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Response of a Bishop Pine (*Pinus muricata*) Population to Removal of Feral Sheep on Santa Cruz Island, California

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Abstract. A Bishop pine (*Pinus muricata*) population was sampled on the northern shore of Santa Cruz Island 4 yr after the removal of feral sheep (*Ovis aires*) from the area. I measured foliar cover of woody perennials, and recorded new establishment of woody perennials. I compared my results to those obtained by a previous study in 1977–1978 and an aerial photograph from 1985, when sheep were still present in the area. More woody perennial species were recorded in 1990 than in 1978. Newly established woody perennials were abundant in 1990, whereas few if any were recorded in 1978. The age structure of the pines changed from senescent to having successful seedling germination and survival. Bishop pine more than doubled in extent between 1985 and 1990. Re-establishment of native woody perennials in this area, including Bishop pine, coincided with the removal of feral sheep.

Keywords: Santa Cruz Island; feral sheep (*Ovis aires*), Bishop pine (*Pinus muricata*).

Introduction

Domestic sheep (*Ovis aires*) have been present on Santa Cruz Island for close to 150 yr (Brumbaugh 1983). Their detrimental effect upon the native vegetation of the island has been noted for almost as long (Rothrock 1876). Despite this, active sheep ranching took place until the late 1930s (Stanton and Daily 1989), and feral sheep were not eliminated from much of the island until the mid 1980s (Schuyler 1993). The purpose of this study was to measure the effect that the removal of feral sheep had upon a Bishop pine (*Pinus muricata*) population on the northern shore of Santa Cruz Island.

Study Area

Santa Cruz Island, the largest of the California Channel Islands at approximately 250 sq km, lies at 34°N, 119° 45' W, approximately 40 km south of the city of Santa Barbara (Fig. 1). It is 39 km long, and ranges in width from 3 to 11 km. The island is aligned along an east-west axis, and is bisected by a central valley created by the Santa Cruz Island fault. This valley separates the northern and southern mountain ranges. The northern side of the island is more rugged, with a maximum elevation of approximately 750 m. The southern range is lower, with a maximum elevation of 465 m. Santa Cruz Island is geologically complex, being composed of plutonic, volcanic, metamorphic, and sedimentary parent material (Weaver et al. 1969).

The island has a Mediterranean climate, marked by warm dry summers, and cool rainy winters (Brumbaugh 1983). Rainfall measured at the main ranch in the central valley averaged 506 mm per year between 1904 and 1990 (Main Ranch, unpubl. data). Most precipitation falls between October and March. Mean temperatures for the central valley range from 12° C in the winter to 21° C in summer (Brumbaugh 1983). Roughly 90% of the island is owned by The Nature Conservancy (TNC), while the eastern 10% of the island is controlled by the Gherini family.

There are 3 primary populations of Bishop pine on Santa Cruz Island (Fig. 2): (1) the western population, located on the north-facing slopes of Cañada Christy and Cañada de los Sauces; (2) the northern population with most of the trees found between Pelican Bay and Twin Harbors; and (3) the eastern population, which consists of scattered groves above China Harbor on the eastern isthmus of the island.

The study area is located between Pelican Bay and Twin harbors, amidst the greatest concentration of Bishop pines within the northern population. This is the only area where the pines approach sea level. The site is approximately 160 ha in size, and ranges in elevation from sea level to 230 m. The area is primarily open, with scattered groves of mature pine. Other common woody perennials are coast live oak (*Quercus agrifolia*), scrub oak (*Q.* aff. *dumosa*), manzanita (*Arctostaphylos* sp.), summer holly (*Comarostaphylis diversifolia*), toyon (*Heteromeles*

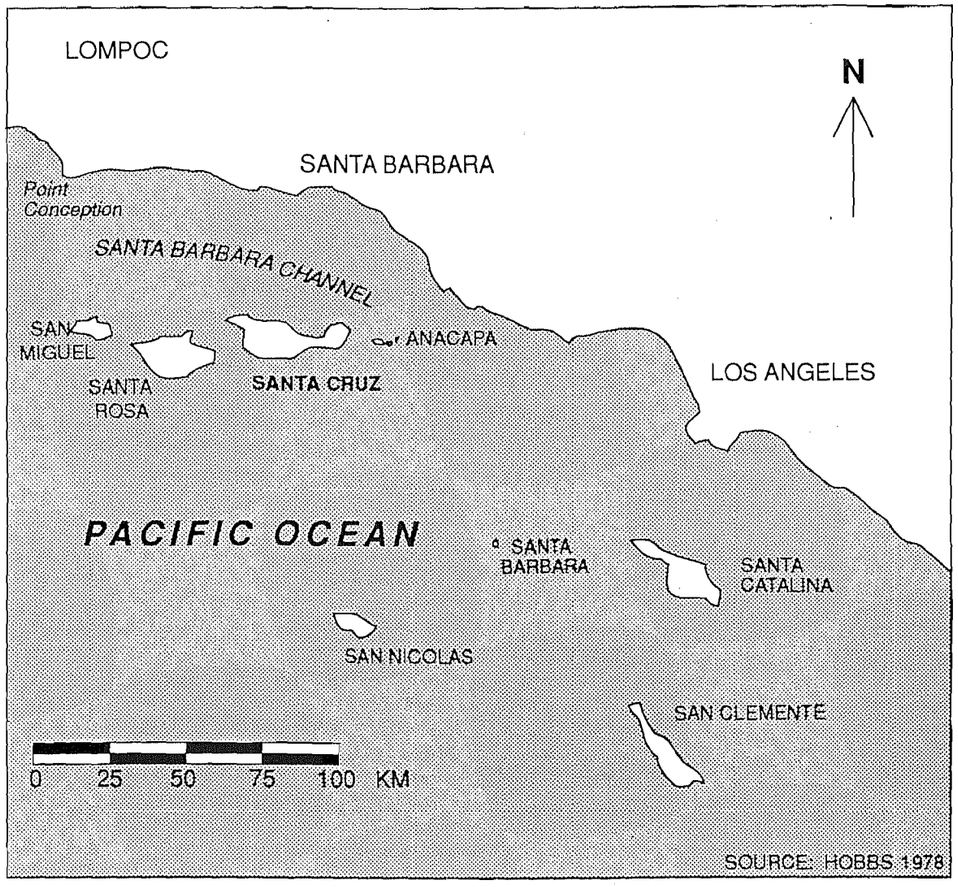

Figure 1: The California Channel Islands.

arbutifolia), and island ironwood (*Lyonothamnus floribundus* subsps. *asplenifolius*). Most of the site, however, is bare or covered with grass, predominantly nonnative wild oats (*Avena barbata*) with some native *Stipa* species.

Grazing history

Sheep were probably introduced onto Santa Cruz Island in the early 1850s. By 1860, 15,000 sheep were present, and 10 yr later the herd numbered 45,000 (Brumbaugh 1983). In 1875, Rothrock (1876) estimated the population at 60,000, of which 15,000 were killed that summer for hides and tallow. He also considered the island to be severely overgrazed, noting that:

> we now have abundant signs of forests that have disappeared at the sea-level, where their stumps and roots still remain *in situ*. On the grounds most visited by the herds of sheep, all vegetation, save sage-brush, *cactees* [sic], and the erodium . . . have been entirely swept away. Even the sage-brush was disappearing . . . (Rothrock 1876).

The sheep population stayed at this level for 20 yr before being reduced in numbers, and by the 1920s was estimated at 20,000 (McElrath 1967). When most of Santa Cruz Island was converted to a cattle ranch in 1939 (Stanton and Daily 1989), those sheep that were not rounded up and sent to the mainland at this time were left on their own.

During the mid 1950s, in order to improve grazing for cattle, the better pastures were fenced and the sheep within them shot or shipped to the mainland (Brumbaugh 1983). By the late 1950s, most remaining sheep were limited to the area north and south of the central valley in the more rugged and inaccessible portions of the island. Once

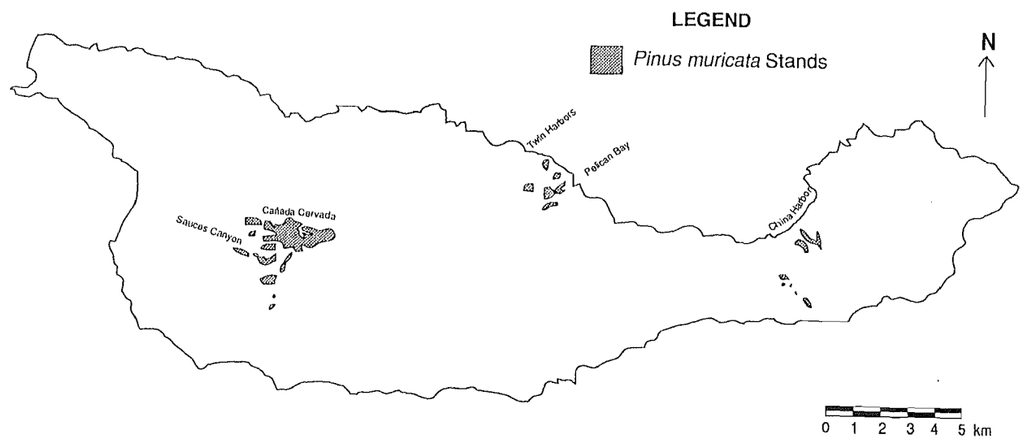

Figure 2: Extent of Bishop pine on Santa Cruz Island.

the sheep had been cleared from the cattle pastures, sheep control efforts were relaxed, with limited recreational hunting of the sheep taking place in the northern pastures (Van Vuren and Coblentz 1989).

When TNC acquired an interest in the island in 1978, the sheep population on their portion of the property was estimated at approximately 21,000 (Van Vuren and Coblentz 1989). In heavily impacted areas sheep had removed all shrub leaves within reach, and prevented any shrub regeneration. The Nature Conservancy embarked upon a sheep removal project in 1981. Within 8 yr, 37,871 sheep were killed in an ultimately successful effort to rid the TNC-owned portion of the island of feral sheep (Schuyler 1993). In 1985 hunting commenced in the area that includes the study site, and sheep numbers were drastically reduced very quickly (J. D. Sterner 1991, pers. comm.). Today, sheep are only found on the Gherini property.

Fire history

There are few historical records of fires on Santa Cruz Island. The last fire to occur in the northern pine forest was a lightning-caused fire in 1988, which burned approximately 1.4 ha (L. Laughrin 1991, pers. comm.). Prior to that, a fire believed started by a boater burned across most of the study site in the early 1930s (Hobbs 1978). I found charcoal, presumably from this fire, throughout the study site.

Previous studies

The only previous study of the northern pine population was conducted by E. Hobbs in 1977–1978 (Hobbs 1978, 1980). She established 14 systematically-located, 25-m X 25-m plots across the study site at approximately 300-m intervals. Foliar cover was measured using the line intercept method, with 2, 25-m line transects established within each plot. The interception of all woody perennials was measured to the nearest 0.1 m. Age structure of the pines was estimated by measuring the height and diameter at breast height (dbh) of every tree intercepted by the line transects. Species composition of the study area was determined in the spring of 1978 by recording all annual and perennial species present within each plot. Pine seedlings and saplings were surveyed in 1977 by censusing every plot for all pines less than 3 m in height.

Hobbs' study provides baseline data on the pine stand while sheep disturbance was still taking place. She found the northern forest to have lower foliar coverage and fewer woody species than either of the western or eastern pine population, both of which had been ungrazed by sheep for close to 20 yr at the time of her study. Nor were any pines younger than 15–25 yr of age found in the study area. She predicted that if sheep were allowed to remain, the northern pine population had a limited future (Hobbs 1980).

Methods

I mapped the occurrence of Bishop pine in the study area in 1985 using an approximately 1:7,200 color infrared (CIR) aerial photograph of the area taken on 1 July 1985. For comparison, I mapped the extent of mature pines and the occurrence of pine seedlings by surveying the site on foot in August 1990. This resulted in the designation of 3 different habitat types: (1) old pine forest (present in the 1985 photograph), (2) newly established pines (not visible in the 1985 photograph, or less than 6 yr old), and (3) non-pine area. Twenty randomly located points were sampled in each habitat type.

I chose a stratified random sampling scheme to ensure that enough sites in each of the habitat types were sampled, as well as to reduce bias in plot selection (Husch et al. 1972). This design differed from that used by Hobbs, thereby preventing detailed comparisons between the 2 studies.

I recorded foliar cover along a 25-m transect line at each sample point to obtain an estimate of forest stand structure. Vegetation along these transect lines was measured using the line intercept method. The distance that any woody perennial covered the transect line was recorded to the nearest 0.1 m. In contrast to Hobbs, overlapping individuals of the same species were recorded separately, resulting in vegetation coverage in excess of 100% in several cases.

New woody perennial growth was recorded using 20, 2.52-m radius plots per stratum. All recently established (< 12 yr old) woody perennials were recorded. The number of species of woody perennials present, the number of individuals of each species (live and dead), and the percentage of the fixed plot that each species occupied were recorded. All pine seedlings less than 4 m tall were individually measured, and their height and probable age recorded.

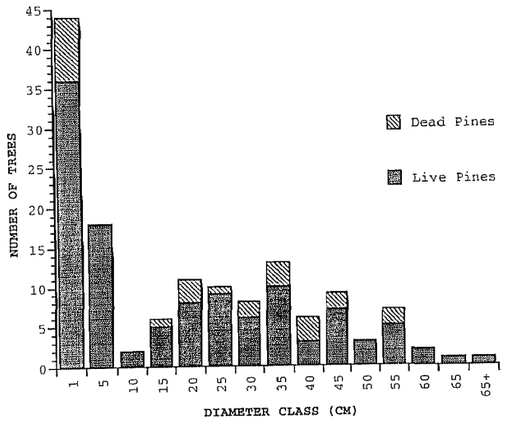

Figure 3: Diameter classes of pine trees intercepted by transect lines.

Results

Bishop pine distribution and regeneration

Bishop pine was the most common species in the study area both in terms of foliar cover and number of individuals in the fixed plots. The line transects in the 2 pine strata intercepted 141 trees, which ranged in dbh from 0 (< 1.3 m tall) to 83 cm (Fig. 3). Of these pines, 17.7% had died within the past 2 years, the majority of which were mature trees.

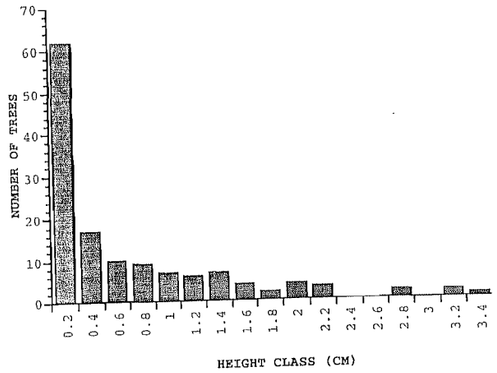

Figure 4: Height distribution of trees found on study plots.

Of the live trees intercepted, 49% had a dbh < = 5 cm. The > 30–35 cm diameter class was the second largest group. Of interest is the paucity of trees in the > 5–10 cm dbh class. Only 2 trees of this size were measured, suggesting that the seedling survival rate was very low when these trees became established. The diameter distribution of the pine population suggests a 2-aged strand structure in the study area. There is a large proportion of younger pines in the understory, with a scattered overstory of pines, most of which are older than 40 yr. The overstory pines experienced a mortality rate of 22% between 1988 and 1990.

Numerous pines were found in the fixed plots. As most of them were < 1.3 m high (the height at which dbh is measured), they were grouped by height class (Fig. 4). Approximately 57% of the pines recorded were < = 0.4 m high, indicating that most seedlings had become established within the past few years. This finding was supported by the estimated ages of these trees, which indicated that 65% were 5 yr or younger (Fig. 5). The estimated ages are generally accurate, however, any bias

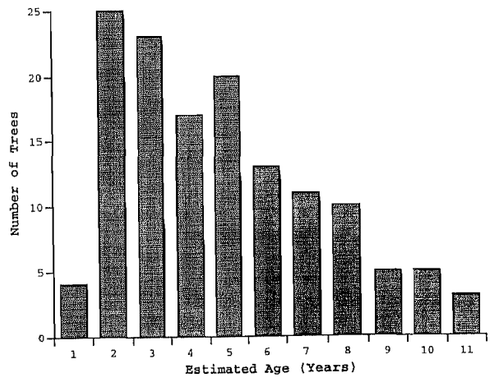

Figure 5: Estimated ages of trees found on study plots.

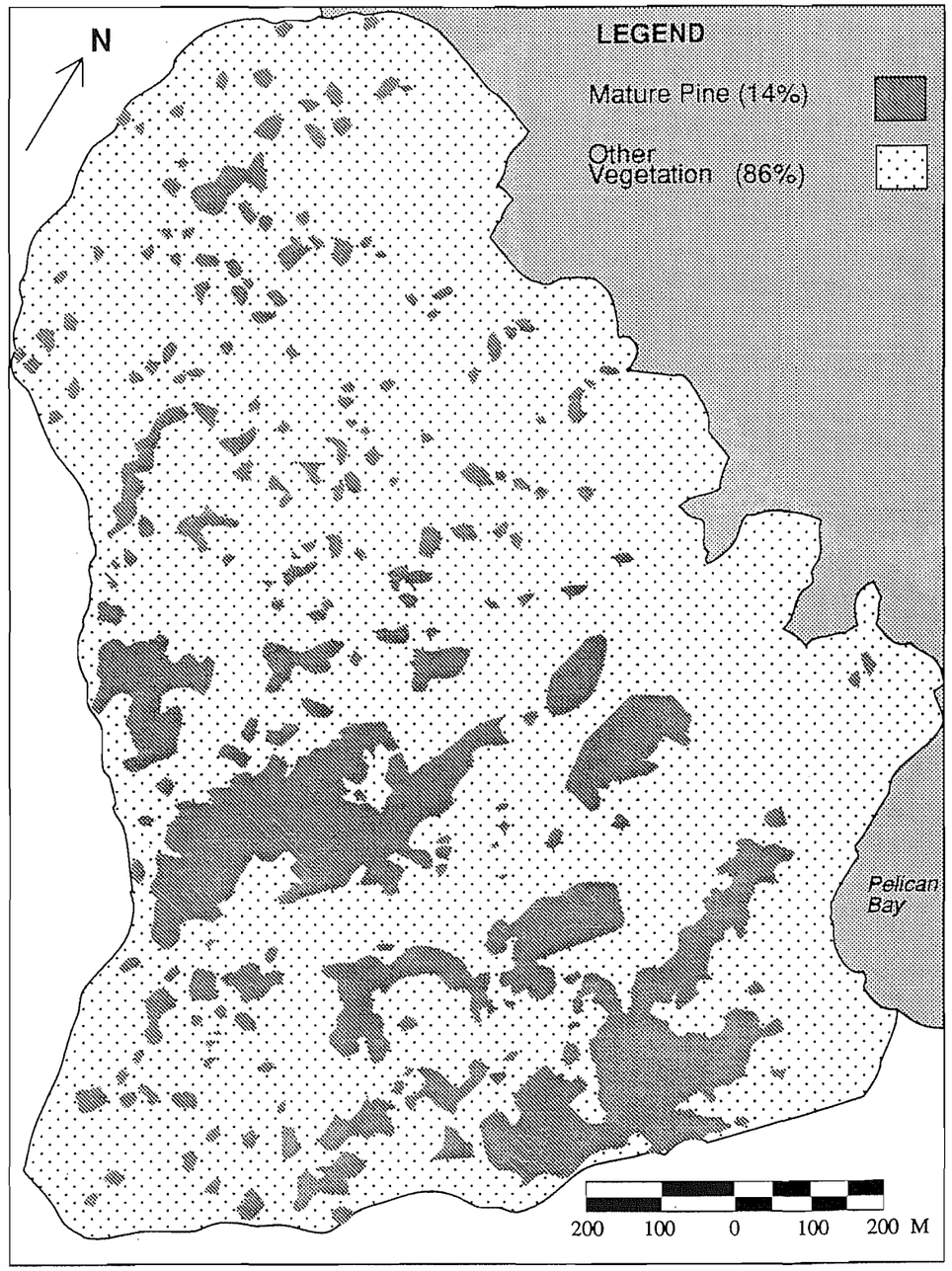

Figure 6: Distribution of Bishop pine in study area, 1985.

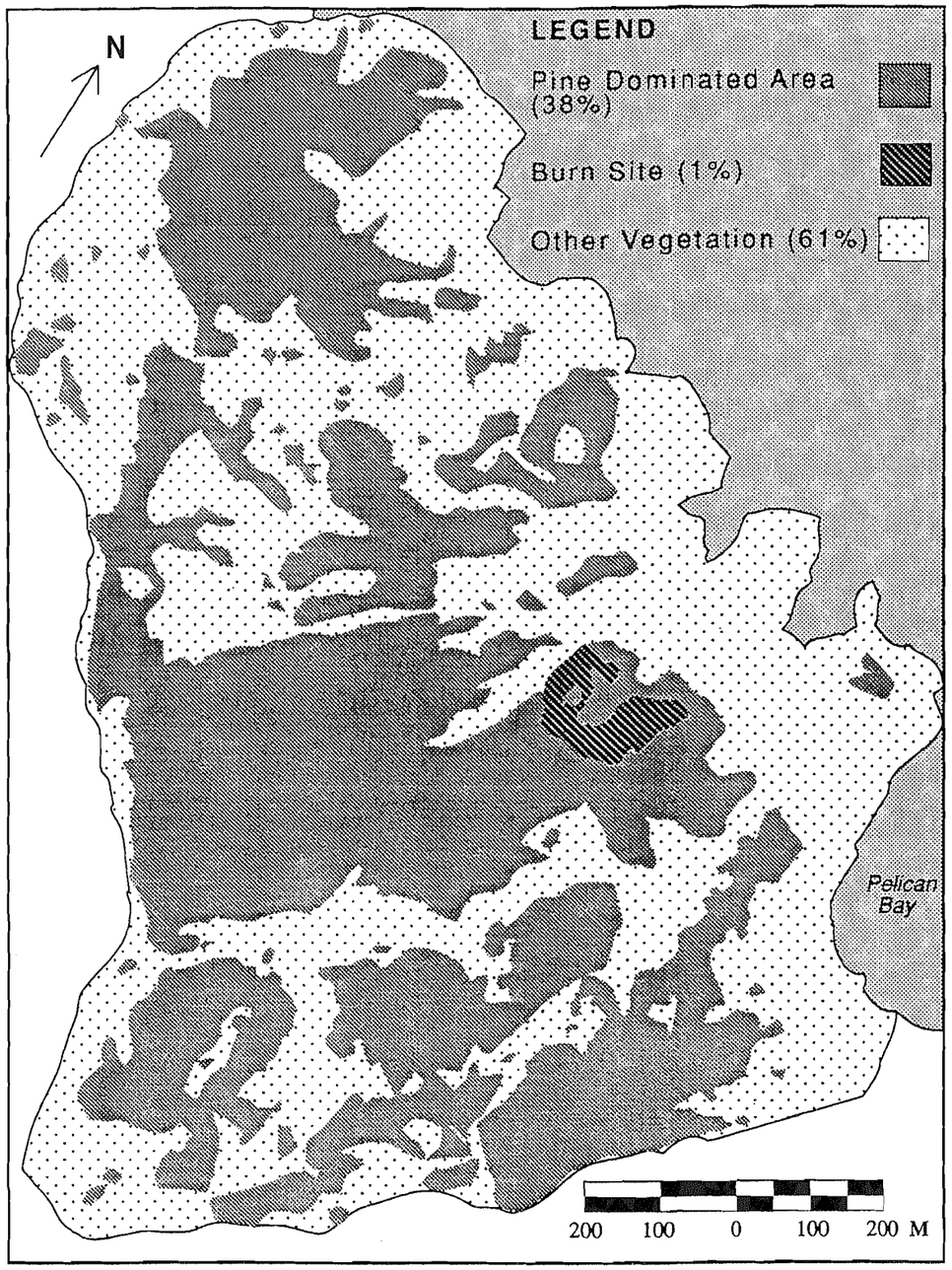

Figure 7: Distribution of Bishop pine in study area, 1990.

probably results in ages that are too high by a year or 2. Bishop pine will occasionally produce 2 whorls per growing season, thereby making exact age estimates difficult. It is interesting to note that few first-year seedlings were recorded in 1990. This was probably due to the low amount of precipitation received during the winter of 1989–1990.

The distribution of Bishop pine in the study area changed markedly between 1985 and 1990 (Figs. 6 and 7). In 1990 pines dominated close to 40% of the study site, as compared to 14% in 1985. The area burned in 1988 is being recolonized by pines and was, therefore, included in the pine-dominated area. In the 5 yr since sheep were removed, Bishop pine has successfully invaded close to 25% of the study area. The recorded ages of the pine seedlings and saplings measured suggests that some young pines were present in 1985. However, 75% of those seedlings and saplings measured were 6 yr of age or younger, indicating that most became established after the sheep were removed.

Foliar cover

A total of 25 woody perennial species was recorded on the transect lines and sample plots combined (Table 1). Total foliar cover of woody perennials for the entire study area was 21.6% (Table 2). Of the 20 species intercepted, only 5 occurred at percentages greater than 1%. Most of the species present were not common. Half of the species intercepted were only found on 1 transect line each. Dead foliar cover comprised 1.9% of total foliar cover. Bishop pine was the only species with a significant percentage of recently dead individuals.

The line transects describe an area with sparsely distributed woody perennials. The most common species, Bishop pine, is not present over most of the area, but dominates the vegetation where it occurs. Manzanita, although not as dominant as Bishop pine, is its most common associate. All other woody perennial species are rare. Their presence is generally limited to one large individual dominating a transect line, or in the case of island ironwood, a single grove of trees.

Comparisons with 1977–1978

The diversity of woody perennial species found on the sample sites increased between 1978 and 1990. In 1978, a total of 18 woody perennial species were found on the sample sites, whereas in 1990, 25 woody perennial species were recorded on the sample sites (Table 1).

Of these new species, MacDonald oak (*Quercus x macdonaldii*) and poison oak (*Toxicodendron diversilobum*) were present in 1977–1978 but overlooked. Both individuals were well older than 15 yr, but grew in inaccessible areas. The many steep slopes and narrow ravines in the study area make it difficult to search for every species which may be present. By chance I found a small grove of island oak (*Quercus tomentella*) in a ravine. This was another species present in the study area that Hobbs had not found. Similarly, it was not recorded on any of my sample sites.

Other new species, *Baccharis pilularis*, *Ceanothus megacarpus*, *Cercocarpus betuloides*, *Calystegia macrostegia*, *Gnaphalium microcephalum*, *Hazardia detonsa*, *Helianthemum scoparium*, and *Lotus dendroideus* appear to have become established since the sheep were removed. Hobbs found most of these species in the other pine forests, so they appear to be natural associates of Bishop pine on Santa Cruz Island. Other species such as *Ceanothus arboreus*, *Coreopsis gigantea*,

Table 1. Occurrence of woody perennials in study area, 1990 and 1978

	1990	1978
Adenostoma fasciculatum	X	X
Arctostaphylos species	X	X
Baccharis pilularis	X	—
Ceanothus megacarpus subsp. *insularis*	X	—
Cercocarpus betuloides	X	—
Comarostaphylis diversifolia	X	X
Calystegia macrostegia subsp. *macrostegia*	X	—
Coreopsis gigantea	*	X
Dendromecon harfordii	X	X
Gnaphalium microcephalum	X	—
Hazardia detonsas	X	—
Helianthemum scoparium	X	—
Heteromeles arbutifolia	X	X
Keckiella cordifolia	X	X
Lotus dendroideus	X	—
Lyonothamnus floribundus subsp. *asplenifolius*	X	X
Mimulus flemingii	X	X
M. longiflorus	X	X
Opuntia species	X	X
Pickeringia montana	*	X
Pinus muricata	X	X
Prunus ilicifoia subsp. *lyonii*	—	X
Quercus agrifolia	X	X
Q. aff. *dumosa*	X	X
Q. dumosa x douglasii	X	—
Q. parvula	X	X
Rhus integrifolia	X	X
Toxicodendron diversilobum	X	—
Total number species present:	25	18

X = Present on sample sites.

* = Present in study area, but not found on sample sites.

Table 2. Percentage foliar cover within entire study area, and by each stratum, 1990

Species	Study area	Old pine stratum	New pine stratum	Bare stratum
Adenostoma fasciculatum	0.2	—	—	0.4
Arctostaphylos species	1.8	5.4	2.7	0.6
Dead *Arctostaphylos sp.*	0.1	0.8	0.1	—
Ceanothus megacarpus	0.1	—	—	0.2
subsp. *insularis* Cercocarpus betuloides	X	0.2	—	—
Comarostaphylis diversifolia	2.0	0.2	0.1	3.2
Calystegia macrostegia	X	—	0.1	—
subsp. *macrostegia Dendromecon*	0.2	—	—	0.3
Gnaphalium microcephalum	0.1	—	—	0.2
Helianthemum scoparium	0.2	—	0.1	0.2
Heteromeles arbutifolia	2.0	0.3	—	3.3
Lotus dendroideus	0.1	—	0.4	—
Lyonothamnus floribundus	2.4	—	—	4.0
subsp. *asplenifolius Mimulus*species	0.2	0.2	0.7	—
Opuntia species	X	—	X	—
Pinus muricata	9.3	52.3	8.3	—
Dead *Pinus muricata*	1.5	9.7	0.6	—
Quercus agrifolia	1.3	1.3	0.7	1.5
Dead *Quercus agrifolia*	0.2	—	—	0.4
Q. aff. *dumosa*	X	—	0.1	—
Q. x macdonaldii	0.8	—	—	1.4
Q. parvula	0.3	—	—	2.1
Dead *Q. parvula*	X	—	—	X
Toxicodendron diversilobum	0.5	—	—	0.8
Percent live foliar cover	21.6	62.1	13.2	16.1
Percent dead foliar cover	1.9	10.5	0.7	0.4
Grass	42.2	5.3	24.4	58.4
Deadwood	2.7	2.6	5.9	1.4
Bare ground	26.2	25.6	49.3	17.3
Bedrock	1.4	6.9	7.5	6.4
Total*	101.0	107.5	100.4	101.1

X = Present at < 0.1% total coverage.

* Total exceeds 100% due to overlapping coverage.

Table 3. Woody perennial seedlings present in study area, 1990.

Species	Percent coverage	Number of seedlings per hectare
Arctostaphylos species	0.8	434
Baccharis pilularis	X	10
Comarostaphylis diversifolia	0.1	247
Calystegia macrostegia subsp. *macrostegia*	X	15
Dendromecon harfordii	X	15
Gnaphalium microcephalum	X	71
Hazardia detonsus	X	61
Helianthemum scoparium	X	105
Heteromeles arbutifolia	X	28
Lotus dendroideus	X	6
Mimulus species	0.3	301
Pinus muricata	2.4	632
Quercus agrifolia	0.2	57
Q. aff. *dumosa*	X	3
Q. parvula	0.1	34
Rhus integrifolia	X	7
Grass	39.5	—
Deadwood	3.5	—
Bare	43.1	—
Bedrock	8.8	—

X = Present at < 0.1% total coverage.

Eriogonum arborescens, *E. grande*, and *Hazardia squarrosa* were not recorded on my sample sites, but were observed in the study area.

Regeneration

In addition to the greater number of woody perennial species present in 1990 than in 1977–1978, seedlings of several tree and shrub species were also found in 1990 (Table 3). Young individuals of almost all the species intercepted by the transect lines were found on the fixed plots.

As previously discussed, the age structure of the Bishop pine population underwent significant changes after sheep were removed. In 1977–1978, only 1 pine younger than 15–25 yr old was found within the study area, with none present on any of the 14 sample sites (Hobbs 1980). In 1990 pine seedlings were abundant.

Another difference between 1978 and 1990, which is not directly measurable, is the increase in grasses within the study site. Hobbs noted that after the winter rains grass dominated the bare area; by August the sheep had grazed all of that year's growth (Hobbs 1978). In 1990, after removal of sheep, the grass remained ungrazed and dominated much of the "bare" area.

Discussion

It is apparent that since the removal of feral sheep the survival of pine seedlings has been greatly enhanced. This conclusion is supported by the increase in area dominated by Bishop pine since sheep were removed, as well as by its dominance in the fixed plots.

New growth of other species within the study area is taking place, but in an irregular fashion, with most newly established species found in the presently forested parts of the study area. The non-pine stratum remains primarily grass-covered with few young woody perennials, and will probably remain so until fruiting trees and shrubs establish themselves closer to these areas. It is possible that animal vectors of seed dispersal such as island foxes, common ravens, and scrub jays are important in spreading some of the less mobile fruits, especially near isolated trees. Janzen (1988) found that in Costa Rica, single trees in open fields were attractive to mammals and birds as shelter and perches, which increased the dispersal of fruit seeds into open areas. From casual observation, it appears that the island fox feeds heavily on summer holly and manzanita fruits in season, as do the common ravens, while scrub jays cache acorns and Bishop pine seeds. Irrespective of the manner in which seeds and fruit are disseminated, the study area will probably experience an increase in woody perennial species diversity and abundance in the future even as Bishop pine remains the dominant species.

At present, the study area is experiencing a rapid recolonization by Bishop pine and other woody perennials. Even though pines colonized close to 25% of the study area between 1985 and 1990, much of the site is still bare of vegetation or covered with annual grasses. This is most likely the result of sheep grazing in combination with the 1930s fire. The presence of charcoal indicates that most of the study area has burned. The 1930s fire probably killed a large percentage of the shrubs and pines present in the study area. Bishop pine appears to be very sensitive to fire damage. Many of the trees affected by the 1988 fire died, even when only scorched. Monterey pine (*P. radiata*) and knobcone pine (*P. attenuata*), 2 species closely related to Bishop pine, are both considered very susceptible to fire damage (Hepting 1971). After the 1930s fire, feral sheep probably grazed much of the emerging vegetation, thereby keeping the area deforested. As the fencing operations of the 1950s excluded sheep from the more productive pastures, grazing pressure in the northern pine population probably increased until few if any Bishop pines survived the seedling stage. Hobbs' study indicated that pine seedling survival came to a complete stop by 1960 (Hobbs 1978). When Hobbs conducted her study, she found that the area only supported those woody perennials that were unpalatable and/or long-lived. Few if any of these remnant species, however, were successfully reproducing.

By 1990, the situation had changed dramatically. Since no other limiting factors changed between 1978 and 1990, the removal of feral sheep appears to have allowed for the survival of plant seedlings, with Bishop pine dominating new growth. Other species are also colonizing the area, but at much lower densities than Bishop pine as a result of fewer available seed sources. As these species grow old enough to disseminate their own seeds, their presence in the study area should increase markedly.

Summary/Conclusion

The TNC sheep removal program resulted in a remarkable recovery of the vegetation in the study area. The data collected in this study show that Bishop pine dominates the vegetation of the study area and will continue to do so in the near future. The reasons are as follows: (1) Bishop pine is longer lived than most other species in the study area, persisting even though no seedlings survived for close to 2 decades; and (2) It produces large numbers of seeds that are able to disperse over long distances. Additionally, other species not found when sheep were present are colonizing the area, and new species can be expected to occur in the future as seeds from less severely grazed areas are dispersed onto this site.

In a broader sense, this case study from Santa Cruz Island suggests that removing feral animals is a large step towards restoring island ecosystems that have been disturbed by human actions. Island biota are very vulnerable to nonnative herbivores, but in this case, Bishop pine showed remarkable recuperative abilities once the disturbance was removed.

Acknowledgements. I am grateful to Tiki Baron, Jackie Gallaghar, Steve Junak, Dr. Lyndal Laughrin, and Peter Schuyler for providing unpublished data, assisting in the field work, and critically reviewing this manuscript.

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The Fourth California Islands Symposium: Update on the Status of Resources
Edited by W. L. Halvorson and G. J. Maender. 1994. Santa Barbara Museum of Natural History, Santa Barbara, CA.

Vegetation Response to the Removal of Feral Sheep from Santa Cruz Island

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Abstract. From 1984 through 1993, we monitored the response of herbaceous vegetation in grasslands during and after the eradication of feral sheep (*Ovis aries*) from Santa Cruz Island. Although species diversity did not increase significantly between 1984 and 1993, herbaceous cover increased and bare ground decreased after sheep were eradicated from the island. The relative frequency of native herbaceous species was inversely related to increased frequency of nonnative species, while the number and relative frequency of nonnative species remained unchanged. There was no evidence that native species were being displaced by invading nonnative species, but rather the increase in cover was due to nonnative species that already occurred in an area. The composition of the herbaceous vegetation was independent of the number of species in each class but reflected the composition prior to the eradication and the ability of nonnative annuals to rapidly colonize disturbed areas. Measuring other parameters in addition to herbaceous vegetation would have given a more complete picture of the ecosystem's response to the eradication, and monitoring a variety of ecosystem parameters should be made a central part of any eradication program. Eradication programs should be designed to be only the first step in protecting and restoring biodiversity on the Channel Islands and not considered an end in themselves; other management programs will be necessary so that one type of nonnative impact is not replaced with another.

Keywords: Santa Cruz Island; eradication; feral animals; feral sheep; nonnative plants; monitoring; succession; restoration.

Introduction

For more than 150 years, the California Channel Islands have been impacted by feral animals, primarily sheep (*Ovis aries*), goats (*Capra hircus*), and pigs (*Sus scrofa*) (Coblentz 1977, 1978, 1980; Van Vuren 1981, 1984). These impacts were especially severe on Santa Cruz Island, where more than 50,000 sheep were estimated to be on the island in the 1890s. Attempts were made in the 1900s to control the sheep population by trapping and shooting, but the efforts were not successful (Van Vuren 1981). By the 1980s, there were an estimated 20,000 sheep on Santa Cruz. The density was more than double that of the maximum stocking rates of mainland sheep operations, and more than one-third of the island was classified as being heavily impacted (Van Vuren 1981). This resulted in an increase in bare ground and subsequently higher erosion rates, decreased herbaceous vegetation, reduction and modification of shrub communities, and a decrease in abundance and diversity of birds (Brumbaugh 1980; Hobbs 1980; Hochberg et al. 1980; Minnich 1980; Van Vuren 1981).

Beginning in late 1981, The Nature Conservancy (TNC) undertook a program to eradicate feral sheep from the 90% of Santa Cruz in which TNC had an interest. The goals of the program were to preserve, protect, and restore the natural systems, flora, and fauna of the island (Schuyler 1993). From 1981 through 1987, more than 36,000 sheep were shot on Santa Cruz.

In addition to the eradication efforts, a monitoring program was established to evaluate the response of herbaceous vegetation to the sheep eradication. In this paper, we present the general pattern of herbaceous species response to the eradication, test whether the frequency of occurrence and number of native species increased on Santa Cruz as a result of the eradication, and give recommendations for monitoring future feral-animal eradication programs.