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# Effects of Grazing on the Northern Population of *Pinus muricata* on Santa Cruz Island, California

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## INTRODUCTION

The effects of grazing on the vegetation of Santa Cruz Island have been apparent since 1875 (Wheeler 1876), only 22 years after the earliest documented introduction of sheep to the island (Shaw 1857). Although grazing damage has been mentioned in the literature since that time (Dunkle 1950, Linhart, Burr, and Conkle 1967), it is difficult to determine the extent or degree of damage from these descriptions.

Of the three main populations of *Pinus muricata* on Santa Cruz Island (Fig. 1), the western (Cañada Cervada) and eastern (Chinese Harbor) populations have been protected from grazing since about 1958 (C. Stanton, pers. comm.). The northern (Pelican Bay) population, however, has been subjected to continuous grazing pressure which, combined with the effects of an extensive fire that occurred sometime between 1929 and 1932 (C. Stanton and M. Daily, pers. comm.), has had a dramatic effect on the pines and associated species.

## METHODS

Study areas were defined for each of the three pine populations on the island (Figs. 2 to 4). The sizes of the northern and western study areas were approximately equal (120 hectares) and each contained 14 systematically placed 25 m × 25 m sample sites. The eastern study area was much smaller (30 hectares) due to the much less extensive pine population in that area. Only four 25 m × 25 m sites were sampled in this study area. The proportion of the area sampled to the total study area was held constant for all three populations.

The vegetation of the sites was sampled by line transects to measure foliar cover of pines and other woody species; percentage cover for each site was estimated. Since overlapping individuals of different species were measured separately, it is possible to have greater than 100 per cent foliar cover. However, it should be noted that overlapping individuals of the same species were measured as one individual, so that some dominant species may be underestimated in relation to the rarer species.

Height was estimated visually; diameter at breast height (dbh) was measured for each pine intercepted by a line transect. Increment cores were taken from trees in several different size classes within each population. These data allowed estimation of the age structures of the three populations. In addition, seedling censuses were taken within the sample sites in each population to assess the regeneration potential of each population under present conditions. Seedlings were defined as any trees less than 3 m high.

## RESULTS

### Comparison of Populations

For the purposes of this study, it was assumed that the vegetation of the three closed-cone pine forests on the island was similar prior to disturbance and that gross differences could be attributed to disturbance, particularly grazing. However, the following environmental differences among the three populations should be noted as possibly sufficient to account for some differences in species composition and vegetation density.

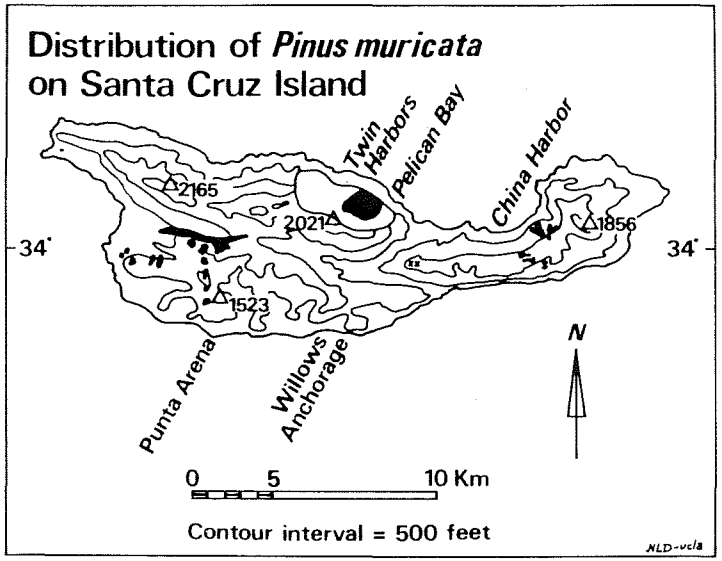


**FIGURE 1.** *Map of Santa Cruz Island showing distribution of Bishop Pines.*

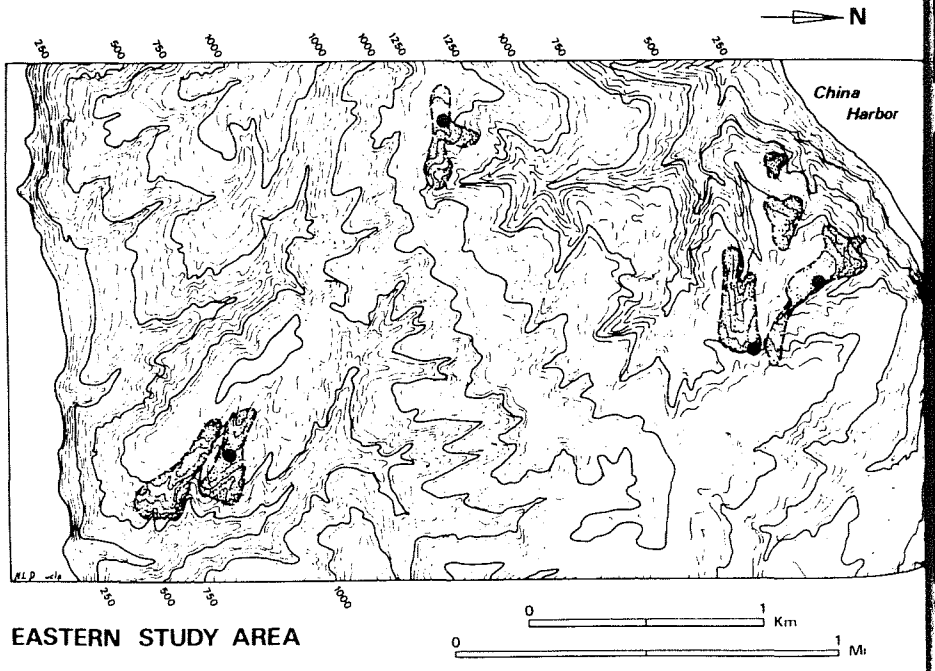


**FIGURE 2.** *Map of eastern study area showing location of sample sites.*



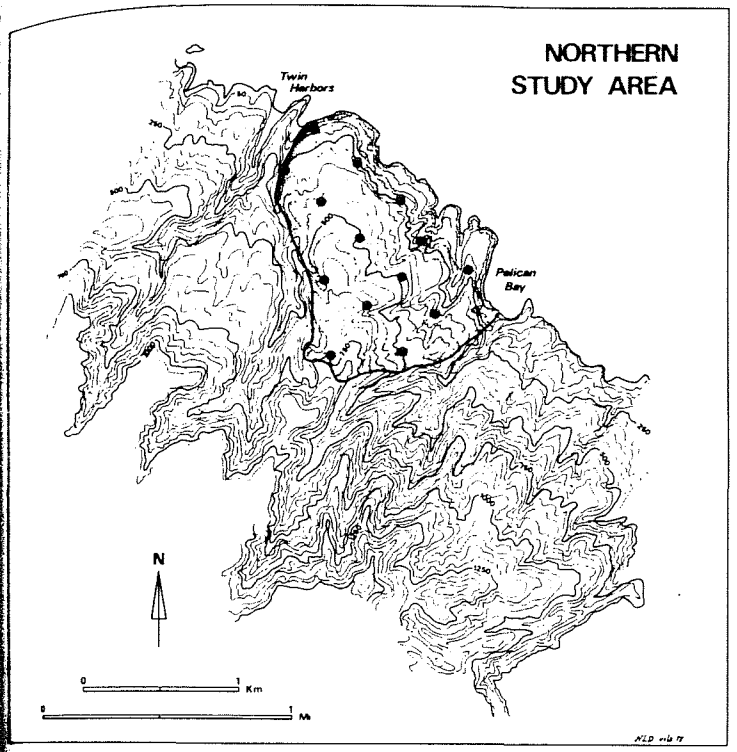


**FIGURE 3.** *Map of northern study area showing location of sample sites.*

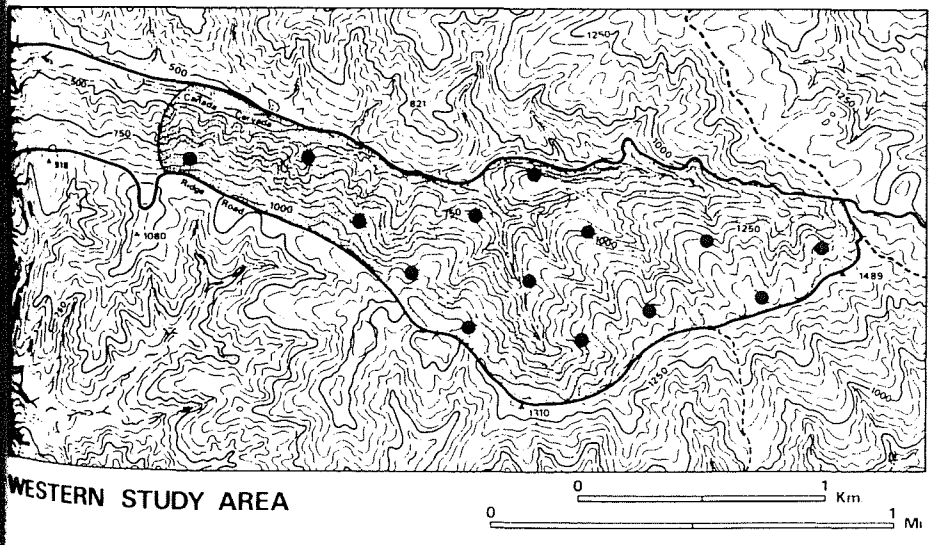


**FIGURE 4.** *Map of western study area showing location of sample sites.*

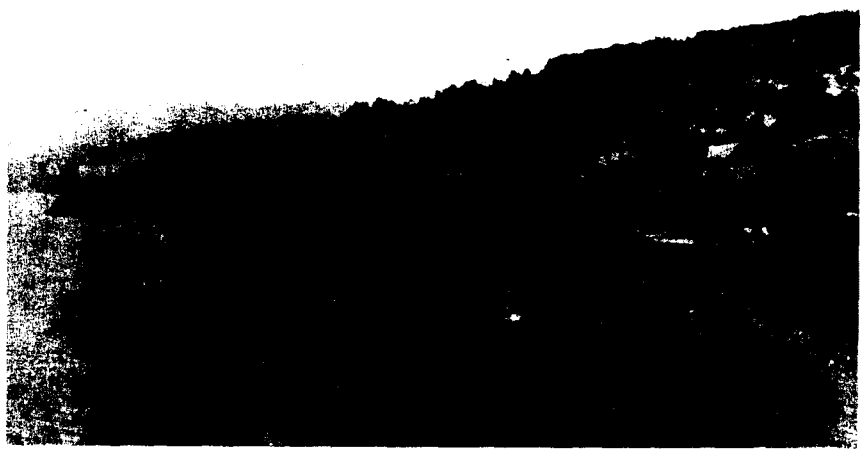

**FIGURE 5.** *View of Pelican Bay,* ca. *1929.*

Each of the three populations is on a different geologic substrate: the northern population is on soil derived from weathered basalt; the western population on soils derived from granitic parent materials; and the eastern population on sandy soils from a diatomaceous parent material (Linhart, Burr, and Conkle 1967). Although the soils of Santa Cruz Island have not been studied and no information is available, differences in water-holding capabilities of the soils could affect the density of the pines and the composition of associated vegetation as they do elsewhere (Cole 1974). Distance from the coast and exposure to wind could account for certain differences between the western (interior) population and the other two (coastal) populations. The northern population, which occurs primarily at elevations lower than the western and eastern populations, may also be unable to capture as much moisture from fog.

The presence, however, of a large number of dead pines and shrubs on the north side of the island attests to the potential of this area to support a greater living biomass than currently exists. Photographs taken in 1929 also give evidence of the formerly greater density of the northern population (Figs. 5 and 6). In contrast, the other two populations do not exhibit a reduction in density between 1929 and the present. Thus, it seems justifiable to assume that disturbance has been a major factor in causing or accentuating differences between the heavily grazed northern and the two protected populations.

### Reduced Foliar Cover

Sheep grazing alone must not have been responsible for the degree of reduction in foliar cover observed on the north side of the island. Fire scars are still apparent over extensive areas as evidence of the Pelican Bay fire more than 45 years ago. Fire is capable of destroying more vegetation in a short amount of time than sheep could. However, the plant species affected should be fire-adapted and, in the absence of disturbance, full regeneration of the vegetation should have occurred in the time that has elapsed.

The northern population is presently well below both the western and eastern populations in both total foliar cover and foliar cover of each individual species (Table 1). Low values for foliar cover of shrub species were especially apparent in the northern population. The most abundant



**FIGURE 6.** *View of Pelican Bay, 1977.*

shrub species, *Heteromeles arbutifolia, Quercus dumosa,* and *Arctostaphylos tomentosa,* each covered only 1 per cent of the total area sampled there.

Even the most densely vegetated sites in the northern population were in the range of the sparsest sites of the other two populations. The greatest foliar cover measured for one 25 m × 25 m site in the northern population was 65 per cent. The most sparsely vegetated sites of the western and eastern populations were 60 per cent and 57 per cent, respectively. Foliar cover of sites in the western and eastern populations was estimated as high as 160 per cent and 138 per cent, respectively, for single sample sites.

### Species Richness

The elimination of some species from portions of Santa Cruz and other California Islands has been referred to in the literature (Dunkle 1950, Thorne 1969). It appears that grazing has significantly reduced the species richness of the northern population. A total of 12 woody species was encountered on study sites within the northern population, as opposed to 28 in the western study area and 11 in the much smaller eastern study area (Table 1). The northern population had from 1 to 5 (average 2.4) species per sample site, while the western population had 7 to 14 (average 9.2) and the eastern population had 4 to 9 (average 7.0).

Many of the species missing from the northern population are subligneous shrubs typical of the coastal sage community. This raises the question of whether these plants might be more susceptible to grazing damage than the chaparral species. Wheeler (1876) describes sheep grazing on the "sagebrush." However, there is nothing in the description to indicate specifically to what plant or group of plants he was referring.

In addition to species that seem to be missing from the northern population due to disturbance, several species were observed in the northern study area which are absent or are found only in disturbed areas within the other two populations. These are *Opuntia littoralis, Pickerin-*

**TABLE 1.** Percentage of foliar cover of woody species by population.

| | Northern | Western | Eastern |
|---|---|---|---|
| *Adenostoma fasciculatum* | 0.1 | 0.5 | 0.1 |
| *Arctostaphylos insularis* | - | 0.5 | - |
| *Arctostaphylos tomentosa* | 1.0 | 4.7 | 14.9 |
| *Artemisia californica* | - | 0.3 | - |
| *Baccharis pilularis* | - | 0.3 | - |
| *Ceanothus arboreus* | - | 0.1 | - |
| *Ceanothus megacarpus* | - | 0.7 | - |
| *Comarostaphylis diversifolia* | 0.1 | 13.3 | 0.8 |
| *Coreopsis gigantea* | - | 0.1 | - |
| *Eriogonum arborescens* | - | 0.1 | - |
| *Eriogonum grande* | - | 2.3 | - |
| *Galium nuttallii* | - | - | 0.4 |
| *Haplopappus squarrosus* | - | 0.1 | - |
| *Haplopappus venetus* | - | 0.1 | 0.2 |
| *Heteromeles arbutifolia* | 1.2 | 11.6 | - |
| *Lotus scoparius* | - | 0.1 | - |
| *Lyonothamnus floribundus* | 2.7 | - | - |
| *Mimulus* spp. | 0.1 | 0.8 | 3.4 |
| *Opuntia littoralis* | 0.1 | - | - |
| *Pinus muricata* | 20.6 | 57.7 | 37.9 |
| *Quercus agrifolia* | 0.1 | 0.1 | - |
| *Quercus agrifolia* x *wislizenii* | - | 0.1 | - |
| *Quercus dumosa* | 1.2 | 12.1 | 23.6 |
| *Quercus tomentella* | - | 1.5 | - |
| *Quercus dumosa* x *wislizenii* | - | - | 1.6 |
| *Quercus wislizenii* | 0.7 | 2.8 | 4.8 |
| *Rhus diversiloba* | - | 0.1 | - |
| *Rhus integrifolia* | 0.1 | 0.9 | 0.1 |
| *Rhus ovata* | - | 0.1 | - |
| *Ribes menziesii* | - | 0.4 | - |
| *Salvia mellifera* | - | 0.9 | - |
| *Vaccinium ovatum* | - | 3.4 | - |
| Total percentage foliar cover | 30.5 | 114.6 | 85.0 |
| Meters transected | 700 | 700 | 200 |
| Total number species | 12 | 28 | 11 |

*gia montana*, and *Eremocarpus setigerus*. All of these seem to be favored within the northern pine population because of their spines or other defenses against grazing.

### Regeneration

The most disturbing effect has been the creation of a senescent population of pines and possibly of associated shrubs due to the prevention of regeneration by the sheep. The western and eastern populations both had a wide range of tree sizes from small seedlings through trees of about 45 cm dbh. The western population had an average of 8.8 seedlings per site, with a maximum of 39. The eastern population had an average of 6.0 seedlings per site, with a maximum of 19. The northern population, on the other hand, had no seedlings on any of the study sites and no trees with a dbh smaller than 7.8 cm or a height less than 4 m. Increment cores taken from trees in each population showed that the majority of trees in the western population are less than 30 years of age. In the eastern population, most trees are about 20 to 40 years old. In the northern population, most trees are 40 to 70 years old. The youngest tree cored in the northern population was estimated to be about 30 years of age. This was not the smallest tree measured; a rough estimate of the age of the smallest tree encountered would be 15 to 25 years.

Trees in the northern population still produce abundant cones. Moreover, presence of viable seed and appropriate conditions for germination were attested to by two seedlings, each about 5 cm high. One of these was within the northern study area, near the coast west of Pelican Bay. The other was southeast of the study area, about halfway between Pelican Bay and Prisoners Harbor. These were the only seedlings observed on the northern side of the island, and it seemed that they would soon be eliminated when they became conspicuous enough to be noticed by the sheep. Moreover, the fact that abundant regeneration was recorded in the other two populations dismisses the question of whether fire is a necessary agent for opening the cones and distributing seeds.



## CONCLUSION

The existing pines in the northern population continue to succumb to age and disease. The other woody species in the area show evidence of their relatively great age by their large sizes and arborescent forms. Most shrubs and pines on the north side of Santa Cruz Island show a distinct browse line. No significant regeneration of shrub species was observed. The foliar cover and species richness of the northern forest has already been greatly reduced. The lack of successful regeneration under present conditions of disturbance implies a limited future for this population of pines.

## ACKNOWLEDGMENTS

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