

EXPERIMENTAL REINTRODUCTION OF THE FEDERALLY ENDANGERED SANTA
CRUZ ISLAND BUSH MALLOW (*MALACOTHAMNUS FASCICULATUS* VAR.
NESIOTICUS)

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ABSTRACT

Studies of *Malacothamnus fasciculatus* var. *nesioticus* were begun in 1995 to understand its distribution, reproductive biology and ecological requirements. After 100+ years of depredation by sheep, two known populations of fewer than 20 plants each survived in 1995. Molecular studies showed that each of the two populations was composed of 1–3 genets. During our study, two additional populations of similar size were discovered. Plants are self-compatible but require insect visitation to augment pollination. Based on seed set, viable embryos, and germination rates, we found no evidence for inbreeding depression. Bush mallow also reproduces vegetatively by rhizomes, the primary means of establishment and persistence in natural populations, and a key feature for maximizing recovery success. *Ex situ* observations and trial *in situ* outplantings suggested that supplemental watering was critical to initial survival. We developed a recovery strategy composed of four plots located at varying elevations and aspects. Each plot was enclosed to exclude feral pigs, which posed a continuing threat. Each plot was planted with twelve rooted plants derived from each of three natural populations. Plants were provided supplemental watering for four months. Survivorship after one year ranged from 46% to 91%. Significant differences in survivorship were observed relative to source of plants. After twelve months some plants were flowering and reproducing vegetatively.

Key words: breeding system, *Malacothamnus*, outplanting, recovery, reintroduction, reproductive biology, Santa Cruz Island.

INTRODUCTION

Malacothamnus fasciculatus (Nutt.) Greene var. *nesioticus* (B.L.Rob.) Kearney, the Santa Cruz Island bush mallow, is endemic to Santa Cruz Island, Santa Barbara County, California. It was listed as endangered by the State of California in 1979 (CNDDDB 2009) and by the U.S. Fish and Wildlife Service [USFWS] in 1997 (USFWS 1997). At the time of federal listing, the baseline for this study, it was known from only two populations composed collectively of 42 plants (Table 1). Low numbers of populations and plants were attributed to a history of overgrazing by sheep and cattle that was observed as early as the 1870s (Junak et al. 1995). Threats to survival included soil loss from erosion, habitat alteration, and feral pig rooting. Subsequent to federal listing, two other populations were discovered on Santa Cruz Island, collectively composed initially of about 21 plants (Table 1). A recovery plan called for studies of life history and seed germination, development of propagation protocols and outplanting techniques, and subsequent establishment of viable populations (USFWS 2000).

Malacothamnus fasciculatus is a rhizomatous, short-lived shrub with spreading branches, pedicellate flowers arranged in open panicles, and pink petals 10–25 mm long. Plants are winter deciduous and flower from early April through May. The species, collectively composed of 4–5 named varieties, occurs from Santa Barbara County south to northern Baja California del Norte (Kearney 1951; Slotta 2004) and has been often characterized as a fire follower, reproducing both by seeds and by sprouts, or ramets (Bates 1963; Rundel 2007). Variety *nesioticus*, based on *Malvastrum nesioticum* B.L.Rob., was first circumscribed to include plants with panicles composed of numerous, erect, leafless branches and shallowly lobed leaves with glabrate adaxial surfaces (Jepson 1936). Most students of the California flora have recognized the distinction of the island bush mallow, regardless of taxonomic status (Kearney 1951; Wiggins 1951; Munz 1963; McMinn 1964; Junak et al. 1995). In contrast, Bates (1993) considered it indistinguishable from var. *nuttallii* (Abrams) Kearney. Benesh and Elisens (1999) were unable to discriminate among the several varieties of *Malacothamnus fasciculatus*, but their phenetic analysis did not include inflorescence structure and

leaf indumentum. In contrast, Swensen et al. (1995) and Slotta (2004) provided molecular evidence showing var. *nesioticus* to be distinct from other varieties of *Malacothamnus fasciculatus*. Swensen et al. (1995) also showed that the then two known populations of var. *nesioticus* were characterized by low levels of genetic variability, estimated from isozymes and ten random amplified polymorphic DNA (RAPD) primers.

Table 1. Location and features of natural and experimental populations of *Malacothamnus fasciculatus* var. *nesioticus* on Santa Cruz Island. Name of population; latitude and longitude (NAD83); substrate; aspect; elevation; dominant perennial taxa. Data for natural populations also include number of plants when first listed as threatened (Christi Ranch, Central Valley) or when first censused (Sauces, Horqueta), and all natural populations when censused in 2006. Number of plants includes both reproductive and vegetative ramets.

Natural Populations

Christi Ranch: 34.021° N, 119.871° W; consolidated Quaternary alluvium; gentle W-facing ridgetop; 30 m; *Artemisia californica* (Less.), *Rhus integrifolia* (Nutt.) Benth. & Hook.f. ex Brewer & S.Watson; 10 plants in 1965, 35 plants in Jul 2006.

Central Valley: 34.001° N, 119.726° W; volcanic rock outcrops (Santa Cruz Island Volcanics), crevices; steep, WSW-facing canyon wall; 140 m; *Artemisia californica*, *Cercocarpus betuloides* Nutt. subsp. *blancheae* (C.K.Schneid.) Thorne, *Heteromeles arbutifolia* (Lindl.) M.Roem.; 33 plants in 1993, 16 plants in Jul 2006.

Sauces: 34.017° N, 119.872° W; consolidated Quaternary alluvium; flat ridgetop; 75 m; *Quercus pacifica* Nixon & C.H.Müll.; 3 plants in 1997, 200+ plants in Jul 2006.

Horqueta: 33.972° N, 119.777° W; colluvium derived from volcanic Blanca Formation; SSW-facing slope; 90 m; *Artemisia californica*, *Eriogonum arborescens* Greene; 79 plants in 1996, 100+ plants in Jun 2006.

Experimental Populations

Valley Anchorage: 33.986° N, 119.671° W; clay-rich alluvium derived from Monterey Shale; gentle S-facing slope; 75 m; *Artemisia californica*.

Albert's: 33.983° N, 119.687° W; colluvium derived from volcanic Blanca Formation; gentle S-facing slope; 215 m; *Eriogonum arborescens*, *Hazardia squarrosa* Greene.

European Field: 34.002° N, 119.742° W; clay-rich colluvium derived from Santa Cruz Island Volcanics; gentle S-facing slope; 105 m; *Artemisia californica*, *Eriogonum arborescens*.

Portezuela: 34.007° N, 119.757° W; colluvium derived from Santa Cruz Island Volcanics; moderate S-facing slope; 230 meters; *Artemisia californica*, *Cercocarpus betuloides*.

The primary goal of this study was to establish experimental populations on Santa Cruz Island for

the purpose of testing methods of outplanting and to monitor both short-term and long-term success of establishment. We also pursued studies of the breeding system and the extent of vegetative reproduction to confirm observations and results reported by Bates (1963), which suggested a self-compatible mating system and reproduction by rhizomes.

METHODS

Reproductive Biology

For purposes of assessing the breeding system, we grew plants at the Santa Barbara Botanic Garden (SBBG) derived from two natural sources (Christi and Central Valley; Table 1). We applied three treatments: bagged flowers which were not manipulated; flowers available to and thus open-pollinated by natural pollinators; and bagged flowers which were provided supplemental pollen by hand. The first treatment was used to estimate fruit and seed set in the absence of pollinators. The second treatment was used to estimate fruit and seed set in the presence of pollinators. In the third treatment, pollen was collected from anthers and applied to stigmatic surfaces using a soft-haired paint brush; pollen was applied several times during a 24- to 48-hour period during which stigmas appeared receptive. In each cross, pollen was secured from flowers of the alternate strain (i.e., Christi pollen applied to Central Valley stigmas and the reciprocal).

Twenty flowers from each natural population were included in each treatment. Flowers were tagged and examined regularly for fruit production. The number of fruits and the number of seeds per fruit were recorded for each treatment. We assessed seed viability in two ways. We dissected 50 randomly collected seeds from each of two samples (Christi, Central Valley), using a surgical blade and examined contents under magnification. Fully developed embryos were considered viable; empty seeds or weakly developed embryos were considered unviable. We also scarified seeds by nicking each seed with a razor blade so that the embryo was exposed but not damaged. Fifty scarified and 50 unscarified seeds of each sample (Christi, Central Valley) were planted individually in 5 cm- (2 in.)-pots and watered regularly. Pots were held at ambient temperatures in a lath-house from 30 Nov 2000 through 30 Apr 2001 to assess germination.

To minimize the impact on natural populations, cuttings from three natural populations (Christi

Ranch, Central Valley, and Horqueta; Table 1) were grown in an experimental plot at the Santa Barbara Botanic Garden. The *ex situ* plot, established in 2000, was used to produce stock plants for vegetative division, and to assess growth rates and vegetative reproduction from rhizomes under uniform conditions. Six plants from each source were planted in three rows ca. 2.5 m apart. We censused the plot twice a year for three years to determine the number of new shoots arising from rhizomes at distances greater than 10 cm from the base of established plants. By carefully excavating topsoil around basal shoots we also were able to determine the number and source of rhizomes.

Recovery Project

For the purpose of the *in situ* recovery project, we chose four sites on Santa Cruz Island that differed primarily in elevation, geological substrate, and influence of coastal, summer conditions (cooler and moister near the coast versus warmer and drier in the interior). All four experimental sites were located on property owned by The Nature Conservancy. Much of the northern part of the island is inaccessible by roads. Thus choice of sites (Fig. 1) was constrained by access on four-wheel drive roads to facilitate maintenance and monitoring. Feral pigs (*Sus scrofa*) had not been removed when experimental recovery sites were established; consequently each site was enclosed in a fence that excluded pigs. The dimensions of each enclosure were about 9 m × 9 m (30 ft × 30 ft). Except for fencepost holes, holes dug for planting, removal of invasive species at two sites (e.g., *Foeniculum vulgare* Mill.), and access during maintenance and monitoring, every attempt was made to minimize disturbance to the substrate and natural vegetation.

Approximately 18 months prior to outplanting, we transferred actively growing, 15 cm- (6 in.)-cuttings to a mist bench for ten weeks to initiate rooting. Successfully rooted cuttings were transferred to 3.8 liter- (1 gal)-pots and watered regularly. At least one month prior to transport to Santa Cruz Island, both plants and pots were treated with a systemic insecticide and fungicide to reduce potential contamination of experimental sites by alien organisms. Each of the sites was planted in December 2005. We purposely outplanted cloned plants from different natural populations to maximize genetic diversity at each experimental site, to determine potential differences among source populations and to maximize genetic diversity within experimental populations, should establishment prove successful.

Although we planned to implement a random block design, the effort was constrained by the presence of native shrubs, which we chose not to remove from the enclosed sites. Every attempt was made to ensure equal distances among plants as much as was possible and avoid nearest neighbor combinations involving plants from the same source. At the time of planting, shoots had developed woody bases and averaged a height of 23–27 cm (9–10.6 in.), and roots had developed throughout the soil volume of the pot (ca. 2650 cm³, [162 in.³]). Prior to planting, approx. 10–15 g (0.35–0.42 oz) of 20:20:20 NPK soluble fertilizer was mixed with *in situ* soil and placed at the bottom of each planting hole. Planting was immediately followed by saturation of the volume filled by the potted plant root system. A polyvinyl plumbing pipe measuring 2.5 cm (1 in.) in diameter and 30 cm (12 in.) in length was placed vertically within 15 cm (6 in.) of the crown of each plant to economically facilitate irrigation of the root system near the base of the planting hole. We provided supplemental water to plants when more than seven days had passed without 0.64 cm (0.25 in.) of rain during the first growing season, which ended in May 2006. Estimates of precipitation were obtained from an automated weather station located at the historic Stanton Ranch, The Nature Conservancy headquarters on Santa Cruz Island. An average of 3.8 liters (1 gal) of water per plant was applied on seven separate occasions between December 2005 and February 2006, at which time supplemental watering was suspended. We assessed survival of plants at four- to eight-month intervals between January 2006 and July 2008, coinciding with spring and summer months. We also measured plant height, canopy area, and number of new shoots at several sampling dates to estimate growth rates of individual plants. We examined plants during each annual census for the presence of flowers and/or fruits as an estimate of sexual reproduction. All statistical analyses were conducted using Systat statistical software vers. 11 (Systat Software Inc., 2004, Chicago, IL).

RESULTS

Reproductive Biology

Only two of the 40 bagged un-manipulated flowers set fruits; the mean number of seeds was 0 (Christi) and 0.1 ± 0.07 , (cm ± standard error [SE], Central Valley). Fifteen of twenty open-pollinated flowers set fruit in each of the two sets of plants. Mean number of seeds per fruit was 1.9 ± 0.3 (Christi) and 2.1 ± 0.3

(Central Valley). During the course of the flowering season at SBBG (April–May), we observed several potential pollinators of which the two most common visitors were *Apis mellifera* and *Diadasia laticauda* Cockerell (Anthophoridae). *Apis* is a generalist, but *Diadasia* is an oligolege (specialist pollinator) of Malvaceae (Robbin Thorp, pers. comm.). Neither have been observed on flowers of *M. fasciculatus* plants on the island (Robbin Thorp, pers. comm.). Relatively higher fruit and seed set were observed in bagged flowers to which pollen was hand-applied. Hand-pollinated, outcrossed flowers yielded 18 fruits on Christi plants and 19 fruits on Central Valley plants. Mean number of seeds per fruit was 4.2 ± 0.4 (Christi) and 3.8 ± 0.3 (Central Valley). The number of filled seeds from Christi and Central Valley was 39 (78%) and 47 (92%), respectively. These results are consistent with a self-compatible breeding system, in which seed set may be enhanced by insect-mediated pollination and outcrossing.

We observed only seven seedlings among 50 pots of unscarified seeds after five months (3 Christi, 4 Central Valley). In contrast, 21 (Christi) and 29 (Central Valley) seedlings were observed among 50 pots of scarified seeds. The first seedlings of either group did not appear until 28 days following planting; germination was sporadic and continued intermittently over a period of 28–90 days following planting; i.e., seedling emergence did not appear to show a modal distribution during any particular period following planting.

Within the experimental plot at SBBG, basal shoots clustered near or at the base of established plants were first observed in the first three months following planting (June 2000). Clusters composed of one or more individual shoots produced at distances >10 cm were first observed in six plants 15 months following planting. Each shoot cluster arose from a separate rhizome. At the end of three years and three months

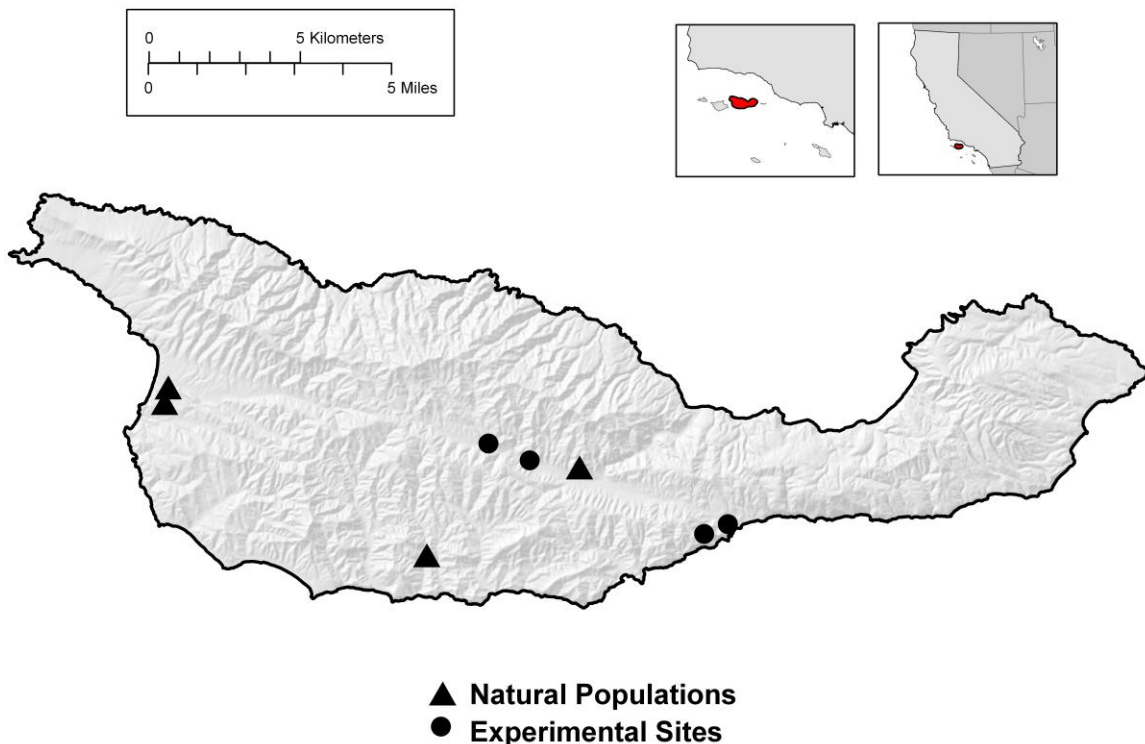


Fig. 1. Distribution of *Malacothamnus fasciculatus* var. *nesioticus* on Santa Cruz Island, California.

(June 2003), every plant had produced rhizomes bearing actively growing shoot clusters. We observed a mean of 4.5 actively growing shoot clusters per plant ($N = 18$; $SE = 0.33$), derived from a mean of 3.1 rhizomes per plant ($N = 18$; $SE = 0.21$). The average rhizome produced 1.6 shoot clusters ($N = 52$ rhizomes; $SE = 0.15$). The mean distance between new shoot clusters and parent plants, excluding basal shoots, was 50.9 cm ($N = 77$ shoot clusters; $SE = 4.1$). At least seven of the new shoots produced flowers by the third year following planting. These results are consistent with *ad hoc* observations of vegetative reproduction by means of rhizomes in natural populations, in which basal shoots often arise from semi-woody bases and solitary or multiple shoots appear at some distance from previously established plants.

Recovery Project

A total of 51 plants were placed into the four experimental sites (Table 2). Mortality was not observed until 18 months following planting (Table 2). Mean survivorship among all four experimental sites after 31 months (December 2005 to July 2008) was 61% and ranged from 23% to 92%. The highest mortality occurred between 2006 and 2007, commencing with the second summer of the study and coincident with cessation of supplemental watering. A much reduced mortality rate was observed between the summer of 2007 and the summer of 2008, suggesting that surviving plants had established an adequate root system. The lowest mortality was observed at two sites (European Field and Valley Anchorage); the highest mortality was observed at Portezuela. Multiple factors may be responsible for the differences in mortality, including soil composition and drainage, elevation, exposure to cooling temperatures and maritime fog, and competition from established native shrubs. Without precise site-specific data on temperature, insolation, and precipitation, it is difficult to accurately attribute causes of relative survivorship. We considered Portezuela to be the most stressful experimental site, primarily because of its elevation, distance from the effects of summer maritime moisture, and relatively steeper slope, which may have contributed to higher insolation and less accumulation of precipitation during the winter rainy season. Conversely, we considered Valley Anchorage to be least stressful, because of its relatively low elevation, proximity to the ocean, and relatively low relief. We consider the

Albert's and European Field sites to be intermediate to both Portezuela and Valley Anchorage.

Survivorship at Valley Anchorage ($11/12 = 92\%$), was greater than at the other three sites, and survivorship at Portezuela ($3/13 = 23\%$) was the lowest, which is consistent with our ranking. In general, mean plant height increased from 1.7 to $3.5 \times$ the height of plants in December 2005 (Table 3). The ranking of mean heights is not clearly consistent with ranking of the sites in which they grew, but it is notable that the second highest mean height (82.7 cm) was observed at Valley Anchorage, and the second lowest (51.7 cm) was observed at Portezuela. Canopy area, estimated in dm^2 , was consistent with our ranking of experimental sites (Table 4). In both June 2007 and July 2008, Valley Anchorage showed the largest mean canopy area (142.3 and 336.3 cm^2 , respectively), and Portezuela showed the lowest mean canopy area (16.8 and 51.5 cm^2 , respectively). Flowering was observed on most plants in the first summer following planting (Table 5). This was not unexpected, because *ex situ* plants of similar age at SBBG have flowered within the first 12 months. In the two successive years (2007, 2008), nearly all surviving plants flowered and produced fruit. Examination of fruits when available showed the presence of seeds. In July 2008, we censused each plot for the number of vegetative ramets recruited, presumably from rhizomes. We counted nine separate ramets at Albert's, 19 at European Field, one at Portezuela, and 32 at Valley Anchorage.

With one exception, plants from all three natural source populations survived in each of the experimental outplanting sites (Table 6). One to five plants from each source survived at each of the experimental sites, except at Portezuela, where both plants representing the Central Valley source failed to establish. Over all four experimental plots, plants derived from Horqueta showed the highest proportion of survivors ($14/19 = 74\%$). Survivorship of plants derived from the Central Valley and Christi populations was similar ($7/14 = 50\%$ and $10/18 = 55\%$).

DISCUSSION

The recovery of rare species has generally embraced coordinated efforts that include inventories, surveys, monitoring, habitat protection, establishment of *ex situ* collections, and recovery, among others (Bratton and White, 1981; Pavlik 1994; Schemske et al. 1994; McEachern and Wilken 2011). Despite a long history of floristic surveys

Table 2. Survivorship. Number of surviving plants in each year and overall proportion of survivors at each experimental site after 31 months. Plants were placed into sites during Dec 2005.

Date	Albert's	European Field	Portezuela	Valley Anchorage	Total
Dec 2005	13	13	13	12	51
Jul 2006	13	13	13	12	51
Jun 2007	7	11	8	11	37
Jul 2008	7	10	3	11	31
Overall survivorship	0.54	0.77	0.23	0.92	0.61

Table 3. Plant height at each experimental site. Mean distance from soil surface to tip of central terminal shoot (cm ± standard error). Sample size restricted to plants with original central shoot remaining. Living plants with basal shoots but without original central stem were not included.

Date	Albert's	European Field	Portezuela	Valley Anchorage
Dec 2005	26.4 ± 1.2 (N = 13)	27.0 ± 1.2 (N = 13)	24.0 ± 1.9 (N = 13)	23.3 ± 1.6 (N = 12)
Jul 2006	38.5 ± 4.1 (N = 13)	66.2 ± 3.3 (N = 13)	50.7 ± 4.1 (N = 13)	62.2 ± 5.8 (N = 12)
Jun 2007	37.4 ± 5.6 (N = 7)	60.7 ± 5.6 (N = 12)	36.8 ± 3.9 (N = 8)	54.9 ± 6.1 (N = 11)
Jul 2008	46.3 ± 7.7 (N = 7)	85.1 ± 4.5 (N = 10)	51.7 ± 6.5 (N = 3)	82.7 ± 6.2 (N = 11)

Table 4. Canopy area in dm² at each experimental site, June 2007 and July 2008 (dm² ± standard error). Canopy area was estimated by the formula Πr^2 using the mean of 0.5 × the maximum diameter and 0.5 × the diameter perpendicular to the maximum diameter.

Date	Albert's	European Field	Portezuela	Valley Anchorage
Jun 2007	43.5 ± 12.2 (N = 7)	108.4 ± 20.8 (N = 12)	16.8 ± 3.6 (N = 8)	142.3 ± 35.1 (N = 11)
Jul 2008	71.0 ± 23.3 (N = 7)	221.6 ± 35.9 (N = 11)	51.5 ± 9.4 (N = 3)	336.3 ± 70.6 (N = 11)

Table 5. Number of reproductive plants at each experimental site, June 2006 through July 2008. Presence of inflorescences or developing fruits was considered evidence of sexual reproduction.

Date	Albert's	European Field	Portezuela	Valley Anchorage
Jun 2006	9	13	11	12
Jun 2007	6	10	3	11
Jul 2008	7	10	3	11

Table 6. Overall survivorship of plants at experimental sites derived from different natural populations (Dec 2005–Jul 2008).

Experimental Site:	Source Population					
	Central Valley		Christi Ranch		Horqueta	
	Dec 2005	Jul 2008	Dec 2005	Jul 2008	Dec 2005	Jul 2008
Albert's	4	2	5	2	4	3
European Field	4	2	4	3	5	5
Portezuela	2	0	5	1	6	2
Valley Anchorage	4	3	4	4	4	4
Total	14	7	18	10	19	14

on Santa Cruz Island, only two *Malacothamnus fasciculatus* var. *nesioticus* populations were known at the time of federal listing in 1997, and despite extensive and continuing surveys (Hochberg et al. 1980; McEachern et al. 1997, 2010), only two additional populations have been found. Under management by The Nature Conservancy and the National Park Service, threats from grazing by sheep and cattle were removed in the mid 1980s, and threats from pigs were finally removed in 2007. Whether intense grazing played a role in reduction of bush mallow populations, or whether the variety was naturally rare prior to introduction of feral animals cannot be objectively determined. However, the widely separated natural populations, each composed of relatively few individuals, suggest a formerly broad distribution reduced to sites that were haphazard refugia, related primarily to their location in areas inaccessible to or unfrequented by feral, non-native animals.

Repeated observations of natural populations between 1994 and 2006 (Table 1) suggest that they are either stable or experiencing expansion, primarily by vegetative reproduction. In 1994, the Christi population included 35 plants, ranging from multiple-branched, flowering shrubs to single-stemmed vegetative shoots. In 1996 and 2006, the same population included approximately the same number of individuals, but locations of mature flowering plants were not the same and vegetative ramets were clustered in different sites within the original area of the population, which had been fenced in the early 1990s by The Nature Conservancy. It is notable that most of the flowering plants observed in 1994 had died by 1996, including all plants tagged for genetic studies (Swensen et al. 1995), but new shoots or clumps of shoots had appeared on recent alluvium in a small arroyo downslope from the original plants.

In 1993, 33 plants were observed at the Central Valley site (Steve Gliessman, UC Santa Cruz, pers. comm.). Gliessman classified them into three kinds of plants: 4 flowering plants ca. 1 m tall with multiple stems, 14 strictly vegetative plants with the same size and architecture, and 15 plants composed of single-stemmed, vegetative ramets varying from 10 to 40 cm tall. At least 33 plants were observed in 1994, and at least three new vegetative ramets were observed in 1996. However, by 2006 the number of plants had declined to 16 flowering, multi-branched plants, each greater than 1 m tall.

Three ramets representing the Sauces site, each ca. 10 m apart, were first discovered in early 1997 at the edge of a controlled burn conducted by The Nature Conservancy (Jeff Howarth, UC Santa Barbara, pers.

comm.). In 1997, the same three plants were observed, each within the canopy of unburned *Quercus pacifica* shrubs, and each with flowers. By 2002, the original plants had died, but were replaced by at least 220 individual ramets, many of them in clusters arising from rhizomes at distances up to 5 m from the original shrubs. However, only eight ramets produced flowers. Since 2002, the numbers have remained relatively stable, but more plants reached reproductive size.

In 1997, the Horqueta population consisted of 79 plants, represented by ca. 63 flowering shrubs and 16 vegetative shoots. In 2006, many of the flowering plants, some of which had been tagged in 1997 for long-term tracking, were dead. However, at least 100 plants, many in flower, occupied the general area, dispersed among three different microsites. In all four natural populations, we were unable to clearly determine if any young ramets were derived from seedlings; the youngest or shortest ramets appeared woody at the base, and did not resemble young *ex situ* plants grown from seeds. However, the most common pattern of shoot development, which often consisted of clusters of two or more ramets from a semi-woody base, strongly resembled that observed in the experimental *ex situ* plot at SBBG, suggesting that most recruitment in natural populations was from rhizomes. These observations, combined with results from experimental studies of seed scarification and germination, focused our attention to developing an experimental recovery task using container plants with relatively rapid potential for establishment.

Understanding the breeding system and maximizing genetic variation have been considered key elements to species recovery and designing reintroduction (Holsinger and Gottlieb 1991; Karron 1991; Fenster and Dudash 1994; Weller 1994; Guerrant and Pavlik 1997). Genetic analyses of two populations (Christi, Central Valley) indicated the absence of substantial genetic variation within populations, but distinct differences were evident between populations (Swensen et al. 1995). We were unable to conduct similar studies of the two additional populations, but assumed that the pattern was similar, given the relatively few numbers of plants in each of them at the time of discovery. Based on the presence of self-compatibility in bagged and unmanipulated flowers and observations of relatively high fruit and seed set in hand-pollinated experimental outcrossed flowers, we predicted that experimental plots would benefit from inclusion of a diversity of potentially different genotypes, derived from widely separated sources on Santa Cruz Island, and that successful reproduction by flowering would

contribute to recruitment of seeds into the substrate. Although reduced fitness as a result of outbreeding depression might be a concern (Barrett and Kohn 1991), preliminary results from experimental interpopulation crosses showed fruit and seed set at levels comparable to augmented self-pollination (Wilken, unpubl. data). Interpopulation hybrids grown at SBBG also show relatively high fruit and seed set when exposed to natural mainland pollinators. These observations suggest that our attempt to maximize genetic diversity within experimental populations on Santa Cruz Island may not be encumbered by potential outbreeding depression. In the short-term (2005–2008), three of the four experimental plots contained plants from three different wild sources, and the remaining plot contained plants from two different sources. In each plot, plants had produced fruits by 2008, whose seeds presumably dispersed and were incorporated into the immediate soil seed bank. Without a formal genetic analysis of progenies derived from the experimental plants, it is premature to estimate the genetic composition of viable seeds in the soil seed bank. However, it is likely that they may include some level of genetic diversity greater than that in any of the natural populations.

The persistence of 61% of the original outplanted individuals (Table 2) after 30 months, observations of flowering and fruiting in the second and third year, and recruitment of new vegetative ramets in all experimental sites provide evidence for short-term success. Long-term success depends, however, on successful establishment in which populations become self-sustaining (Guerrant 1996; Pavlik 1996). For *Malacothamnus fasciculatus* var. *nesioticus*, assessment over the long-term may prove difficult for several reasons. Although seeds produced under ex situ conditions show relatively high viability and evidence of germinability following scarification, the demography of seeds in the wild remains unstudied. Recruitment among related congeners by seeds and by vegetative means appears related to fires (Bates 1963; Malanson and O’Leary 1982; Keeley et al. 2005), but natural fires on Santa Cruz Island are apparently a rare event (Junak et al. 1995). Recruitment of plants at Sauces (Table 1) is the only case in which fire may have contributed to population growth, and it was difficult to determine if any recruitment resulted from seed germination. Furthermore, no information is available on the longevity of seeds under *in situ* soil conditions, and how dormancy is eventually overcome. Our casual observations of plants in natural and tended garden populations suggests that most plants live less than

ten years, and that vegetative recruitment represents the norm. Thus, success in terms of recruitment from seeds within *in situ* experimental populations may depend on monitoring protocols requiring several decades.

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