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POTENTIAL OF REVILLAGIGEDO ISLAND FOR A GOAT TRANSPLANT

By
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Final Report
Federal Aid in Wildlife Restoration
Project W-22-2, Job 12.6R

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FINAL REPORT (RESEARCH)

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SUMMARY

Approximately 1,000 km^2 (400 mi^2) of the northeast third of Revillagigedo (Revilla) Island were evaluated as potential mountain goat (Oreamnos americanus) habitat. Point sampling of topographic and timber type maps provided data for use in frequency distribution and discriminant function analysis comparisons with occupied habitat on the adjacent mainland. Results indicate that the areas are similar with respect to topography and gross vegetation communities and that approximately 32% of the sampled area may be adequate winter habitat for goats. At current densities on the mainland, this area would support approximately 600 goats.

On-site vegetation sampling was conducted on the mainland and island to assess similarity of understory composition and browse availability/utilization. Major species were the same in both locations, and browse production was comparable. Utilization was moderate on the mainland and nonexistent on the island. Abundant forage is present in the transplant area.

Evaluation of interspecific relationships and snow depth patterns on the island and mainland suggests that neither should adversely affect transplanted goats. Winter range overlap of introduced goats with resident deer (Odocoileus hemionus sitkensis) should be minimal, and wolves (Canis lupus) may even benefit from presence of a buffer prey species.

It is recommended that a transplant be undertaken to mitigate anticipated losses associated with development of the U.S. Borax molybdenum mine at Quartz Hill. State and Federal agencies should negotiate with private industry to seek an equitable cost sharing for this project.

Key words: mountain goat, Oreamnos americanus, transplant habitat assessment.

CONTENTS

BACKGROUND

Public interest in transplanting mountain goats (Oreamnos americanus) to Revillagigedo (Revilla) Island from the adjacent mainland to provide for increased and more readily accessible recreational use of goats has existed for some time. In response to public inquiries, the U.S. Forest Service made some preliminary observations on habitat suitability of part of the island in 1963, but lack of coordination with the Alaska Department of Fish and Game (ADF&G) and failure to follow up on the idea resulted in no transplant taking place. Since that time, the concept of a transplant has been discussed off and on, but ADF&G has generally opposed this action based on the lack of a clear need to increase local goat numbers, funding limitations, and a generally conservative policy toward transplants. Recent events have led to a reevaluation of the potential benefits of a transplant.

Impending development of a major molybdenum mine in the vicinity of Quartz Hill, 65 km (40 mi) southeast of Ketchikan, is expected to have a dual effect on the region's goat populations. Direct impacts resulting from habitat alterations, displacement due to human activity, and illegal killing of goats may result in a reduction of the goat herd in the immediate vicinity of the mine site and access corridors. Indirect effects include increased competition and/or higher hunter demand for goats due to the influx of mine workers and their families to the Ketchikan area. The net result of this activity will be a reduced supply and increased demand for goats on the mainland. To some extent, it may be possible to offset these changes by establishing a new goat population in vacant habitat on Revilla Island.

The ADF&G has the primary responsibility for wildlife management in Alaska and is the lead agency in dealing with any proposed transplants. Policy decisions developed by ADF&G's Game Division clearly require evaluation of 3 elements before authorizing and conducting a transplant (ADF&G 1973). First, there must be a recognized public demand and benefit from the transplant. Second, studies must demonstrate that sufficient habitat exists at the proposed transplant site to support the introduced species. Third, it must be demonstrated that the proposed introduction will not have detrimental effects on resident wildlife species.

The initial requirement of identification of public support and potential benefit appears to have been fulfilled. (Yet to be resolved, however, is how the public benefits and need for the transplant to offset mine development impacts relate to sharing the anticipated costs of a transplant.) The purpose of this study was to evaluate the latter 2 points, habitat suitability and potential interspecific relations on Revilla Island.

OBJECTIVE

To evaluate potential transplant locations for mountain goats and to assess feasibility and possible impacts of establishing an introduced population on Revillagigedo Island.

PROPOSED TRANSPLANT AREA

The northeast third of Revilla Island was selected as a potential transplant site (Fig. 1). This area of roughly 1,000 km^2 (400 mi^2) is part of the coastal foothills formation (Jaques 1973) with peaks reaching elevations over 1,200 m (4,000 ft). It appears similar in bio-geo-physical characteristics to the adjacent mainland which supports healthy goat herds (Wood 1981). The area is separated from the mainland by Behm Canal, which averages about 3 km (2 mi) wide.

PROCEDURES

Map Analysis

A grid overlay with 6.4-acre cells was superimposed onto 2-inch to the mile topographic and timber type maps of approximately 600 km^2 (230 mi^2) in the proposed transplant area between Marble Creek and Orchard Creek (Fig. 1). Every other row of cells in alternating columns was sampled for physical and biological parameters: elevation, aspect, slope, distance to the nearest cliff (i.e., area with slope greater than 50°), vegetation type, and timber volume as described by Fox et al. (1982). Similar data were available from the adjacent Upper Cleveland Peninsula (UCP) where Smith (1983) has been conducting radio telemetry studies of mountain goat habitat use.

Frequency distributions of selected habitat traits were analyzed to quantify similarity of the island to the mainland, and discriminant function analysis (DFA) was used to predict locations of winter range on Revilla Island. For the DFA, the 1,527 sampled cells on the UCP were divided into subsets of cells used by radio-collared goats monitored by Smith (1983) between November 1981 and April 1982 and cells unused by those goats. DFA was used to determine the optimal method of classifying these cells into their respective categories. The resulting function was then used to predict whether or not each of the 5,690 cells sampled on Revilla most resembled a used (hence winter habitat) or unused (nonhabitat) cell on the UCP.

Vegetation Sampling

To evaluate floristic similarity within habitat types and to compare forage availability for goats on Revilla versus the mainland, vegetation sampling was undertaken on ridges within the proposed transplant area and in the vicinity of Quartz Hill. Rectangular plots 5 by 25 m were randomly located in alpine and subalpine habitat types. Fifty 0.1-m^2 microplots were located at 1 m intervals along the long axis of the plot to determine forb-subshrub canopy cover values (Daubenmire 1959). Basal diameters of shrub stems rooted in the 0.1-m^2 frames were measured with calipers and recorded. Shrub stems were counted in 10, 1 x 5 m subplots along the long axis of the plots to determine mean stem density. Stem diameter and density were used to calculate estimates of available forage biomass of selected shrub species (Alaback 1980). Arboreal species within the plot were classified as seedlings (less than 1 m high), saplings (dbh less than 2.5 cm), or trees. Counts were made for the 1st 2 classes, while dbh was measured and height estimated for each tree. Abundance of arboreal lichens was determined subjectively in 3 classes (abundant, moderate, rare) in each plot. Sampling was conducted on Revilla Island by ADF&G and at Quartz Hill by VTN Consolidated under contract with U.S. Borax.

Interspecific Relationships

Aerial surveys were flown in a PA-18-150 Super Cub during early morning and evening hours in August 1982 to determine distribution of deer using open subalpine and alpine habitats. No standardized routes were flown, but the main ridge complexes between Marble Creek and Mt. Reid were surveyed on each flight. Additional observations on distribution and activity of deer and wolves were made during vegetation sampling and by searching for tracks in the snow during winter months.

Snow Measurements

Snow measurement poles were distributed at 150, 460, and 760 m (500, 1,500, and 2,500 ft) elevations in the transplant area and in the vicinity of Quartz Hill on the mainland to monitor snow depth. As weather permitted, we recorded snow depth in fixed-wing aircraft and helicopters from November 1982 through February 1983.

RESULTS AND DISCUSSION

Map Analysis

A total of 5,690 points was systematically sampled on Revilla Island maps. Results of frequency analysis of these data in comparison with UCP data (1,527 random points sampled by Smith 1983) are presented in Table 1.

Distribution of elevational classes is similar, particularly in the areas above 460 m (1,500 ft). This is not surprising as the ridges in both areas are part of the same major geological formation. Aspects in the 2 areas are more dissimilar, as the UCP has more flat ground than Revilla and the general east-west orientation on the mainland results in varying exposures. The relatively low amount of flat ground on Revilla is to some extent due to the drawing of the sample area boundary; in other words, lowlands on the edge of the proposed transplant region were excluded from sampling to a greater extent than on the previously sampled UCP. Although the distribution of south-facing slopes differs between the 2 areas, when southeast, south, and southwest slopes are lumped together, the island and mainland have similar amounts (36% vs. 37%, respectively) of these heavily used aspects.

The greater amount of flat ground on the UCP contributes to the higher percentage of cells with 0-15° and 16-20° slope there than on Revilla. Correspondingly, the island has a higher percentage of the moderate to steep (e.g., 26-50°) slopes than the UCP. Cliff areas (slopes greater than 50°) are slightly more common on the UCP; however, overall, nearly 50% of Revilla is in the slope categories over 30° which are preferred by goats (Smith 1983).

Distribution of cells based on their distance from the nearest cliff also indicates relatively more extreme terrain on the UCP, but fully 75% of the sample area on Revilla is on or within 0.8 km (0.5 mi) of a cliff. In absolute terms, this means there is substantially more of the preferred terrain on the island than the mainland sample areas.

Both areas have similar proportions of commercial volume old-growth forest, cliff and slide forest, muskeg, and muskeg forest. Of the other vegetation types, Revilla has more subalpine forest, brush, and alpine than the UCP. The latter area has less soil and vegetation development above 600 m (2,000 ft) than the island, resulting in relatively greater amounts of bare rock and other (primarily lake) areas. This distribution of vegetation types accounts for the variation in timber volumes. Revilla has less nonforested and more noncommercial timber than the UCP, and although distribution by volume class varies, the total commercial volume forest land is virtually equal on the 2 sites.

DFA identified 1,827 cells, or 32% of the area, as potential winter habitat (Large-scale maps of the identified winter habitat are on file in the Ketchikan office of ADF&G.) This implies that of the total 600 km^2 (230 mi^2) area, an estimated 191 km^2 (74 mi^2) could be suitable winter habitat for goats. If winter range density of an introduced goat population reached the levels currently sustained in the vicinity of Quartz Hill (about 8 goats/2.59 km^2 [1 mi^2]) (ADF&G, unpubl. data), the estimated winter range on Revilla could support over 600 animals.

Vegetation Sampling

The nonforested plant communities above tree line were divided for sampling into alpine meadows dominated by forbs and herbs, alpine heaths dominated by sub-shrubs, and xeric alpine ridges.

Alpine Meadow:

Revilla Island. The alpine meadow plots were located in a forb-sedge community on a ridge complex 5 km (3 mi) northwest of Lake Grace at 760 m (2,500 ft) elevation on moderately steep (35-45°) southerly aspects (Fig. 2). Fauria crista-galli and Carex spp. dominated this moist type with 68 and 18% ground cover, respectively (Table 2). Other major species include Erigeron sp., Geum calthifolium, Luetkea pectinata, Pedicularis ornithorhyncha, Sanguisorba sp., Valeriana sitchensis, and an unknown Compositae. The species-area curve (Fig. 3a) indicates that sampling was adequate to identify most species present, although several other species, such as Gentiana platypetala, were noted to be present but not located in the sample plots. The site was extremely moist with surface drainage apparent at the time of sampling.

Quartz Hill. The alpine meadow plots were located on ridge tops (slope 10°) near Bakewell Head and north of Tunnel Creek at approximately 915 m (3,000 ft) in elevation. Fauria crista-galli and Carex were abundant, but Cassiope mertensiana and Cassiope stelleriana were codominant. Empetrum nigrum, Geum calthifolium, Luetkea pectinata, Vaccinium caespitosum, and Vaccinium uliginosum were other major vascular species; the lichen Cladonia sp. was common (Table 2). Although the species-area curve (Fig. 3a) has more or less leveled off, its lower slope and asymptote than the Revilla curve indicate reduced floral diversity in the area sampled.

Major summer forage species such as Fauria crista-galli, Carex spp., Luetkea pectinata, and Geum calthifolium were found to be abundant in both areas. Numerous other forb species, which goats probably utilize, also occur. The major differences between the 2 locations are the greater abundance of forbs and sedges on Revilla versus higher sub-shrub and lichen densities at Quartz Hill. To some extent, these differences may simply be due to site moisture and exposure characteristics; the presence of Cladonia sp. at Quartz Hill indicates these sites may be more like the exposed ridge site on Revilla. In addition, it is possible that the lower forb density at Quartz Hill may reflect grazing by goats.

Alpine Heath:

Revilla Island. The alpine heath plots were located in Cassiope-forb communities on moderate slopes (15-20°) and south and east aspects at about 670 m (2,200 ft) elevation. These communities overlaid old scree or rock slopes with relatively limited soil development and were well drained relative to the alpine meadows. Cassiope mertensiana, Cassiope stelleriana, and Luetkea pectinata clearly dominate this community (Table 2). Fauria crista-galli, Carex spp., grasses, and several species of Compositae are also common, as are young, stunted yellow cedar Chamaecyparis nootkatensis and mountain hemlock Tsuga mertensiana. Floral diversity is lower here than in the alpine meadows as evident from the species-area curve (Fig. 3b). This type is the most extensive in the alpine zone on Revilla and the adjacent mainland.

Quartz Hill. One heath plot was located on a ridge at 1,070 m (3,500 ft) near the head of Falsegate Creek, the other at the 915 m (3,000 ft) level on East Ridge. Both sites were relatively flat and near the top of the ridge. Goats and/or sign were observed in the immediate vicinity of the plots. As on Revilla, the heath type at Quartz Hill is dominated by Cassiope mertensiana and Cassiope stelleriana (Table 2); Carex spp., Fauria crista-galli, Luetkea pectinata, and Phyllodoce aleutica are also relatively common and/or abundant. The high level of occurrence of Cladonia sp. and Vaccinium caespitosum indicates the sites were dry, as would be expected for ridge tops. The species-area curve (Fig. 3b) reveals that sampling was adequate.

As with the alpine meadow type, the sites on Revilla were floristically more diverse than those on Quartz Hill, and forbs (specifically Fauria crista-galli and Luetkea pectinata) are more abundant on the island. Reduced available moisture and grazing by goats at the Quartz Hill sites probably account for most of the differences. The abundance of forbs in the alpine heath of Revilla Island indicates that this extensive community would provide large quantities of summer forage for goats.

Alpine Ridge:

This type was sampled separately on Revilla Island because it was felt that it was different from either the meadow or heath type. Due to limited development of soil and extreme wind, this site was the most xeric on the island. Although relatively limited in extent, it is expected to receive extensive use by goats during the summer months due to the proximity of steep, broken terrain. Fauria crista-galli, Carex spp., and Cassiope mertensiana are the dominant vascular plants, but the abundance of Cladonia sp. and the presence of Empetrum nigrum, Loiseleuria procumbens, Vaccinium caespitosum, and Vaccinium uliginosum reveal the difference between this site and the forb-sedge meadows (Table 2). These sites are similar to the "alpine meadow" plots from Quartz Hill (as might be expected since those sites were located closer to the ridge-top than the meadow plots on Revilla), and confirm the presence of several additional species on both the island and mainland.

Subalpine Forest Zone:

Revilla Island. Open and closed canopy stands were sampled in the subalpine zone on a tributary of Carroll River (Fig 2). The open stands were located on a moderately steep (25-40°) south slope at 760 m (2,500 ft) elevation. Average canopy closure was 33%, composed primarily of mountain hemlock and yellow cedar with a well-developed intermediate layer of seedlings and saplings (Table 3). The closed canopy sites were on the same south slope but were much steeper (60-70°) and averaged 73% canopy cover. Hemlock dominated the stands, and though seedlings were common, saplings were not found in the plots (Table 4). Arboreal lichens, including Alectoria spp. and Lobaria sp. were found at intermediate to abundant levels in the open stands and intermediate levels in closed forests, while Cetraria sp., and Parmelia sp. occurred on some trees in the closed canopy forest.

The understory shrub layer was well developed in both stands. Vaccinium spp. (ovalifolium and alaskensis) dominated and were estimated to produce 158 and 55 kg/ha of leaf and twig biomass per year in open and closed stands, respectively (Table 5).

The forb layer in the open stands was lush and dominated by Fauria crista-galli, Streptopus sp., Rubus pedatus, Cornus canadensis, Coptis asplenifolia, and Blechnum spicant (Table 2). In closed stands, species composition was similar, except for the

lack of Fauria, but the combination of steeper slopes and reduced light resulted in lower ground cover of forbs and much higher moss and lichen cover.

Quartz Hill. Open and closed canopy subalpine sites were sampled at a variety of locations. The open stands were on moderate (17-25°) slopes at 640-790 m (2,100-2,600 ft) elevation and averaged 25% canopy closure (Table 3). The overstory was dominated by hemlock with some mature yellow cedar, while the seedling and sapling layers contained an abundance of young and/or stunted yellow cedar with less hemlock. The closed canopy stands were slightly steeper (17-34°) and had a mean canopy cover of 69% (Table 4). Hemlock was the only tree species found in the plots; seedlings were abundant but saplings were relatively rare. Arboreal lichens, including Alectoria spp. and Lobaria sp., were found in low to abundant density throughout subalpine stands; Cetraria sp., Parmelia sp., and Bryoria sp. occurred occasionally.

The understory shrub layer was again dominated by Vaccinium spp. (Table 5), which showed signs of past browsing by goats in both open and closed stands. Although stem densities were lower than on the island, mean diameters were larger and forage biomass was estimated to be 108 and 71 kg/ha for Vaccinium in open and closed stands, respectively.

The forb layer in the open stands was somewhat heath-like with an abundance of Cassiope spp., Phyllodoce aleutica, and the fern Polypodium vulgare were well represented (Table 2). Cover values for most of the common species were lower in the closed canopy stands, but a greater total number of species was found.

Recent evidence of grazing by goats on Fauria was noted in some plots.

The presence of tracks, trails, and fecal pellets as well as evidence of grazing and browsing in the subalpine forests at Quartz Hill demonstrate that this habitat is intensively utilized by goats. The areas sampled on Revilla Island indicate that the vegetation is very similar with at least comparable quantities of major winter forage in the form of Vaccinium spp. and conifer browse. The larger mean diameter and reduced stem density of Vaccinium at Quartz Hill may be due to the noted browsing by goats. Basal diameters may increase due to "hedging" effect, and these plants may have fewer resources to put into berries due to the need to replace vegetative tissue annually. On Revilla, where the shrubs are virtually untouched, growth may be more equitably shared between vegetative and propagative growth, resulting in relatively abundant new young plants. Within the areas sampled on Revilla Island, it is apparent that sufficient forage is available to support goat population densities similar to those at Quartz Hill.

Interspecific Relationships

A major consideration in judging the possible effects of a transplant is how the introduced species will interact with, and affect populations of, resident species in the area. In the case of this proposed transplant, concern is minimal inasmuch as goats are endemic to the local area and most species with which goats would coinhabit the island are also found on the mainland; no adverse interspecific relationships are known to exist there. Nevertheless, Game Division policy requires an evaluation of this potential. The main species of concern on the island are deer and wolves.

Deer:

Two fixed-wing surveys were flown in August 1982 to assess deer use of the alpine and open subalpine areas. Flight routes are illustrated in Fig. 4. On 4 August, a total of 11 deer (9 bucks and 2 does) was seen in 1.5 hours, yielding a rate of 7.3 deer per hour of survey time. On 28 August, 6 deer (4 bucks, 1 doe, and 1 fawn) were observed in 1.1 hours for a rate of 5.5 deer per hour.

Comparable survey data are extremely limited, but 2 areas of Prince of Wales Island were flown under similar conditions on 20 August 1980 and 9 August 1982 by R. Wood. Estimated sighting rate for the Cholmondeley Sound-Craig portion of Prince of Wales Island in 1980 was 25-30 deer per hour, while the Coffman Cove-Thorne Bay area yielded approximately 50 deer per hour in 1982 (ADF&G, unpubl. data). Sighting rates for many areas of Admiralty and Baranof Islands exceed 100 deer per hour (L. Johnson, pers. commun.).

During other nonsurvey fixed-wing flights over the transplant area, as well as on helicopter flights to and from the vegetation sampling plots, no deer were observed in the alpine. While on the ground to complete the vegetation sampling on Revilla, 1-2 sets of tracks were observed and an occasional pellet group was located, but no browsing was evident on plants within the plots. A single set of tracks was observed in the snow at 760 m (2,500 ft) on 8 November 1982 during the helicopter flight to place the snow poles on the island, but no other tracks were observed in the snow in the course of checking the poles through late February 1983.

General opinion and hunter success statistics indicate that the deer population on northeast Revilla Island is significantly reduced from levels of the mid to late 1960's (Wood 1982a). The low numbers seen from the air combined with the lack of sign observed on the ground also suggest that relatively few deer are currently using the mid- to high-elevation areas northeast of Carroll Inlet.

Radio telemetry studies of deer (Schoen et al. 1979) and goats (Smith 1983) in Southeast Alaska indicate that winter range areas for these species are relatively distinct. Although both deer and goats utilize medium to high volume old-growth forests on southerly aspects when snow cover is present, deer generally exploit lower elevations, gentler slopes, and smoother terrain than goats (Table 6). Given this inherent separation and low deer numbers, it is unlikely that these species will compete for limited resources, and the introduction of goats to Revilla Island should not adversely affect deer.

Wolves:

Snow cover was not adequate during the winter of 1982-83 to permit effective monitoring of wolf activity at low elevations in the proposed transplant area. Limited observations made during flights to set and check snow poles resulted in no wolf track sightings.

The current wolf population on Revilla Island is significantly reduced from the higher levels of the late 1960's and early 1970's (Wood 1982b) presumably as a result of the decline in their major prey species, deer. Although the possibility exists that the residual wolf packs in the area may locate and prey upon some of the introduced goats, wolves are not expected to eliminate the initial stocking. As the goat population expands, wolves may begin to prey upon the species regularly--as they must on the adjacent mainland--but, once established, goats should be able to sustain these losses.

Regardless of the predator-prey outcome, introducing goats should not have an adverse effect on the wolves. In fact, by increasing prey diversity, the transplant may benefit wolves in the long run. (It remains to be seen how, or if, providing a buffer species will affect the island's deer-wolf relationship.)

Snow Measurements

A combination of poor weather and unavailability of suitable aircraft limited acquisition of snow depth data on Revilla. Destruction of snow poles (presumably by bears) at Quartz Hill had the same effect in that area. Still, the available data are adequate to determine the general similarity of snow depths on the island and mainland.

Fig. 5 illustrates progression of snow depth on Revilla and at Quartz Hill from early November 1982 through February 1983. Snow depth was generally greater at Quartz Hill than on Revilla at any given elevation. In both locations, snow cover was inconsistent and/or incomplete on timbered slopes up to nearly 2,000 ft on southerly exposures.

CONCLUSION

The proposed transplant location on northeast Revilla Island closely resembles areas of the adjacent mainland currently used by goats in many bio-geo-physical and environmental features. In fact, the failure of goats to colonize the island naturally may simply be a consequence of their arrival in the region from a southern glacial refugium after post-pleistocene sea levels rose and flooded Behm Canal, isolating this segment of the coastal foothills (Klein 1965). Based on the results of this study, introduced goats should find adequate forage, shelter, and escape cover to support a population of from several hundred to as many as 1,000 goats.

Establishing goats on Revilla is not expected to have significant direct effects on resident species. Competition with deer should be minimal, even if currently depressed populations increase in future years. Although wolves may prey on goats on the island, current wolf-goat relationships on the mainland indicate that goat populations can increase in the presence of existing wolf densities there. Once the introduced goats have surpassed a threshold level, it is expected that they could withstand predation on the island as well.

If an introduced population of 500-1,000 goats developed on the island, a human harvest of 25-50 goats per year could be sustained under the current 5% harvest guidelines. Although accessibility may restrict actual kill to lower numbers, this would represent a potential increase of approximately 50% over current hunter yield in Subunit 1A. Given the persistence of low deer numbers in spite of mild winters during the past 6 years, this could represent a significant enhancement of opportunity for subsistence and recreational hunting. Opportunities for non-consumptive use would also be increased by providing a more accessible population for recreationists based in Ketchikan.

RECOMMENDATIONS

1. In view of the suitability of habitat, public interest, and availability of "surplus" goats on the adjacent mainland, ADF&G should pursue the option of transplanting goats to Revilla Island.

2. A detailed proposal covering timing, logistics, number of animals to be moved, and monitoring of introduced goats should be developed.

3. ADF&G should confer with the U.S. Forest Service to seek authorization for the transplant under terms of their Master Memorandum of Understanding.

4. ADF&G should meet with representatives of the U.S. Forest Service, U.S. Borax, and interested members of the public to explore options for cost and personnel sharing to accomplish the introduction.

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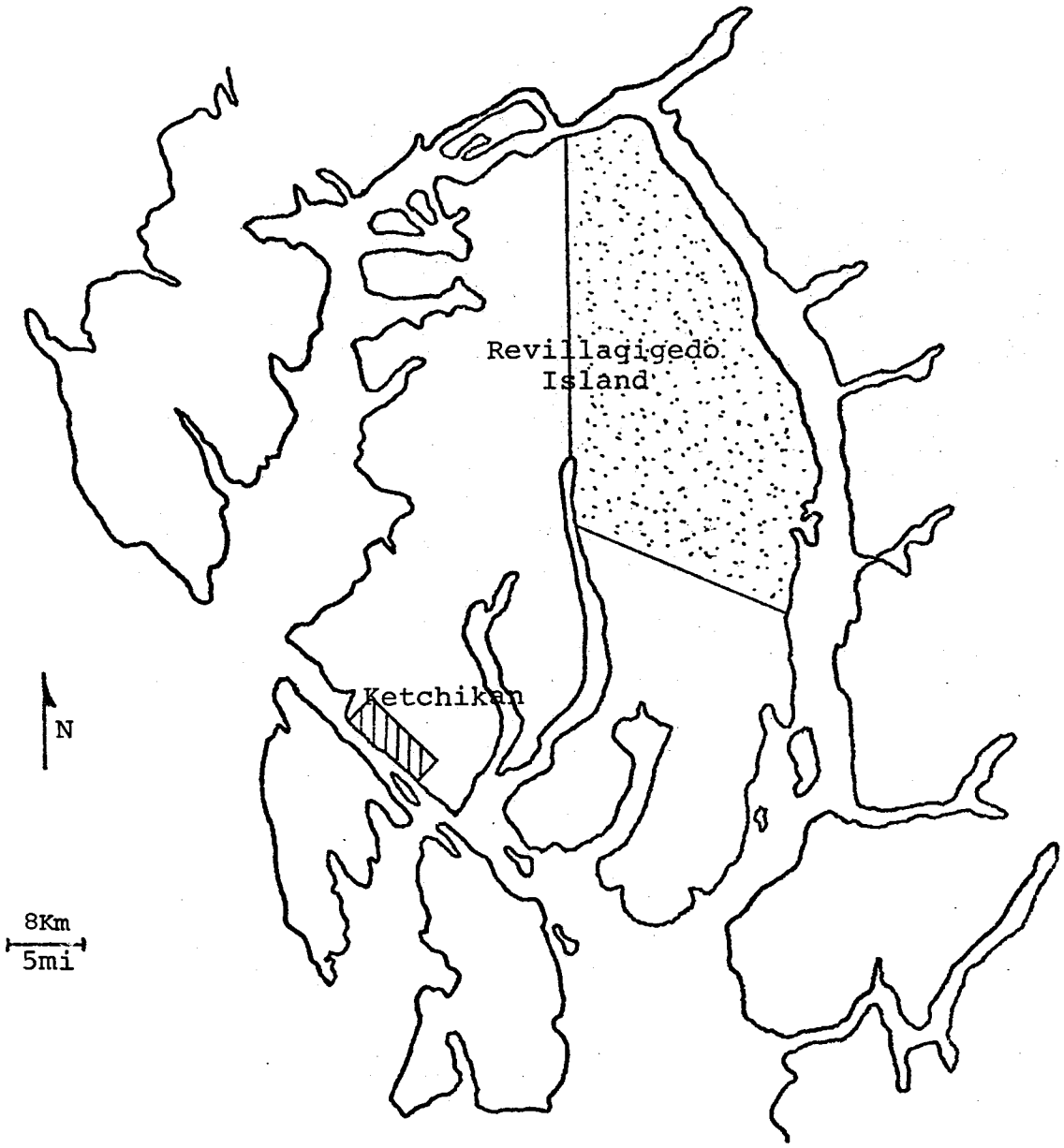


Fig. 1. Revillagigedo Island. Stippled portion is the proposed transplant area.

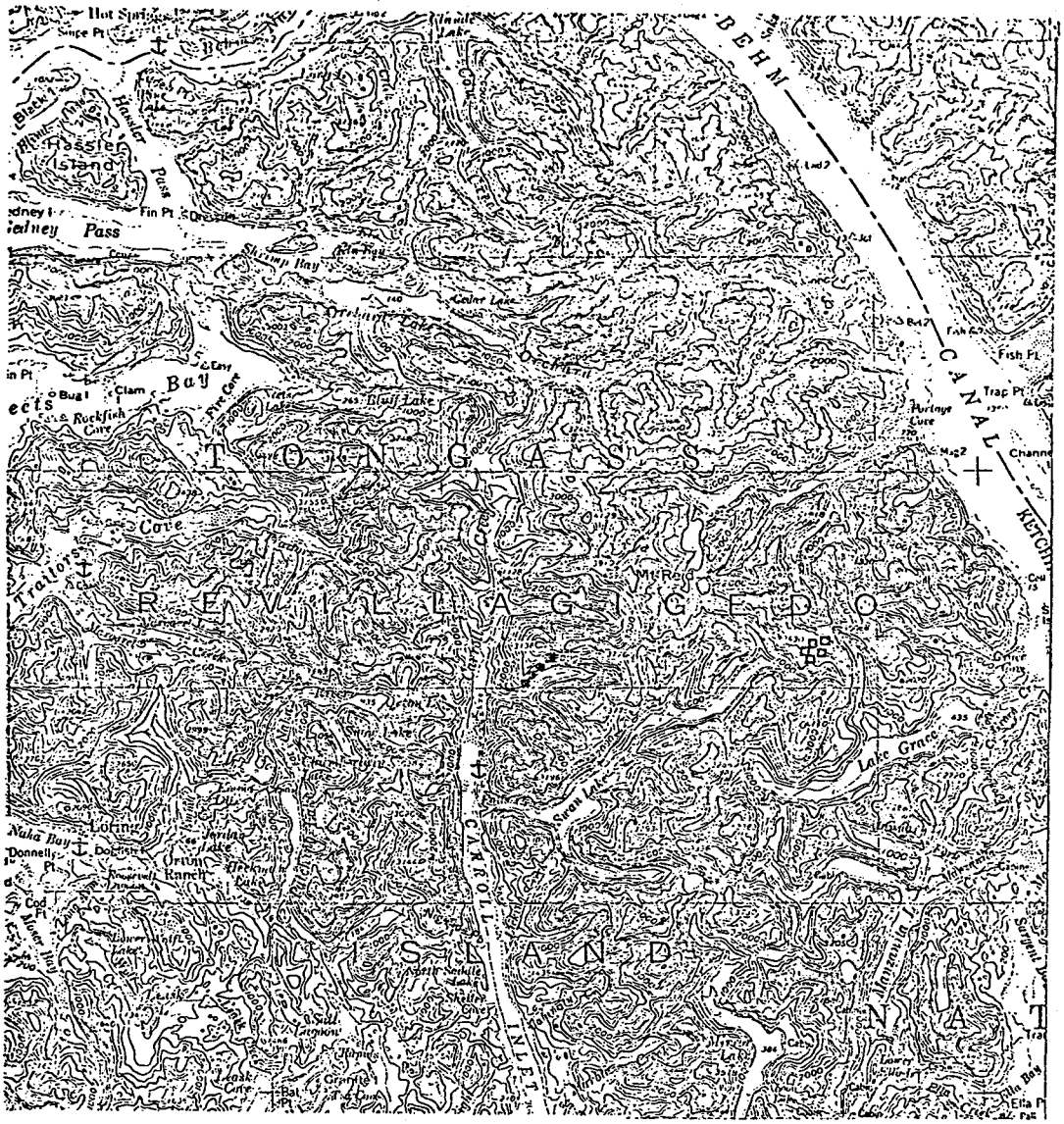
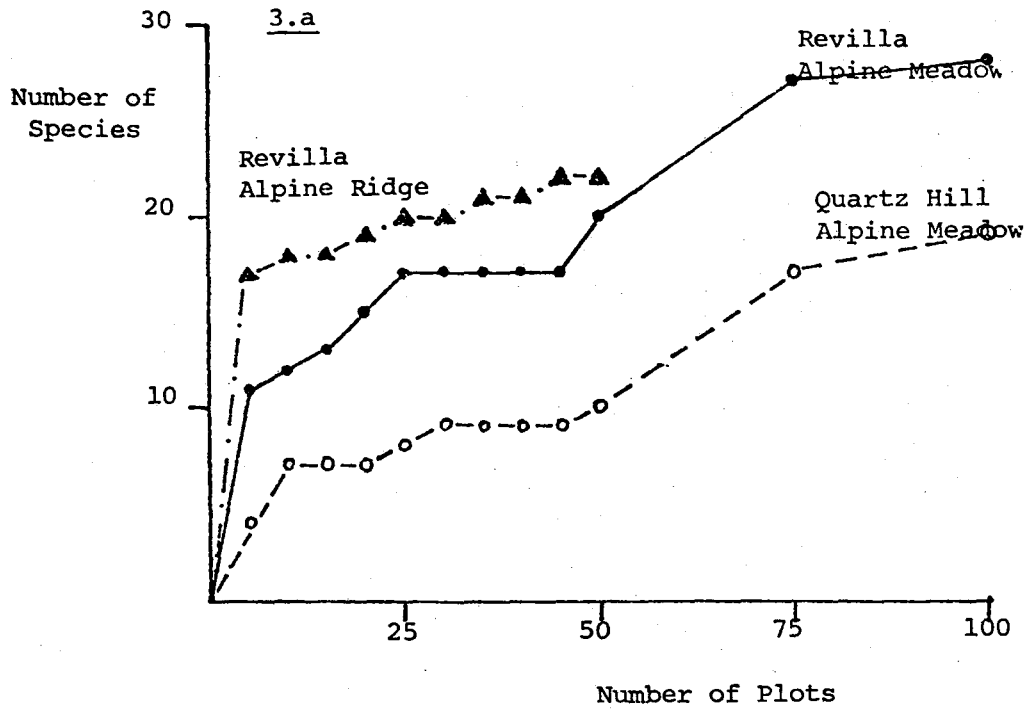


Fig. 2. Alpine (▭) and subalpine (■) vegetation sample plots, Revillagigedo Island.



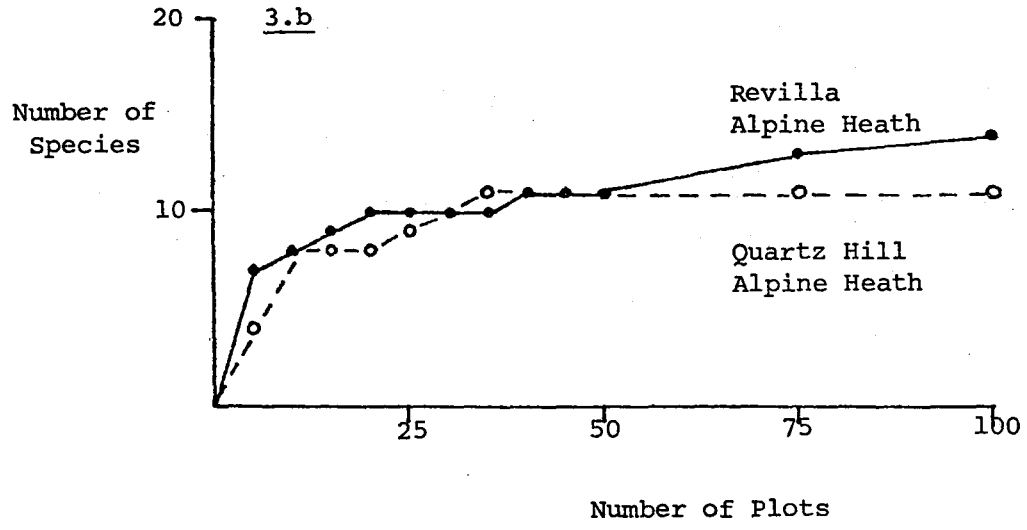
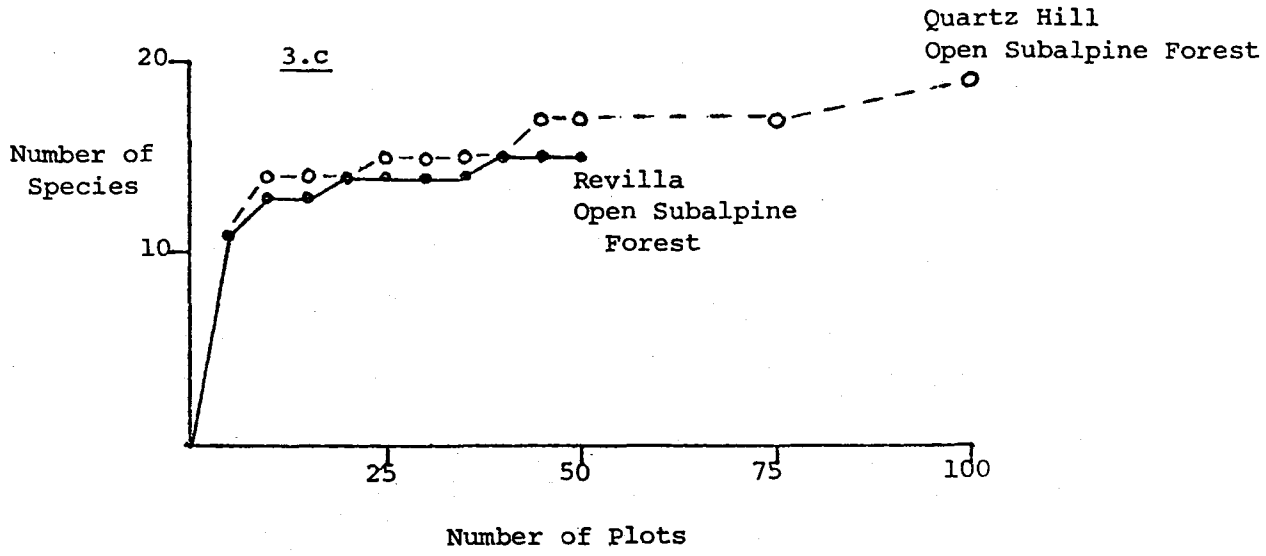


Fig. 3. Species-area curves for Daubenmire (1954) plot samples, Revillagigedo Island and Quartz Hill.



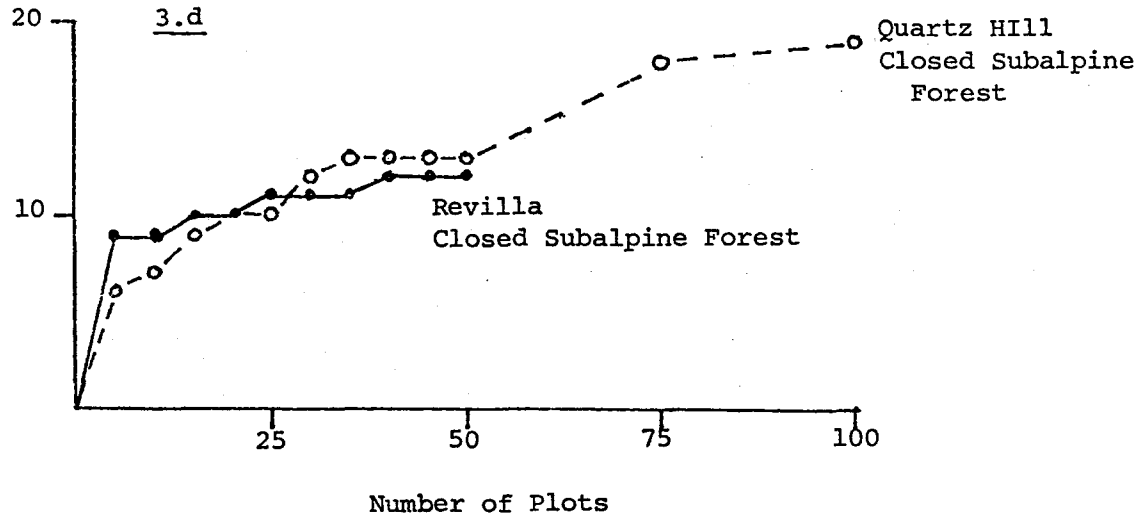


Fig. 3. Continued.

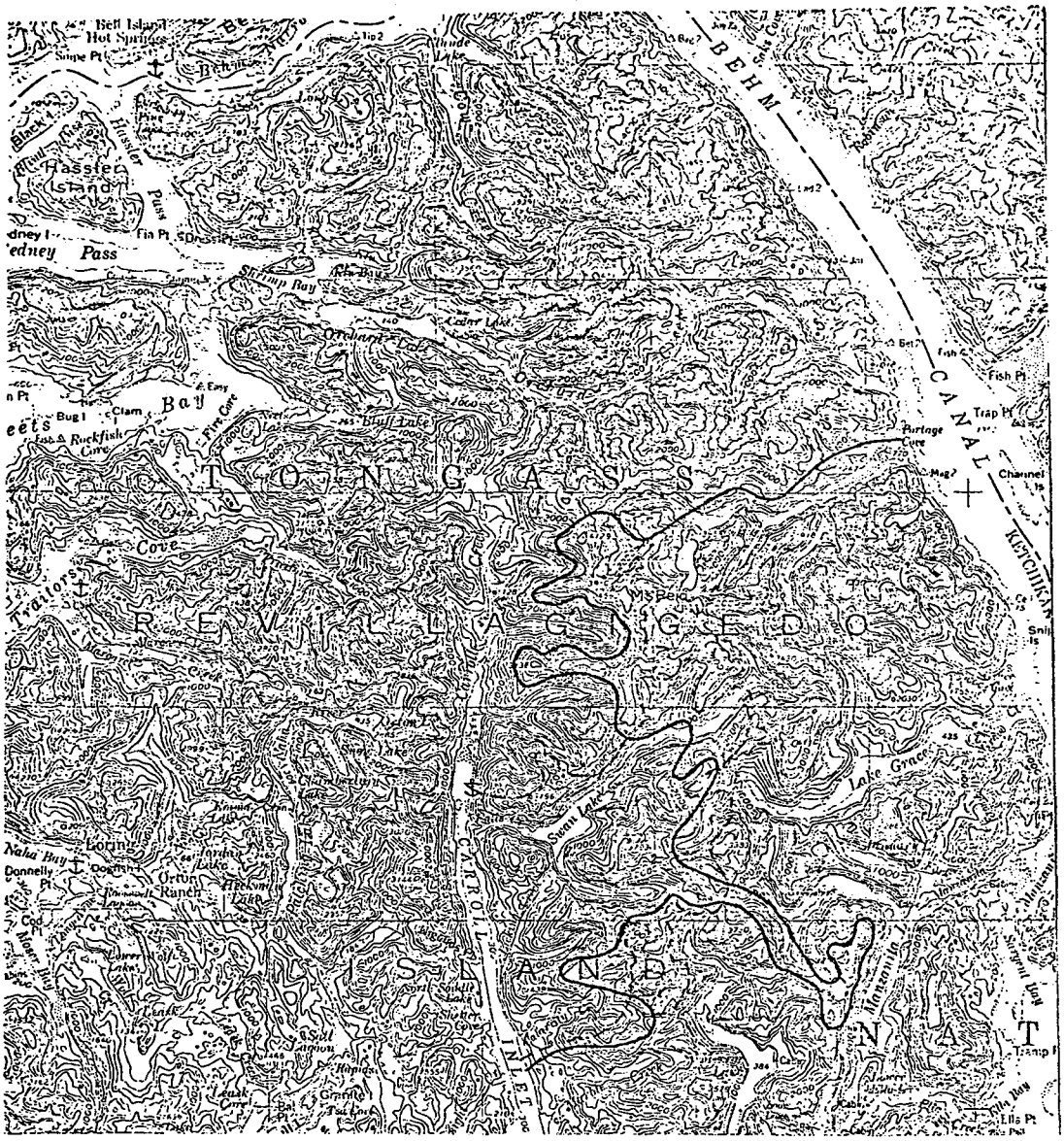


Fig. 4. Alpine deer survey flight routes, Revillagigedo Island. ~~~ = 4 August 1983; —·—·— = 28 August 1983.

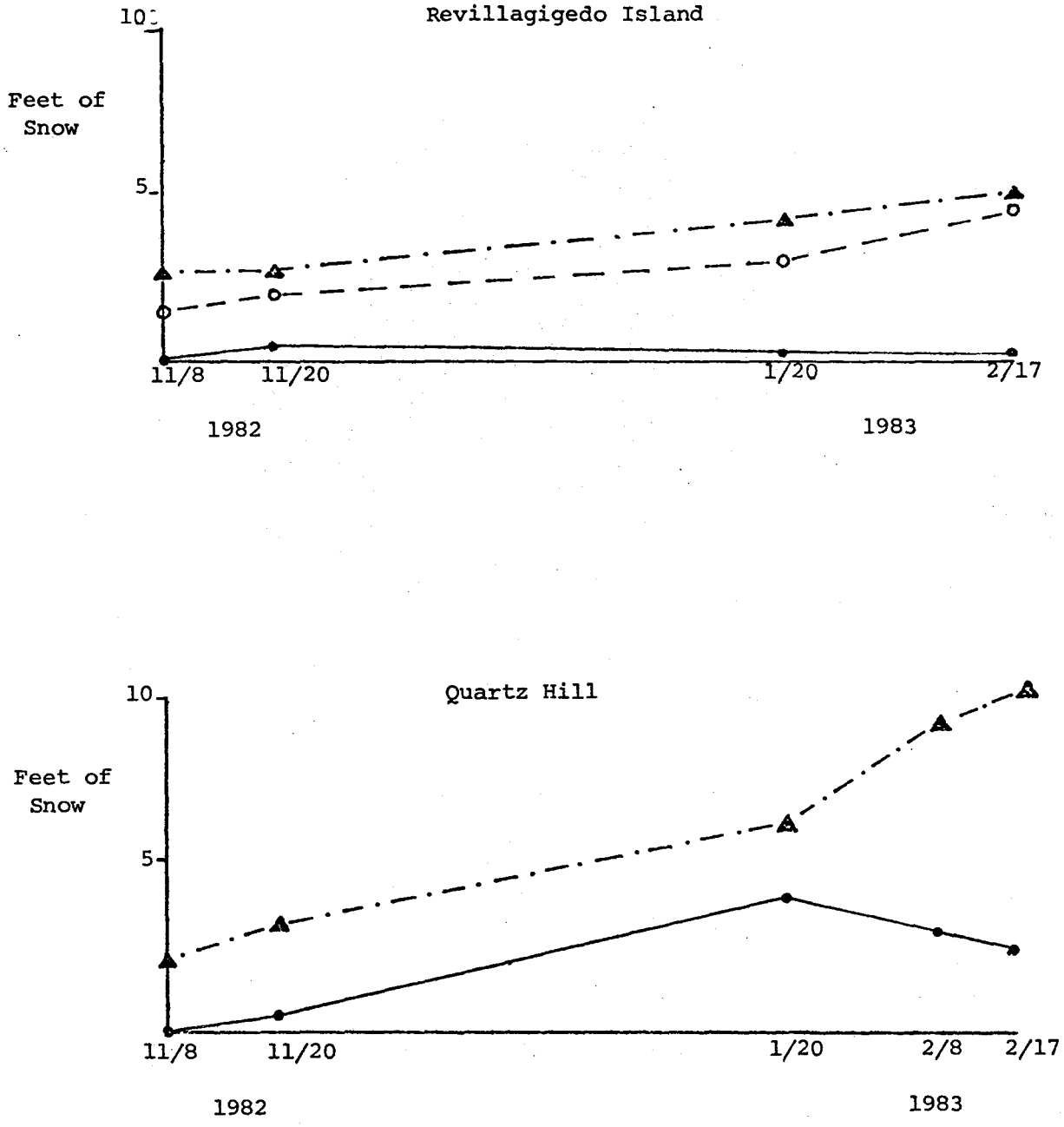


Fig. 5. Snow depth at 500 feet (•——•), 1,500 feet (o---o), and 2,500 feet (▲-.-▲) on Revillagigedo Island and Quartz Hill, 8 November 1982-17 February 1983.

Table 1. Frequency distribution (%) of habitat characteristics on Revilla Island and the Upper Cleveland Peninsula (UCP) based on point sampling of topographic and timber type maps, summer 1982.

Area	Habitat characteristic								
	Elevation in feet (thousands)								
	0-0.5	0.6-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	>4.0
Revilla	13.3	18.4	17.9	17.5	14.8	10.7	5.7	1.7	0.1
UCP	13.9	14.9	19.7	16.3	16.0	11.9	5.1	1.8	0.3

	Aspect						
	Flat	North	NE & NW	E & W	SE & SW	South	Ridge top
Revilla	5.8	12.6	21.0	24.6	21.8	14.2	0.1
UCP	14.0	6.4	19.8	20.6	17.6	9.8	1.8

	Slope (degrees)							
	0-15	16-20	21-25	26-30	31-37	38-50	51-65	66-90
Revilla	14.9	11.5	8.2	15.6	19.2	26.3	4.3	0.1
UCP	29.7	4.7	8.5	21.7	17.2	11.3	5.3	1.6

	Distance to cliffs (mi)							
	0.00	0.25	.25-.50	.51-.75	.76-1.00	1.01-1.25	1.26-1.50	1.50-2.25
Revilla	4.4	42.1	32.9	12.7	2.1	0.6	0.1	0.0
UCP	6.9	49.6	20.0	9.4	3.3	2.0	2.0	0.5

Table 1. Continued.

Area	Vegetation type: Old-growth forest	Cliff/slide forest	Muskeg and muskeg forest	Subalpine forest	Brush	Alpine	Rock and cliff	Other
Revilla	34.0	7.0	9.1	26.7	5.4	9.2	5.8	2.8
UCP	32.4	5.7	11.3	20.4	2.7	5.8	14.8	7.0

	Timber volume (board feet/acre): None	8,000	8-20,000	20-30,000	30-50,000
Revilla	24.1	42.6	11.0	19.6	2.7
UCP	30.3	36.9	16.6	14.7	1.4

Table 2. Results of 0.1 m^2 micro-plot sampling for canopy cover of herb-subshrub layer plants on Revilla Island and Quartz Hill, summer 1982.

Plant species	Alpine meadows		Alpine heath		Alpine ridge	Open subalpine forest		Closed subalpine forest	
	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
Arnica latifolia	10/Tr[a]								
Athyrium filix-femina	5/Tr							24/2.6	
Blechnum spicant	3/Tr					20/2.2	2/Tr	18/2.4	
Caltha biflora									7/1.7
Carex spp.	85/17.8	47/11.0	26/3.3	24/3.9	80/15.7		3/1.4		Tr/Tr
Cassiope mertensiana	12/2.0	41/11.7	99/74.1	88/33.5	48/10.6		36/2.6		29/10.7
Cassiope stelleriana		36/3.2	96/13.9	87/18.1	30/1.5		27/Tr		10/Tr
Castilleja parviflora	7/Tr								
Chamaecyparis nootkatensis			1/Tr		2/Tr		Tr/Tr		
Cladonia spp.		34/9.1	28/1.2	62/18.9	88/13.6	14/1.2	4/Tr		2/Tr
Cladothamnus pyrolaeflorus	10/2.8					6/2.1	19/6.1		15/5.0
Compositae spp.	27/2.4		14/1.0		26/Tr	34/1.1		2/Tr	
Coptis aspleniifolia						14/1.8	21/Tr	58/7.0	
Cornus canadensis						14/2.8	50/3.0	16/2.3	14/2.0
Dryopteris dilatata									15/2.2
Empetrum nigrum		22/1.9			22/2.8		3/Tr		
Epilobium hornemannii	11/2.2		1/Tr						
Erigeron sp.	18/2.4	7/Tr							
Eriophorum angustifolium		12/4.4							
Fauria crista-galli	94/68.5	62/11.8	44/5.1	27/1.2	66/19.4	50/25.0	52/11.6		18/2.1
Galium sp.		5/Tr		5/Tr					2/Tr

Table 2. Continued.

Plant species	Alpine meadows		Alpine heath		Alpine ridge	Open subalpine forest		Closed subalpine forest	
	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
Gentiana douglasiana								Tr/Tr	
Geum calthifolium	20/2.6	22/1.1			30/1.3				
Grasses	12/1.0	8/Tr	52/1.9		38/2.2	8/Tr			1/Tr
Kalmia polifolia							7/Tr		
Leptarrhena pyrolifolia	1/Tr								
Listera cordata						6/Tr	4/Tr	22/1.6	1.3/Tr
Lobaria spp.	2/Tr		9/Tr	2/Tr		16/3.1	11/Tr	86/21.0	12/Tr
Loiseleura procumbens					48/4.6				
Luetkea pectinata	18/4.2	24/1.5	92/19.0	63/5.9	28/2.0				17/2.0
Lupinus nootkatensis	3/Tr			20/1.4					Tr/Tr
Lysichiton americanum							Tr/Tr		
Menziesia ferruginea						12/3.2	29/7.9	10/2.9	10/3.0
Mosses	12/1.8	58/17.8	33/5.3	48/5.2	88/26.3	98/52.6	79/32.3	100/30.4	59/24.9
Echinopanax horridum									5/1.9
Pedicularis ornithorhyncha	24/1.1		5/Tr	3/Tr	12/Tr				
Phyllodoce aleutica	6/1.5	10/Tr	5/Tr	29/3.5	6/Tr		33/3.7		14/2.3
Pinguicula vulgaris	2/Tr								
Platanthera dilatata	9/Tr								
Polypodium vulgare							23/3.0		1.3/Tr
Pyrola spp.							2/Tr		
Ribes laxiflorum									Tr/Tr
Rubus pedatus						90/15.0	47/2.0	96/15.6	43/4.1
Rubus spectabilis									Tr/Tr
Sanguisorba sp.	12/2.2								
Saxifraga tolmiei		10/1.5		3/Tr					
Senecio triangularis	3/Tr								

Table 2. Continued.

Plant species	Alpine meadows		Alpine heath		Alpine ridge	Open subalpine forest		Closed subalpine forest	
	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
Sorbus sitchensis	1/Tr						1.4/Tr		
Streptopus spp.		5/Tr				58/10.2	Tr/Tr	34/3.1	12/1.7
Thuja plicata							8/1.9		
Tiarella unifoliata									3/Tr
Tofieldia glutinosa	1/Tr								
Trientalis europaea		4/Tr							
Tsuga mertensiana		2/Tr	24/4.3		14/2.5	28/11.9		28/1.5	6/1.3
Vaccinium alaskensis/ ovalifolium	8/1.3		5/Tr			92/49.8	69/24.7	76/24.4	51/19.5
Vaccinium caespitosum		17/2.6		11/2.3	28/2.9		25/5.0	34/1.1	6.0/Tr
Vaccinium uliginosum		18/4.1			14/4.2				
Vaccinium vitis-idaea									7/Tr
Valeriana sitchensis	41/8.3								
Veratrum viride	5/1.2					8/2.6			2/Tr
Unknown spp.	4/Tr				14/1.2				
No. of plots sampled	100	100	100	100	50	50	150	50	150
No. of species with 25/x.x	3	4	6	5	10	6	9	5	3
No. of species with x.x/20.0	1	0	1	1	0	2	1	1	0
Total no. of species by area	28	18	13	11	17	14	23	13	27
Total no. of species for both areas	38		17		N/A	27		32	
% floral species overlap	21		41		N/A	37		25	

Table 2. Continued.

Plant species	Alpine meadows		Alpine heath		Alpine ridge	Open subalpine forest		Closed subalpine forest	
	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
No. of species with 25/x.x	6		7		N/A	12		7	
% overlap of Species with 25/x.x	30		57		N/A	25		29	
No. of species with x.x/20.0	1		1		N/A	2		1	
% overlap of species with x.x/20.0	0		100		N/A	50		0	

[a] % frequency of occurrence/% ground canopy; Tr <1.0%.

Table 3. Overstory composition of open canopy subalpine sample plots, summer 1982.

Plant species	Average % canopy closure[a]		Average no. seedlings/ha		Average no. saplings/ha		Average no. trees/ha and (MBF/ha)	
	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
Chamaecyparis nootkatensis			1,320	2,347	400	3,653	360(19)	133(4)
Tsuga spp.			1,120	320	480	453	520(72)	293(14)
Picea sitchensis			200	0	120	0	0(0)	0(0)
Totals	33	25	2,640	2,667	1,000	4,106	880(92)	426(17)

[a] Canopy closure not determined for individual species.

Table 4. Overstory composition of closed canopy subalpine sample plots, summer 1982.

Plant species	Average % canopy closure[a]		Average no. seedlings/ha		Average no. saplings/ha		Average no. trees/ha and (MBF/ha)	
	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
Chamaecyparis nootkatensis			0	0	0	0	200(100)	0(0)
Tsuga spp.			520	4,613	0	187	520(139)	1,147(76)
Picea sitchensis			0	0	0	0	40(29)	0(0)
Totals	73	69	520	4,613	0	187	760(268)	1,147(76)

[a] Canopy closure not determined for individual species.

Table 5. Mean density, stem diameter at ground level, and estimated twig and leaf biomass of selected shrub species in subalpine forests on Revilla Island and Quartz Hill, summer 1982.

Habitat type	Shrub species	Stem density		Stem diameter		Forage biomass (kg/ha[a])	
		Revilla Island	Quartz Hill	Revilla Island	Quartz Hill	Revilla Island	Quartz Hill
Open subalpine forest	*Vaccinium* spp.	87.4(6.7)[b]	23.9(1.6)	5.2(0.3)	8.3(0.5)	157.9	107.6
	Menziesia sp.	3.4(0.9)	7.5(1.8)	[c]	11.5(0.8)	[c]	104.7
	Total					[c]	212.3
Closed subalpine forest	*Vaccinium* spp.	46.0(6.0)	33.0(4.2)	4.2(1.0)	5.7(0.3)	55.3	71.2
	Menziesia sp.	2.3(0.6)	2.6(1.0)	[c]	9.1(1.7)	[c]	20.8
	Total					[c]	92.0

[a] Based on regression formulas in Alaback (1980).
[b] Mean (SE).
[c] *Menziesia* stems were not located within micro-plots and hence were not measured. Biomass cannot be estimated without mean stem diameter values.

Table 6. Comparison of habitat characteristics at winter deer and goat relocations.

Habitat characteristic	Species	
	Deer[a]	Goat[b]
Mean elevation of relocations (ft)	188	2,003
Mean slope at relocations (°)	8	39
% use of smooth terrain	99	5

[a] Schoen et al. 1979.
[b] Smith 1983.