		16
32.00				
X	0.3	0.3	.	0.3
SE	0.3	0.3	.	0.2
N	3	6		9

(continued)

Table 1. (continued).

Island	1989	1990	1991	3-Year Average
33.00				
X	2.7	0.5	1.4	1.4
SE	0.4	0.1	0.2	0.2
N	34	46	35	115
34.00				
X	4.2	1.5	.	2.8
SE	0.7	0.7	.	0.6
N	13	14		27
35.00				
X	5.7	2.6	.	3.3
SE	0.7	0.6	.	0.6
N	3	11		14
36.00				
X	2.3	2.3	.	2.3
SE	0.4	0.5	.	0.3
N	19	12		31
37.00				
X	1.7	3.2	2.3	2.5
SE	1.2	0.8	0.9	0.5
N	3	5	3	11
38.00				
X	3.0	6.5	4.8	5.1
SE	1.0	1.3	0.8	0.7
N	2	4	4	10
39.00				
X	5.8	7.4	11.3	7.9
SE	1.0	0.8	2.4	0.9
N	8	8	6	22
40.00				
X	1.5	0.6	0.6	1.0
SE	0.3	0.2	0.2	0.2
N	56	30	42	128

(continued)

Table 1. (continued).

Island	1989	1990	1991	3-Year Average
41.00				
X	2.8	6.4	.	4.8
SE	1.6	1.9	.	1.4
N	4	5		9
42.00				
X	0.8	2.3	.	1.6
SE	0.4	0.8	.	0.5
N	10	10		20
43.00				
X	2.3	6.0	.	4.8
SE	0.3	1.7	.	1.3
N	3	6		9
44.00				
X	1.8	2.2	.	2.0
SE	0.9	0.4	.	0.4
N	13	23		36
45.00				
X	0.2	0.6	.	0.4
SE	0.2	0.4	.	0.2
N	5	7		12
46.00				
X	5.2	12.3	5.2	8.3
SE	1.5	1.1	1.6	0.9
N	11	18	13	42
47.00				
X	4.6	3.8	.	4.1
SE	0.5	0.5	.	0.4
N	25	36		61
48.00				
X	0.6	0.7	2.5	1.2
SE	0.4	0.4	0.7	0.3
N	5	11	6	22

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
49.00				
X	0.0	0.0	.	0.0
SE	0.0	0.0	.	0.0
N	1	4		5
50.00				
X	4.3	4.3	.	4.3
SE	1.2	0.8	.	0.6
N	3	6		9
51.00				
X	1.8	4.4	.	3.7
SE	0.5	0.9	.	0.7
N	6	15		21
52.00				
X	1.6	1.4	.	1.5
SE	0.4	0.7	.	0.4
N	9	12		21
53.00				
X	5.5	4.8	.	5.0
SE	1.7	1.0	.	0.8
N	6	15		21
54.00				
X	8.3	7.0	.	7.5
SE	1.9	2.0	.	1.4
N	4	6		10
55.00				
X	1.4	0.9	.	1.2
SE	0.3	0.2	.	0.2
N	65	44		109
56.00				
X	0.0	0.0	.	0.0
SE	0.0	0.0	.	0.0
N	3	8		11

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
57.00				
X	0.7	4.1	.	2.2
SE	0.3	1.3	.	0.7
N	15	12		27
58.00				
X	1.3	5.1	4.0	3.6
SE	0.4	1.4	0.7	0.6
N	7	8	8	23
59.00				
X	1.0	0.8	4.4	1.6
SE	0.2	0.2	0.8	0.3
N	20	41	15	76
60.00				
X	0.0	0.0	.	0.0
SE	0.0	0.0	.	0.0
N	1	4		5
61.00				
X	0.6	1.4	.	1.1
SE	0.6	0.4	.	0.3
N	7	13		20
62.00				
X	1.8	1.4	3.1	1.9
SE	0.3	0.3	0.4	0.2
N	32	31	16	79
63.00				
X	0.5	3.5	.	1.9
SE	0.3	1.2	.	0.7
N	12	11		23
64.00				
X	4.8	2.1	.	3.3
SE	0.6	0.4	.	0.4
N	26	34		60

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
65.00				
X	0.3	0.0	.	0.3
SE	0.1	0.0	.	0.1
N	44	2		46
66.00				
X	1.2	4.2	.	2.0
SE	0.4	1.0	.	0.4
N	32	12		44
67.00				
X	1.4	1.9	.	1.5
SE	0.2	0.4	.	0.2
N	52	14		66
68.00				
X	9.2	4.0	.	5.8
SE	1.1	0.7	.	0.8
N	6	11		17
69.00				
X	1.6	7.6	.	4.3
SE	0.4	1.4	.	0.8
N	19	16		35
70.00				
X	1.0	1.0	.	1.0
SE	1.0	0.6	.	0.4
N	2	3		5
71.00				
X	0.8	0.0	.	0.7
SE	0.2	0.0	.	0.2
N	13	0.3		16
72.00				
X	2.0	3.9	.	2.5
SE	0.3	0.7	.	0.3
N	23	8		31

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
73.00				
X	2.8	4.8	4.9	3.6
SE	0.6	1.0	1.0	0.5
N	32	11	10	53
74.00				
X	2.4	2.7	2.7	2.6
SE	0.5	0.6	1.7	0.5
N	10	10	7	27
75.00				
X	2.7	2.6	.	2.6
SE	1.8	0.7	.	0.7
N	3	5		8
76.00				
X	7.7	6.6	.	7.0
SE	1.5	1.4	.	1.0
N	3	5		8
77.00				
X	.	3.6	.	3.6
SE	.	0.7	.	0.7
N		5		5
78.00				
X	3.1	0.9	.	2.0
SE	0.9	0.2	.	0.5
N	16	15		31
79.00				
X	10.7	2.8	.	5.8
SE	1.2	1.0	.	1.6
N	3	5		8
80.00				
X	2.2	2.5	.	2.4
SE	0.4	0.4	.	0.3
N	5	6		11

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
81.00				
X	1.5	0.7	0.7	1.0
SE	0.5	0.3	0.3	0.2
N	11	15	7	33
82.00				
X	1.4	0.5	.	1.1
SE	0.3	0.3	.	0.2
N	51	19		70
83.00				
X	2.1	2.6	8.7	3.8
SE	0.5	0.9	1.2	0.7
N	12	13	7	32
84.00				
X	2.1	3.4	8.8	4.8
SE	0.4	0.9	1.7	0.9
N	8	10	9	27
85.00				
X	0.5	1.0	.	0.8
SE	0.5	0.6	.	0.4
N	2	3		5
86.00				
X	0.0	0.3	.	0.2
SE	0.0	0.3	.	0.2
N	3	3		6
87.00				
X	0.9	1.6	3.8	1.5
SE	0.2	0.3	0.8	0.2
N	48	21	11	80
88.00				
X	1.5	0.3	.	1.3
SE	0.5	0.3	.	0.4
N	20	3		23

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
89.00				
X	1.0	0.3	.	0.6
SE	0.6	0.3	.	0.3
N	3	4		7
90.00				
X	.	0.5	.	0.5
SE	.	0.2	.	0.2
N		17		17
92.00				
X	.	.	1.8	1.8
SE	.	.	0.4	0.4
N			25	25
94.00				
X	1.3	.	.	1.3
SE	0.2	.	.	0.2
N	27			27
100.00				
X	1.4	.	.	1.4
SE	0.3	.	.	0.3
N	34			34
104.00				
X	.	.	1.6	1.6
SE	.	.	0.3	0.3
N			9	9
105.00				
X	.	.	0.8	0.8
SE	.	.	0.2	0.2
N			34	34
106.00				
X	.	.	0.8	0.8
SE	.	.	0.3	0.3
N			24	24

(continued)

Table 1. (continued)

Island	1989	1990	1991	3-Year Average
107.00				
X	.	.	1.1	1.1
SE	.	.	0.3	0.3
N			30	30
108.00				
X	.	.	1.0	1.0
SE	.	.	0.2	0.2
N			46	46
109.00				
X	.	.	0.2	0.2
SE	.	.	0.1	0.1
N			24	24
110.00				
X	.	.	0.9	0.9
SE	.	.	0.2	0.2
N			24	24
111.00				
X	.	.	0.5	0.5
SE	.	.	0.2	0.2
N			11	11
112.00				
X	.	.	2.0	2.0
SE	.	.	0.7	0.7
N			16	16

Table 2. Deer preference for different *Vaccinium* species, as shown by browse utilization estimates, Sea Otter Sound.

Forage Preference

	Alaskensis/ Ovalifolium	*Parvifolium*
Percent Use		
X	26.3	47.8
SE	1.0	2.1
N	1074	286

Table 3. Nutritional analysis of 3 species of deer browse in Sea Otter Sound, southeast Alaska.

Nutritional Comparison of 3 *Vaccinium* Species

	Ovalifolium	*Alaskensis*	*Parvifolium*
% Crude Protein			
X	3.8	5.1	5.4
SE	0.9	0.4	0.3
N	2	3	5
% Neutral Detergent Fiber			
X	86.4	82.3	78.9
SE	3.2	0.8	1.5
N	2	3	5
% Acid Detergent Fiber			
X	66.0	62.0	59.4
SE	2.3	1.0	1.5
N	2	3	5
% Lignin			
X	48.8	32.4	27.8
SE	7.6	2.5	1.7
N	2	3	5
% Ash			
X	0.4	0.7	0.3
SE	0.3	0.3	0.2
N	2	3	5

Table 4. Biomass of *Vaccinium* available to deer on fragmented and unfragmented blocks, Peril Strait, southeast Alaska

Dry Weight (kg/ha) of *Vaccinium* Available

	Clearcut	Old Growth	Combined
Fragmented			
X	161.0	70.7	136.8
SE	17.8	14.7	13.9
N	123	45	168
Unfragmented			
X	.	7.7	7.7
SE	.	1.3	1.3
N		154	154

Table 5. Biomass of *Vaccinium* consumed by deer on fragmented and unfragmented blocks, Peril Strait, southeast Alaska.

Dry Weight (kg/ha) of *Vaccinium* Consumed

	Clearcut	Old Growth	Combined
Fragmented			
X	69.7	75.0	71.1
SE	10.3	15.1	8.6
N	123	45	168
Unfragmented			
X	.	9.8	9.8
SE	.	1.7	1.7
N		154	154

Table 6. Pellet-group statistics (mean pellet-groups per plot, standard error, N) for fragmented and unfragmented blocks along Peril Strait, southeast Alaska.

Pellet-Group Statistics - Peril Strait

	Clearcut	Old Growth	Combined
Fragmented			
X	3.5	5.5	4.1
SE	0.3	0.5	0.3
N	124	44	168
Unfragmented			
X	.	4.6	4.6
SE	.	0.3	0.3
N	161		161

Table 7. Percentage browse utilization by deer in fragmented and unfragmented blocks in Peril Strait southeast Alaska.

***Vaccinium* Utilization**

	Clearcut	Old Growth	Combined
Fragmented			
X	37%	60%	43%
SE	1.4	2.2	1.3
N	489	183	672
Unfragmented			
X	.	72%	72%
SE	.	1.8	1.8
N		219	219