Report

Transplant success for the endangered herb *Arenaria paludicola* at Golden Gate National Recreation Area: Effect of site, propagation type, and competition

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Abstract

We established experimental populations of *Arenaria paludicola* in two main sites and four additional microsites at the Golden Gate National Recreation Area, within the plant's historical range. We compared establishment success of nursery-grown vs. greenhouse-grown transplants, and we tested the effect of initial clearing around the plants. Planting was completed December 10, 2011, and plots were censused in January, February, April, and at the end of July, 2012. Of the two sites, the Rodeo Beach site was more successful: plants survived better, were more robust, and were substantially larger in July. At the time of site selection, the Rodeo Beach site had less standing water and greater cover of *Oenanthe sarmentosa*, the species considered to be an indicator for *A. paludicola* habitat based on previous work. Interestingly, the biggest jump in mortality occurred from February to April, rather than from April to the end of July, suggesting that moisture stress was not the main cause of mortality over this time period. In fact, locations with higher gravimetric soil moisture content experienced higher, not lower, plant mortality for greenhouse-propagated plants. We expected competition from surrounding plants to have a negative effect on *A. paludicola,* and we tested this by experimentally clearing vegetation from a 20cm-diameter circle around half of the plants. We found that clearing around plants increased survival at Rodeo Beach but decreased survival and health at the wetter Miwok site. The magnitude of the effect was small at both sites and disappeared by July. Thus clearing is probably not worth the extra time and effort in *A. paludicola* outplants. Finally, we expected that propagation methods would strongly influence plant survival, with plants relocated from an outdoor nursery having greater tolerance to natural environmental conditions than plants transplanted directly from greenhouse conetainers. Surprisingly, plants from conetainers had significantly better early survival than nursery transplants, and greenhouse plants were consistently healthier and larger throughout the study at Miwok. However, at the Rodeo site, the nursery plants gained an advantage in later survival, health, and size. It is unclear at this time whether propagation type will have a consistent long-term effect on success. Experimental transplants can provide important information for endangered species management; our results suggest that site selection is the most important factor in the early success of *A. paludicola* reintroductions.

Introduction

Identifying the factors determining the success of plant reintroductions is vital to increasing the effectiveness of restoration efforts. Most transplant efforts do not achieve permanent, viable populations (Godefroid et al 2011). Habitat location (including soil moisture), surrounding vegetation, and the origins of propagation can all influence the success of plant reintroductions, but it is unclear which factor is most important because few examine multiple factors simultaneously (Pavlik et al 1993; Menges 1990). Neighboring plants may either compete with or facilitate transplants, and this relationship may depend on abiotic factors (Callaway and Walker 1997;Casper and Jackson 1997; Goldberg et al 1990; Holmgren 1997).

Marsh sandwort (*Arenaria paludicola*) was listed by the U.S. Fish and Wildlife Service (Service) as endangered in 1993, and was listed as endangered by the State of California in 1990. In its recovery plan, the Service (1998) recommended augmenting existing populations and establishing new populations so there are at least five, self-sustaining populations. Marsh sandwort is a perennial flowering plant that occurs in freshwater marsh and stream habitats, with a historical distribution along the Pacific Coast from southern California, north to San Francisco, and in Washington near Tacoma. *Arenaria paludicola* has only one known population remaining in the wild at Oso Flaco Lake. *Arenaria paludicola* has been introduced into three sites, all in California: Sweet Springs Marsh at Morro Bay, the Guadalupe-Nipomo Dunes National Wildlife refuge in southern San Luis Obispo County, and at Wilder Ranch/Baldwin Creek in Santa Cruz County.

We implemented an experiment in six sites at Golden Gate National Recreation Area (GGNRA) located near one of the known historical populations, using plant genets originally provided by the USFWS. We compared the success of two propagation types (year-old nursery plants and greenhouse conetainer starts) and studied the effect of a neighbor removal treatment. Furthermore, we studied the variation in soil moisture at each site and the relationship between soil moisture and plant survival. We expected that propagation type would influence plant survival most and that plants propagated in a nursery would have higher survival rates than plants grown in a greenhouse, because nursery grown plants have had time to build up tolerance to typical natural environmental conditions. Furthermore, we expected that neighboring vegetation density would decrease plant survival success as a result of competition for resources, and thus the clearing treatment would increase plant health and size. Since *Arenaria* is a wetland plant species, we predicted that lower soil moisture would decrease plant survival.

Methods

Study Site

We conducted our study at two main wetland sites at the Golden Gate National Recreation Area in Marin Headlands, California. The sites were chosen for their environmental similarity to locations on the central coast of California where *Arenaria* was successful in a previous reintroduction (Parker, unpublished data). There were two main sites and four "microsites." The main sites were Rodeo Beach and Miwok Trail. Each main site had 2 microsites within approximately 500m.

Experimental Design

The *Arenaria* individuals all were generated asexual propagules of 12 genotypes originally collected from the field by the Service. There were two types of propagation used: some plants were grown outside (with irrigation) in a nursery for over a year, while others were grown from small cuttings in conetainers the University of California, Santa Cruz, growing for a matter of weeks rather than years before transplanting.

Transplanting was done 8-10 December 2011. The main sites, Rodeo Beach and Miwok Trail, had 10 rows planted 1 meter apart, with 33 plants per row (with the exception of the tenth row, which contained 11 plants each), planted 0.5 meters apart, for a total of 308 plants per site. Positions were randomized for the 11 genotypes and nursery and greenhouse grown individuals. There were 10 nursery-grown plants per genotype, and 18 greenhouse-grown plants per genotype at each of the main sites. In order to study the effect of surrounding vegetation density on survival success, we randomly assigned each plant to neighbor removal or control; we cleared a 20-cm radius circle around the *Arenaria* for the treatment plants at the time of planting. Some additional light clearing was done to these plants at the February census as well.

The microsites consisted of 24 plants in pairs of nursery and greenhouse grown individuals of randomized genotypes. In the microsites, pairs of plants were planted haphazardly within a 50m area.

Survival Census

We conducted the first census on 15 January 2012, approximately 5 weeks after transplanting; we assessed plant health on an index from 0 to 3, where 0 signified a dead or absent individual and 3 marked a thriving individual (Table1). Our second census took place approximately one month later on 18 February 2012, approximately 10 weeks after transplanting; we again assessed each plant using our 0-3 index and re-cleared any surrounding vegetation within 20-cm of the treatment plants. We conducted our third census on 21 April 2012, approximately 19 weeks after transplanting, and our final census on July 27, 2012, 33 weeks after transplanting. At the final census, in addition to assessing the health of each plant, we also estimated the relative size of each plant using the following equation:

$$\text{Relative size} = \text{\# of shoots} \times \text{length of longest shoot (cm)}$$

Soil Moisture

During the second census, we took volumetric moisture content (VMC) readings using a time domain reflectometry (TDR) probe at 10 haphazardly chosen locations at both the Rodeo and Miwok sites, and 5 haphazardly chosen locations at each of the four microsites, for a total of 40 readings. We also collected soil samples at each of the TDR sampling locations in order to get gravimetric moisture percentages. Gravimetric soil moisture was calculated using the following equation:

$$\text{Grav. Soil Moisture} = \frac{\text{wet soil weight (g)} - \text{dry soil weight (g)}}{\text{wet soil weight (g)}}$$

We then compared the survival indices at each site, clearing versus control treatment, propagation type, and the effect of soil moisture on plant survival for each census.

Statistical Analyses

We used logistic regression to study the effect of clearing treatment, propagation type, and their interaction on plant mortality (a "0" on the health index was classified as "dead" and "1-3" were classified as "alive"). We also used two-way ANOVAs to test the effect of these factors on plant health score and plant size. Plant size was log-transformed to achieve normality. We used regressions to quantify the relationship between TDR VMC estimates and soil moisture as measured by gravimetric percent, analyzing the Miwok site with associated microsites separately from the Rodeo site with its associated microsites. We compared soil moisture between the Rodeo and Miwok sites with a t-test. Finally, we regressed the proportion plant mortality on gravimetric soil moisture with sites/microsites as replicates. All statistics were done using JMP9.0 and JMP10.0 (SAS Institute).

Results

Rodeo Beach. At the Rodeo Beach site after one month, there was a significant difference in plant mortality between propagation types, with greenhouse plants surviving better than nursery-grown plants (chi-sq=5.54, N=308, P=0.019) (Fig.1). There was a significant positive effect of clearing on plant survival (chi-sq=4.81, N=308, P=0.028), and no significant interaction between propagation type and clearing treatment (chi-sq=1.86, N=308, P=0.173) (Fig.1). These patterns were maintained in February (Fig.1); the effect of propagation type was significant (chi-sq=5.77, N=308, P=0.016), the clearing treatment was marginally significant (chi-sq=3.71, N=308, P=0.054), and the interaction between propagation type and clearing treatment was not significant (chi-sq=0.140, N=308, P=0.71). By April 2012, the effect of propagation type on mortality was not significant (chi-sq=0.064, N=308, P=0.80), but clearing treatment marginally significantly decreased plant mortality (chi-sq=3.48, N=308, P=0.062). The interaction between propagation type and clearing treatment was not significant (chi-sq=0.74, N=308, P=0.39). In our final census visit in July 2012, there was again a significant effect of propagation type on mortality (chi-sq=5.43, N=308, P=0.020), but the direction changed so that greenhouse plants had higher mortality (Fig.1). There was no significant effect of the clearing treatment (chi-sq=1.13, N=308, P=0.29) or the interaction between propagation type and treatment (chi-sq=0.01, N=308, P=0.92).

Patterns for the average health score per plant at the Rodeo site complemented the analyses for mortality., On 15 January 2012, at the Rodeo Beach site, there was a significant difference in health score depending on propagation type, with the greenhouse plants looking more robust, on average, than those grown in nurseries (F=39.5, df=1,304, P<0.01). There was no significant main effect of the clearing treatment (F<.01, df=1,304, P=0.98) or interaction between propagation type and the clearing treatment (F=2.40, df=1,304, P=0.12). None of the factors were significant on 18 February (P>0.35) However, by April 2012, there was a significant main effect of the clearing treatment, with the plants having a higher average health score in the clearing treatment (F=5.55, df=1,304, P=0.02). In April the nursery-propagated plants had significantly higher health scores than greenhouse plants (F=5.55 df=1,304, P=0.02), while the interaction between propagation type and clearing was not significant (F<0.01, df=1,304, P=0.97). The higher health scores in nursery plants were maintained in the July census (F=10.5, df=1,304, P=.010). Clearing had no significant effect on health score in July (F=0.26, df=1,304, P=0.61), and there was no significant interaction between propagation type and treatment (F=0.04, df=1,304, P=0.85) (Fig.2).

Plant size at Rodeo Beach, measured in July 2012, showed a significant effect of propagation type (F=22.6, df=1,162, P=0.032), with the nursery plants showing higher average plant size (Fig.3), The clearing treatment did not have a significant effect on size (F=0.50, df=1,162, P=0.48), and there was no significant interaction between clearing and propagation type (F=0.055, df=1,162, P=0.81).

Miwok Trail. In January 2012, one month after transplanting, the Miwok Trail site showed a significant effect of propagation type on plant mortality (chi-sq=39.4, N=308, P<0.0001), with the greenhouse plants showing higher survival rates relative to nursery grown plants (Fig.1). There was also a significant effect of clearing on plant survival (chi-sq=7.04, N=308, P=<0.008), with cleared plants fairing worse, not better. The interaction between the propagation type and clearing treatment was marginally significant (chi-sq=3.54, N=308, P=0.060), with the negative effects of clearing being more pronounced in greenhouse-grown plants (Fig.1). In February, the greenhouse plants still had a significantly lower mortality than nursery plants (chi-sq=26.0, N=308, P<0.0001), and cleared plants still showed higher mortality rates than controls (chi-sq=3.69, N=308, P=0.055). The interaction between propagation type and clearing treatment was not significant (chi-sq=2.65, N=308, P=0.103).

By April at Miwok Trail, the effect of propagation type was only marginally significant (chi-sq=3.23, N=308, P=0.072), and the effect of the clearing treatment was not significant (chi-sq=0.81, N=308, P=0.37), nor was the interaction between propagation type and clearing treatment (chi-sq=0.16, N=308, P=0.69). By July 2012, plant mortality showed no significant effect of propagation type (chi-sq=1.04, N=308, P=0.31), clearing treatment (chi-sq=0.37, N=308, P=0.54), or their interaction (chi-sq=0.07, N=308, P=0.79) (Fig.1).

The health scores of *Arenaria* at the Miwok Trail site basically mirrored the results on mortality rates. In January there was a significant main effect of propagation type on health score (F=31.0, df=1,304, P<0.01), with the greenhouse plants showing higher health scores than nursery grown plants (Fig. 2). There was also a significant effect of clearing (F=4.66, df=1,304, P=0.03), with cleared plants having lower health scores on average. The interaction between clearing and propagation type was not significant (F<0.01, df=1,304, P=0.96). In February, there was still a significant effect of propagation type (F=15.21, df=1,304, P<0.01), and a significant effect of, clearing treatment (F=6.0, df=1,304, P=0.01), with greenhouse plants and uncleared plants still growing more robustly. The interaction between clearing and propagation type was not significant (F=0.02, df=1,304, P=0.90) (Fig.2). In April, both the propagation type and clearing treatment effects, as well as their interaction, were no longer significant (P>0.59). In July 2012, greenhouse plants were again looking significantly better than nursery plants (F=3.98, df=1,304, P=0.05), but there was no significant effect of clearing treatment or interaction term (P>0.58) (Fig.2).

At Miwok Trail in July, greenhouse plants were significantly larger than nursery plants (F=6.40, df=1,94, P=0.013). The clearing treatment had no significant main effect on plant size (F=0.50, df=1,94, P=0.50), and the interaction between the clearing treatment and propagation type was not significant (F=0.05, df=1,94, P=0.82). Notice that even though there was a significant difference between greenhouse and nursery plants, that difference was dwarfed by the dramatic differences in plant size between the sites (Fig.3). Plants at Rodeo Beach were much larger than plants at Miwok.

Moisture differences among sites. We compared soil moisture estimates measured in two ways: using a TDR moisture reader in the field, and collecting soil cores and quantifying gravimetric soil water content back in the lab. For the combined data from the Rodeo Beach site and surrounding microsites, the TDR estimates of volumetric moisture content

(VMC) significantly predicted the gravimetric moisture content measured from soil cores (Grav%=0.07+0.59*TDR%, R^2=0.40, N=20, P<0.01) (Fig.4). For the combined Miwok Trail, microsite 3, and microsite 4 sites, the relationship was also significant, although there was lower predictive power (Grav%=0.41+0.21*TDR%, R^2=0.21, N=20, P=0.04) (Fig.4). We felt the predictive accuracy of the TDR measurements (R^2 values of 21% and 40%) was too low to rely on these data to answer questions about the effects of soil moisture at these sites; therefore we only used gravimetric moisture data for this purpose.

The gravimetric soil moisture content was significantly higher at Miwok Trail than at Rodeo Beach (t=2.78, df=15.4, P=0.01)(Fig.5). Combining all six main sites and microsites, soil moisture on 18 February 2012 did not significantly predict mortality of nursery plants (PropDead=-0.20+0.99*Moisture%, R^2=0.20, N=6, P=0.38) (Fig.6). However, soil moisture did significantly predict plant mortality in the greenhouse propagated plants (PropDead=-0.44+1.15*Moisture %, R^2=0.65, N=6, P=0.05). Surprisingly, the wetter sites had higher mortality (Fig.6).

Discussion

After seven months of growth at reintroduction sites in the Golden Gate National Recreation Area (GGNRA), *Arenaria paludicola* persisted to some degree in all sites and microsites. However, we found strong patterns of variation in the establishment success. This experimental transplant provides useful information on the relative importance of site selection, propagation approaches, and removal of competitors to the survival and growth of *A. paludicola* at GGNRA.

Site Selection

Our two main sites, Rodeo Beach and Miwok Trail, differed greatly. Plants at Rodeo Beach showed very high early survival, and greater survival (45-65%) into July 2012 than plants at Miwok Trail (25-35%). At Rodeo Beach, many individuals had expanded substantially by July and were even flowering in April, only four months after reintroduction. Plants at the Miwok Trail site earned lower health scores and were much smaller in July, and none of the individuals were flowering.

One possibility for the discrepancy between sites is the significant difference in soil moisture between Rodeo Beach and Miwok Trail. Because *A. paludicola* is known as a wetland specialist species and its one extant wild population is perennially wet, we predicted that the wettest sites would be the most successful sites. The Miwok Trail site was selected in part because it showed standing water in November 2011. Surprisingly, this study suggests that excessive water can be detrimental to *A. paludicola* establishment. Combining survival data from all six sites and microsites, we found a negative rather than a positive relationship between moisture and survival (for greenhouse-propagated plants). At Miwok, many plants were submerged in water during January and February, even as late as our census in April (personal observation). We observed anecdotally that plants on soil mounds lifted out of the water seemed to have higher survival. This hypothesis is also consistent with previous observations that *A. paludicola* could not survive in areas with sheet flow at Baldwin Creek State Park (Bontrager et al. manuscript). We also note that the biggest jump in mortality was from February to April, not from April to the end of July, as might be expected if drought was the main cause of mortality within this seven month period. Although the drier Rodeo site was still promoting more robust plant growth into July 2012, we don't yet know whether mortality from desiccation might reverse these trends in the future.

Propagation Method

Propagation methods strongly influenced the success of *Arenaria paludicola* outplants. We had originally expected that plants translocated from an outdoor nursery would have higher survival rates than plants raised for a few weeks in the greenhouse, because the greenhouse grown plants had not undergone the same natural stresses of growing outdoors as the nursery plants, nor did they have thick blocks of roots like the nursery plants. Therefore it was surprising to find that survival for the first two months was higher for the greenhouse-grown plants at both sites, and that greenhouse-grown plants were more successful overall at Miwok throughout the study and larger at the end. The nursery transplants held up better at Rodeo and eventually expressed a size and survival advantage at that site in July. In other words, by the end of this study, nursery plants had better survivorship at Rodeo and poorer survivorship at Miwok, and nursery plants were larger at Rodeo but smaller at Miwok. The extra time and expense of extended outdoor propagation does not seem to be a good investment for this species: at this time, we cannot say that there is any consistent advantage to growing *A. paludicola* for extensive periods in a nursery before introduction; however, it is too early to say definitively that there will not be a long-term benefit.

Neighbor Removal

Many previous studies show that competition from neighboring plants can have a negative effect on plant growth, but the effect may depend on site conditions (Reader et al. 1994; Choler et al. 2001). We predicted that the clearing treatment would increase the survival success of the *A. paludicola* because of competitive release, and we did see a significant effect of clearing on early plant survival at the Rodeo site. However, clearing had a significant *negative* impact on plant survival at the Miwok site. The magnitude of the effect in both cases was modest in comparison to differences between sites and between propagation types. Our results indicate that plant competition does not exert strong control over transplant success at either site. This contrasts with other studies that have shown a negative impact of neighboring plants on endangered plant species in translocation studies (Jusaitis 2005).

One possibility for the discrepancy between sites in the effect of our clearing treatment is the difference in hydrology between Rodeo Beach and Miwok Trail. The *A. paludicola* at Miwok may be relying on surrounding vegetation for structural support out of the highly saturated soil. Alternatively, the clearing treatment itself could have caused inundation of the plants by changing the soil structure. We observed that cleared circles, particularly at Miwok, frequently created pools around or over the plants. At Rodeo Beach, the clearing treatment significantly increased the health scores in April and July, perhaps indicating that as the plants became established and grew in size, the plants benefitted from greater space for expansion. More studies need to be done on how hydrology, seasonality, and soil moisture influence the interacting positive and negative effects of clearing.

Identifying the different habitat components that may play a role in the survival success of endangered plant species is a key to successful restoration efforts. In the case of *Arenaria paludicola*, soil moisture, propagation methods, and clearing treatments all seem to play important roles in determining success, depending on other factors such as the time of year and site selection. Success rates for transplants have historically been low (Godefroid et al 2011), and therefore it is important to understand the components of plant success on a species-specific basis in order to increase restoration success rates.

Management Implications

As with any science-based conservation action, there is uncertainty involved in making specific recommendations about outplant procedures for *Arenaria paludicola*. Our recommendations are admittedly based on incomplete knowledge and may change with time. However, the comparatively large scale of this experiment as well as previous experience with outplants in three habitat types at two sites in Santa Cruz County (Bontrager et al. manuscript) lend credence to a few specific suggestions for reintroduction efforts on the Central Coast of California.

1. Seek transplant sites with high abundance of *Oenanthe sarmentosa*, avoiding sites with persistent standing water.

The Rodeo Beach site was chosen because of its similarity to sites in Santa Cruz County that showed high success of *A. paludicola*. Specifically, we have found that sites with a substantial component of *Oenanthe sarmentosa* tend to support more successful populations of *A. paludicola*. This pattern is consistent enough to suggest *O. sarmentosa* as an indicator of *A. paludicola* habitat.

Although *A. paludicola* requires soil moisture throughout the year and cannot survive long periods of desiccation (Bontrager et al.), excessive moisture is also detrimental, especially standing water or sheet flow.

2. Propagating *Arenaria paludicola* in conetainers in the greenhouse and transporting them in racks is a much simpler, easier, and cheaper approach than translocating plants from field nurseries. The logistics of moving conetainers in racks was preferable to handling the nursery "bricks," and creating holes was also much simpler for the more vertical conetainers. So far, the data suggest that the greenhouse-grown plants perform nearly as well, sometimes better, in the short term. Extended monitoring is needed to determine if this conclusion will change over time.

3. Clearing around *A. paludicola* plants is time consuming and does not show a consistent positive effect on plants. When soils are saturated, clearing may even be detrimental. A reasonable approach may be to wait until after the plants are established and expanding, approximately 145 days after transplanting, then clear around the survivors.

Monitoring of these transplants needs to continue in order to determine the longer-term viability of the introduced populations. We predict that plants will persist, at least at the Rodeo Beach site. We expect at least some individuals will flower in the coming year and perhaps will make seed.

This study, designed with guidance from a smaller initial transplant experiment in Santa Cruz County, has in turn provided useful information to help guide future reintroductions of *Arenaria paludicola*. We recommend this type of investigation to help determine the relative importance of different factors influencing success for the translocation of any endangered plant species.

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Table 1. *Plant Survival Index*. Index used to rate plant health at each site; indices were used to determine plant survival in relation to clearing treatments and propagation type at Golden Gate National Recreation Area in Marin Headlands, CA.

Plant Survival Index	Index Description
0	fewer than 2 small shoots (hardly visible), dead, or absent
1	fair condition, more than 2 "shoots/recruits," but vegetation is brown/green (looks fairly unhealthy)
2	good condition, but little/no expansion since planted, all green vegetation, may contain 1-2 flowers/buds
3	thriving, many "recruits/shoots," noticeable expansion, all green vegetation, may contain multiple flowers/buds

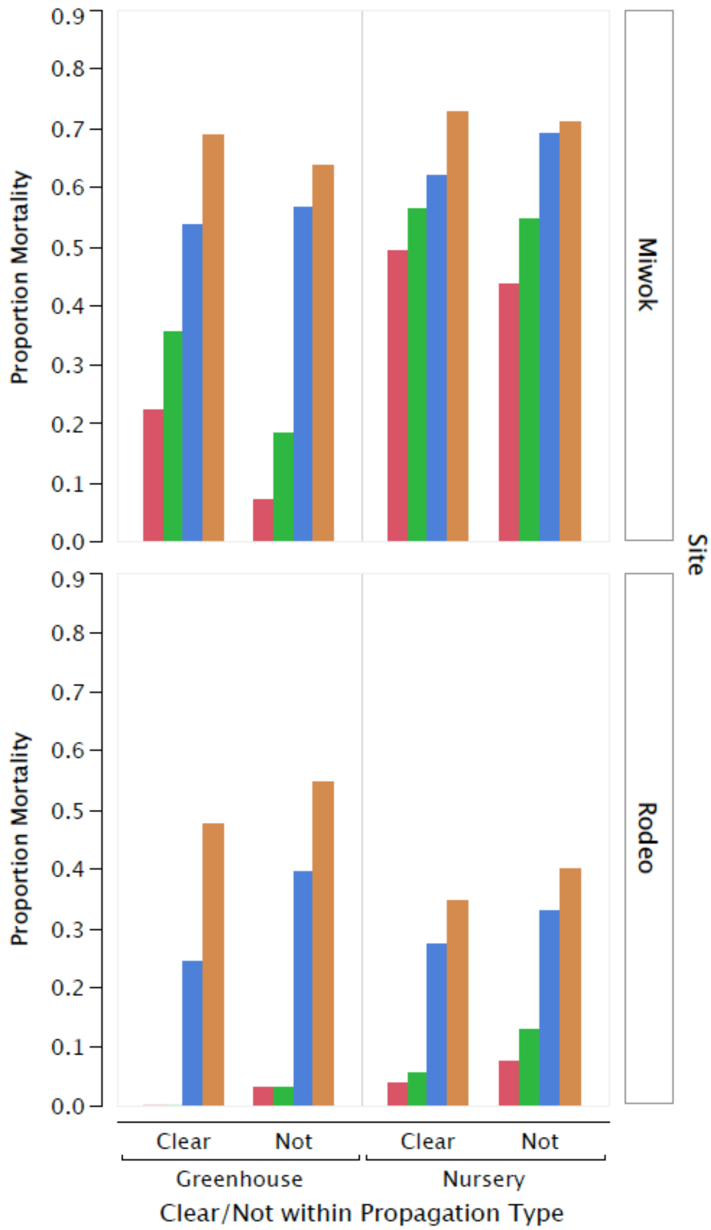

Figure 1. Proportion mortality of transplanted *Arenaria paludicola* individuals (health score of 0) at Rodeo Beach and Miwok Trail at the Golden Gate National Recreation Area, split by treatment (clearing versus control) and propagation type (greenhouse versus nursery grown). Missing bars indicate 0% mortality in the January and February census. Censuses were done on 15 January 2012 (red), 18 February 2012 (green), 21 April 2012 (blue) and 27 July (orange).

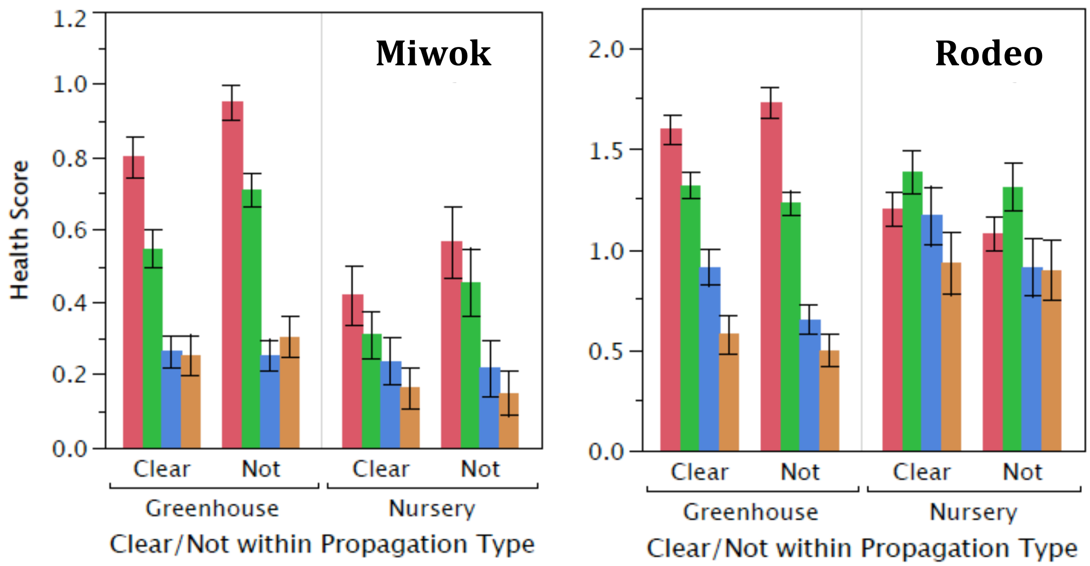

Figure 2. Average health scores of *Arenaria paludicola* as indicated by a 0-3 plant health index (Table 1) at Rodeo Beach and Miwok Trail at the Golden Gate National Recreation Area in Marin Headlands, CA. Censuses were done on 15 January 2012 (red), 18 February 2012 (green), 21 April 2012 (blue) and 27 July (orange). Error bars are ±1SE; note the difference in Y axes.

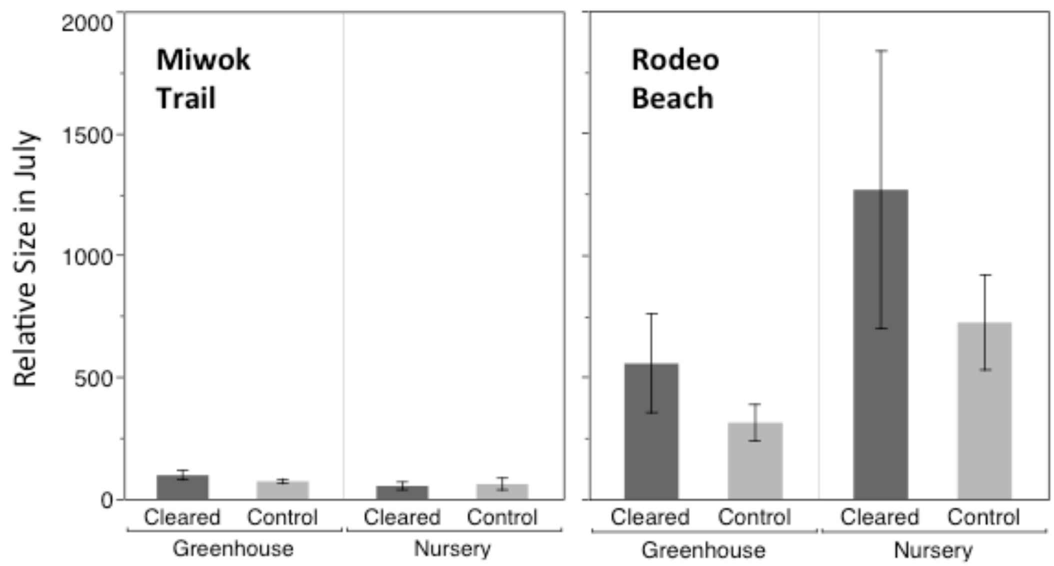

Figure 3. Average plant sizes on 27 July 2012 of transplanted *Arenaria paludicola* at Rodeo Beach and Miwok Trail at the Golden Gate National Recreation Area in Marin Headlands, CA. Relative size was calculated as number of shoots x length of longest shoot (cm). Error bars are ±1SE.

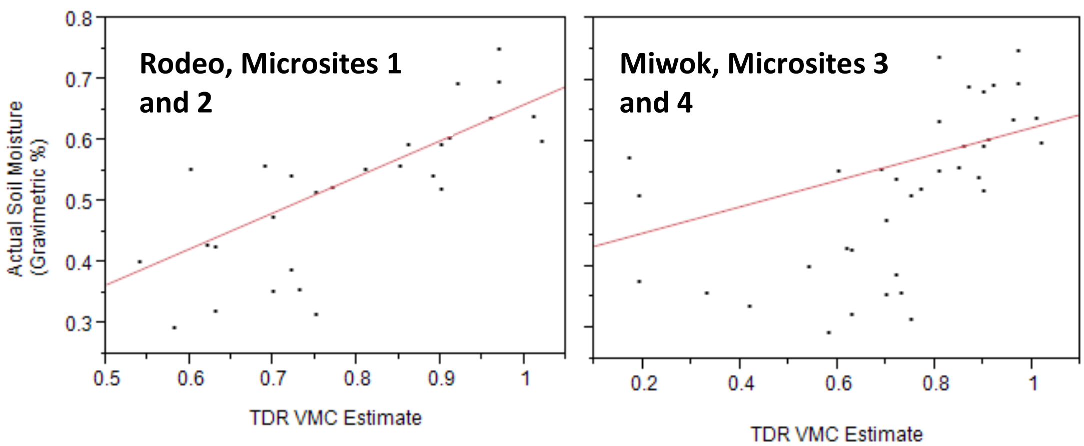

Figure 4. Gravimetric soil moisture (percent) versus volumetric moisture content estimated by TDR in the field, at the greater Rodeo site (includes Rodeo Beach, microsite 1, and microsite 2) and the greater Miwok site (includes Miwok Trail, microsite 3, and microsite 4) in the Golden Gate National Recreation Area. Measurements and soil samples were taken from the same points on 18 February 2012.

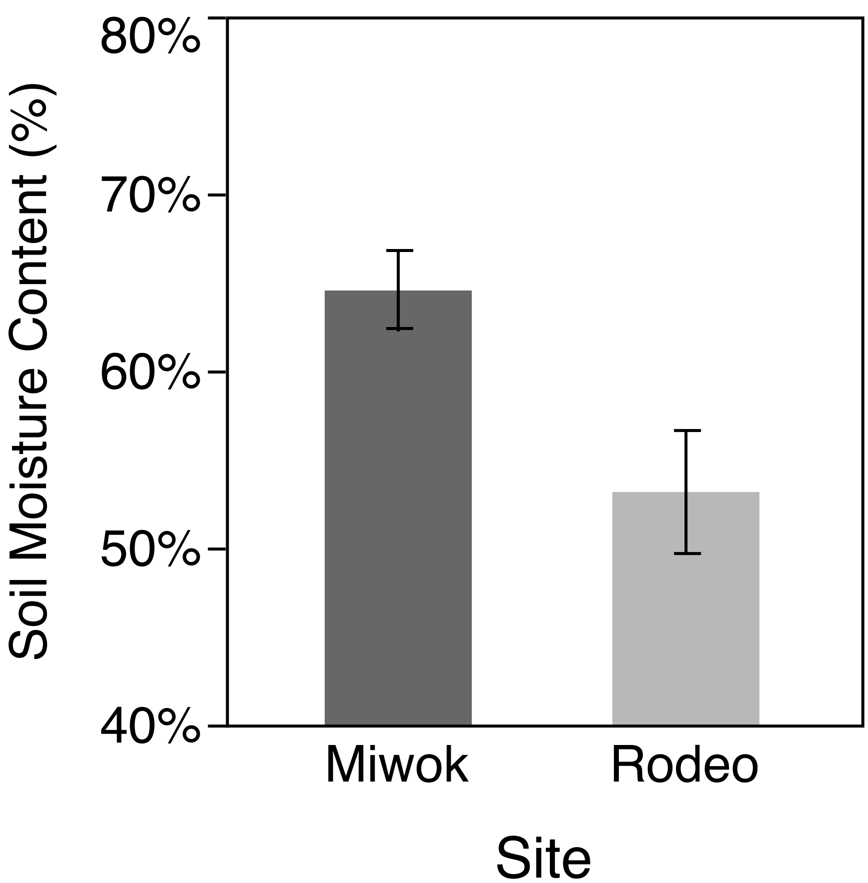

Figure 5. Soil moisture (gravimetric percent) at the two main sites (Miwok Trail and Rodeo Beach) at the Golden Gate National Recreation Area in Marin Headlands, CA. Soil samples were collected on 18 February 2012. Error bars are ±1 SE.

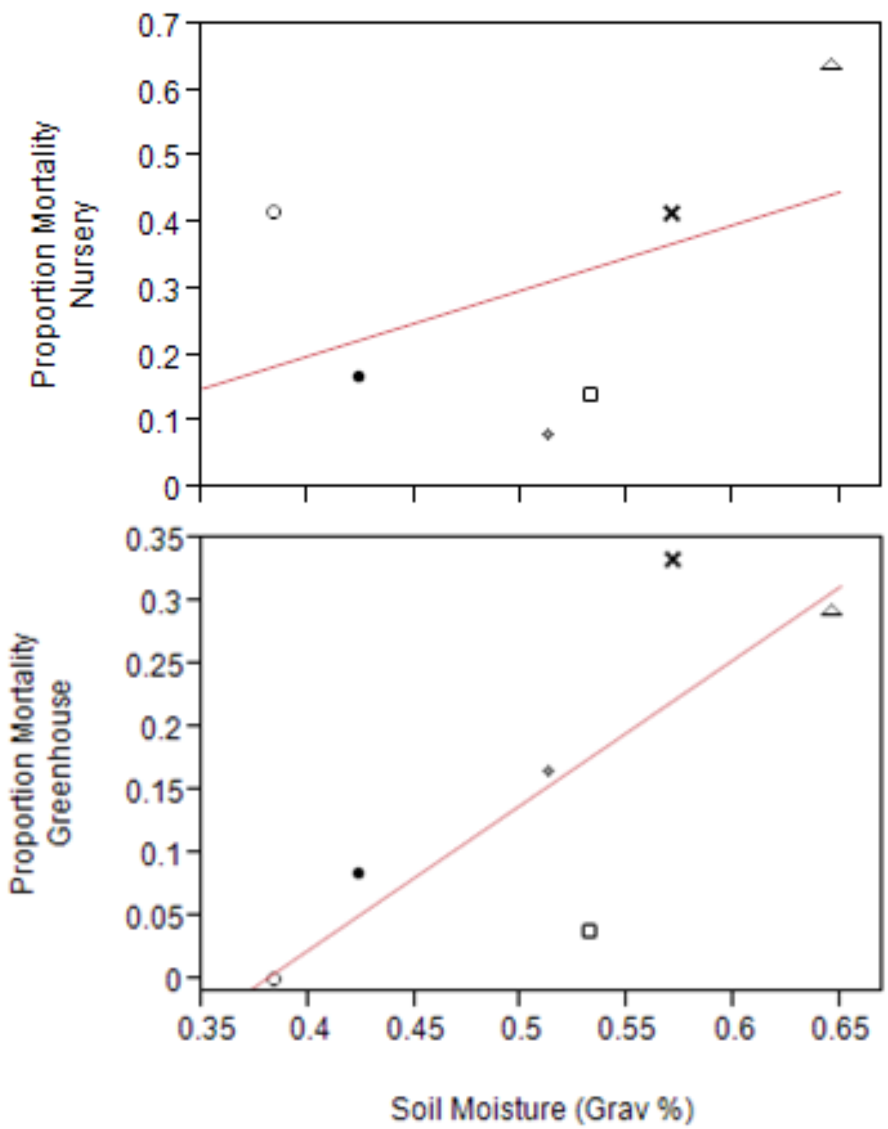

Figure 6. Proportion mortality of nursery-grown (top) and greenhouse-grown (bottom) *Arenaria paludicola* at each site (Rodeo=square, Miwok=triangle, microsite 1=open circle, microsite 2="x", microsite 3=closed circle, and microsite 4=diamond) in response to the soil moisture (gravimetric percent) on 18 February 2012. Sites are at Golden Gate National Recreation Area in Marin Headlands, CA.