

The Effect of Management on the State-listed Endangered Species  
*Symphotrichum concolor* (Asteraceae) on Nantucket Island.

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## Introduction

Sandplain grassland and coastal heathland plant communities and their associated rare species are primary targets for conservation on Nantucket Island, Massachusetts. These globally significant habitats have been and continue to be lost to development and the encroachment of trees and shrubs throughout the coastal regions of New England. Sandplain grasslands consist of a variety of grasses and forbs interspersed with dwarf shrubs such as black huckleberry (*Gaylussacia baccata*), lowbush blueberry (*Vaccinium angustifolium*), and bearberry (*Arctostaphylos uva-ursi*) (Dunwiddie et al. 1996). Dominant sandplain grassland species on Nantucket include little bluestem (*Schizachyrium scoparium*) and Pennsylvania sedge (*Carex pensylvanica*). When dwarf shrubs contribute a larger component of the species composition, the plant community is considered a coastal heathland (Dunwiddie et al. 1996).

The early successional sandplain habitats that exist on Nantucket today are the result of an extensive history of both natural disturbance (i.e. salt spray) and anthropogenic disturbance by Native Americans and European settlers. Native Americans used fire to reduce woody cover and increase open land for agriculture (Dunwiddie 1994). Heavy grazing of domestic livestock and other agricultural practices of European settlers created the large expanses of early successional habitat that existed on Nantucket until the early to mid-twentieth century. With the cessation of fire, grazing, and other agricultural practices, much of the sandplain grasslands and coastal heathlands are now being overgrown with woody species (Dunwiddie 1989). Currently, management practices such as prescribed burning, mowing, and to a lesser extent, grazing are being employed in an attempt to arrest or reverse the encroachment of woody species.

To effectively conserve the sandplain grassland and coastal heathland plant communities, it is necessary to understand the population dynamics of the individual constituent species, including rare species, within the context of ongoing habitat management. The long term monitoring protocols currently in use are not designed to evaluate the effects of habitat management on rare species. Thus, there is a need for research projects specifically intended to address management impacts on individual species of concern.

*Symphotrichum concolor* (eastern silvery aster) is declining at its northern range limit in the Northeast and is currently listed as “Endangered” in Massachusetts. The only extant populations in New England are on Nantucket Island. In the fall of 2003, we examined the distribution, abundance, and ecology of *S. concolor* on Nantucket (Freeman et al. 2003). In part, the impetus to perform this work was to facilitate an investigation into the effects of habitat management practices on *S. concolor*.

In the fall of 2004, we examined the effects of prescribed burning and mowing on *S. concolor* and also gathered a second season of data on the pollination biology of this species. Ultimately, through research on the ecology and effects of habitat management on this species, we hope to develop a conservation plan for *S. concolor* that will maintain and increase extant occurrences on Nantucket.

To determine the effects of prescribed burning and mowing on *S. concolor*, we asked the following questions:

- 1) What is the average height of plants in the burn, mow, and control treatments?
  - a. Is there a relationship between plant size and percentage of viable achenes produced?
- 2) How many flowers are produced by plants in the burn, mow, and control treatments?
- 3) Do rates of herbivory differ between burn, mow, and control treatments?
- 4) What percentages of flower heads are affected by pre-dispersal seed predation on plants in the burn, mow, and control treatments?
- 5) What is the average number of viable achenes produced by plants in the burn, mow, and control treatments?

To continue our examination of the pollination biology of this species, we asked the following questions:

- 1) Is *S. concolor* pollen-limited?
- 2) Do *S. concolor* plants exhibit outbreeding or inbreeding depression?
  - a. Do *S. concolor* plants fertilized by pollen from a disjunct population (outbreeding) produce a greater number of viable achenes than *S. concolor* plants fertilized by pollen from within the same population (inbreeding)?

## Methods

### Study System

*Symphytotrichum concolor* (Asteraceae), previously known as *Aster concolor*, is declining throughout the northern limits of its range. Records from 2001 (NatureServe) indicate occurrences of *S. concolor* in 16 states along the Atlantic coast, from Massachusetts to Florida. Current data suggests that populations exist in only 14 states, with the only remaining populations north of New Jersey occurring on Long Island, New York and Nantucket Island, Massachusetts (Table 1, Polloni 2001). Potential reasons for decline include loss of habitat due to successional processes and development. The number of occurrences in New Jersey has declined from 80 to an estimated eight at present. Furthermore, populations have been extirpated in Rhode Island and only one known population remains on Long Island, New York. Although once found in Wareham and on Chappaquiddick Island, the only remaining populations in Massachusetts are on Nantucket Island (Polloni 2001).

On Nantucket, *S. concolor* is generally restricted to open sites on dry, sandy, glacial outwash soils. Moisture requirements are likely augmented by fog and the high humidity levels associated with coastal environs. Populations of *S. concolor* in the southern United States occupy a greater variety of habitats than northern populations including both coastal and inland habitats. However, plants in inland habitats that are not exposed to the

high relative humidity of the coast are often found growing in moist soils such as near stream beds (Polloni 2001).

*Symphotrichum concolor* is a perennial plant that produces multiple, weakly rhizomatous, somewhat prostrate stems. The leaves are covered with a fine pubescence and generally lie flat against and point towards the apex of the stem. On Nantucket, *S. concolor* blooms from the end of August to the end of October. Flowers consist of lilac-colored ray flowers surrounding a cluster of white disc flowers that darken to purple with age. Propagules consist of an achene and a pappus, with dispersal occurring from the beginning of October to the middle of November (Polloni 2001).

## **Experimental Design**

### *Effects of Management*

Three sites (Madaket, Big, and the Potato Field, Fig. 1) were selected to examine the effects of two management treatments, prescribed burning and mowing, on the growth and reproductive success of *S. concolor* during the summer of 2004. The sites selected represent a subset of the populations used to examine the ecology of *S. concolor* during 2003. The Big and Madaket sites were divided into three equal sized plots. Due to the structure of the Potato Fields site, the three plots were discrete occurrences separated by at least 100m. Plots were randomly assigned to a burn, mow or control treatment. Dormant season burn treatments were implemented prior to the emergence of *S. concolor* plants on April 21, 2004. Mow treatments were performed with a tractor pulled brushhog within the same week.

Within the three sites, all emergent plants were marked and 20 plants from within each management treatment were randomly selected for further study. On study plants, we counted the total number of stems and measured the height of each flowering stem to provide an estimation of plant size. Over the course of flowering, stems were continuously monitored and flower heads counted. Open flower heads were counted and marked at the base of the bracts with a black dot applied using a permanent “Sharpie” marker. This marking helped to differentiate flowers that had already been counted from flowers recently opened and not yet counted. Rates of mammalian herbivory were estimated by determining the percentage of stalks per plant showing signs of browsing. Stems were considered browsed if the upper portion of the stem was completely removed.

Mature fruits were collected to determine the percent of viable achenes using the same protocol we used in 2003 (Freeman et. al. 2003). One stem on each of the 20 randomly selected plants within each treatment at the three study sites was covered with a mesh bag until all achenes had matured. The bagged stems were collected at the end of the growing season and the total number of flower heads, number of flower heads damaged by pre-dispersal seed predators, number of undamaged flower heads and, within the undamaged flower heads, the number of filled and unfilled achenes were counted. Flower heads were scored as damaged if any of the achenes within a flower head exhibited signs of seed predation. Visual discrimination between filled and unfilled achenes was used to establish viability (Freeman et. al. 2003).

### *Pollination biology*

Pollination studies in 2003 showed that there was no difference in the effect of pollination treatments between sites. Implementing pollination treatments in composite species is extremely labor intensive, and the results are highly dependant on how well the treatments are performed. To maximize the effectiveness of our pollination treatments, we elected to perform pollination treatments only at the Big site during 2004.

Ten plants with greater than six stems were selected from within untreated (i.e. not burned or mowed) portions of the Big site. For each plant, individual stems were randomly assigned to one of the following treatments: control, bagging control, pollen addition, out-cross, and in-cross. Control treatment stems were accessible to natural pollinators and were not otherwise treated. Bagging control stems were bagged and not hand-pollinated. The bagging control treatment was used to determine the effect of the bag on flowering and to determine whether bags were effective at excluding natural pollinators. Pollen addition stems were open to natural pollinators with additional pollen from within the same population but from surrounding plants growing further than 1m away from the pollinated plant. Plants in the out-cross treatment were bagged and flowers on those stems were hand-pollinated using pollen from a separate occurrence that was a minimum of 100m away from the Big site. Plants in the in-cross treatment were bagged and flowers on those stems were hand-pollinated using pollen from within the same population but from surrounding plants growing further than 1m away from the pollinated plant.

Pollinator exclusion bags were constructed from fine tulle mesh sewn into various size “bags” that were placed over flowering stems and secured at the base of the stem with small segments of wire. Bags were designed to exclude natural pollinators while having a minimal impact on environmental factors such as light or moisture.

Individual flowers on out-cross, in-cross, and pollen addition stems were hand-pollinated daily when stigmas became receptive. Flowering phenology, total flower production, and seed set was determined for individual stems on plants within the pollination studies.

### **Statistical Analysis**

Two-way ANOVAs were performed to assess the effect of site and management treatment on flower production, percentage of browsed stems, percentage of flower heads damaged by seed predators, seed set, and the percentage of filled achenes. To examine whether the overall distribution of flowering differed between management treatments, we compared the cumulative frequency of flowering using a two sample Kolmogorov-Smirnoff test (Sokal and Rohlf 1995). To examine the effects of pollination treatments on seed set and the percentage of viable achenes, we performed One-way ANOVAs. Tukey-Kramer HD multiple comparison tests were used to compare means within treatments for ANOVAs. Statistical analyses were performed using SYSTAT (v. 10 SPSS, Chicago, IL, USA). Phenotypic selection analysis was performed using SAS/STAT (v.9 SAS Institute Inc. Cary, NC, USA) software to determine relationships between total flower production, number of flowering stems, average stem height, bloom date, bloom time and

the reproductive fitness, which was estimated using the percentage of viable achenes. Percentage of destroyed flower heads, and percentage of visibly filled achenes were arcsine square root transformed and seed set was square root transformed prior to analysis (Zar 1999).

## Results

Mowing in April, 2004 was constrained at the Big site to an area thought to contain few, if any *S. concolor* plants. The original section of the population marked to be mowed during 2004 was mistakenly mowed by a private party during December 2003. To maintain consistency in the time treatments were implemented, the mow treatment was reassigned to a location that had not previously been treated and was adjacent to areas known to contain *S. concolor*. However, because the mow treatment was moved after plants had senesced, there was no confirmation that plants existed in the new location. When plants emerged, surveys showed there were no plants in the mow treatment area at the Big site. Although the mow treatment in the Potato Fields site was not moved from its original location, the area yielded only 5 plants. Thus, due to insufficient replicates, mow treatments were excluded from analyses. Results will be presented for only the burn and control treatments.

The average total number of flowering stems was significantly greater for plants in the burn treatments compared to controls at both the Big and Madaket sites ( $F_{1,88}=10.96$ ,  $P=0.001$ ) (Fig. 2). There was a significant difference in the average height of unbrowsed stems in the burn ( $31.05\text{cm} \pm 1.05$ ) and control ( $39.80\text{ cm} \pm 1.12$ ) treatments ( $F_{1,72}=32.56$ ,  $P<0.0001$ ) (Table 2). Similarly, there was also a significant difference in the average height of unbrowsed stems on plants in the Madaket site and the Big site ( $F_{1,72}=16.83$ ,  $P=0.0001$ ). The average height of unbrowsed stems on plants in the Madaket site was  $38.56\text{cm} \pm 1.03$  and the average height of unbrowsed stems in the Big site was  $32.27\text{cm} \pm 1.13$ . Data for stem number and stem height was not collected for plants in the Potato Field.

Plants in the burn treatments produced similar numbers of flowers to plants in the control treatments ( $F_{1,127}=2.658$ ,  $P=0.106$ ) (Fig. 3). However, there was a significant effect of site on the number of flowers produced ( $F_{1,127}=3.175$ ,  $P=0.045$ ). Plants in the Potato Fields produced significantly more flowers than plants at the Big site ( $P=0.045$ ). There was no significant difference in total flower production between the Madaket site and the Big or Potato Field sites ( $P=0.835$  and  $P= 0.130$ , respectively).

The timing of flower production was similar at the Big and Madaket sites and the burn treatment at the Potato Field site. Flower production occurred later in the season at the Potato Field control site. There were more flowers produced by plants in the burn treatment compared to controls at the Madaket site but not at the other sites (see appendix). To explore the observed site differences, we excluded the Potato Field from an analysis of total flower production. When the Potato Field site was excluded from analysis of total flower production, plants in the burn treatment areas produced significantly more flowers than plants in the control treatment ( $F_{1,87}=5.27$ ,  $P=0.0242$ )

(Fig. 4) and there was no difference in flower production between Madaket and the Big site ( $F=0.456$ ,  $P=0.501$ ).

There was a significant effect of management treatment on average weekly floral display of plants. Plants in the burn treatment areas at all three sites had a significantly larger weekly floral display than plants in the control treatments ( $F_{2,116}=4.18$ ,  $P=0.043$ ) (Fig. 5). There was also a significant effect of site on the average weekly floral display ( $F_{2,116}=3.85$ ,  $P=0.024$ ). Plants in the Potato Field ( $10.70 \pm 1.36$ ) produced significantly more flowers than plants in either Madaket ( $6.74 \pm 1.27$ ) or the Big ( $5.71 \pm 1.32$ ) sites ( $P=0.026$ ). A two-sample Kolmogorov-Smirnoff test on the cumulative distribution of flowering showed a significant difference between management treatments. Plants in the burn treatment area bloomed earlier and reached peak bloom earlier than plants in the control treatment (Fig. 6).

There was a significant interaction between site and management treatment ( $F_{1,88}=18.90$ ,  $P<0.0001$ ) for the percentage of browsed stems. In Madaket, there was no significant difference in the percentage of stems browsed in the control and burn treatments, whereas at the Big site, there was a significantly greater percentage of stems browsed in the control area when compared to the burn area ( $P<0.0001$ , Fig. 7). Data for stem browsing was not collected for plants in the Potato Fields.

Seed predation was consistent across sites ( $F_{2,52}=1.01$ ,  $P=3.727$ ) and management treatments ( $F_{1,52}=0.443$ ,  $P=0.509$ ). An average of 6.43 % of all flower heads had at least some seeds destroyed by pre-dispersal seed predators and within plants that experienced seed predation, an average of 19.76 % of flower heads were destroyed.

Neither seed set or the percentage of viable achenes differed between sites ( $F_{2,52}=1.71$ ,  $P=0.190$  and  $F_{2,52}=2.16$ ,  $P=0.126$ , respectively) or management treatments ( $F_{1,52}=0.099$ ,  $P=0.755$  and  $F_{1,52}=0.002$ ,  $P=0.968$ , respectively). There was a significant effect of management treatment on the total number of achenes, filled and unfilled, produced per flower head ( $F_{1,52}=4.04$ ,  $P=0.0495$ ). Plants in the burn treatment produced an average of  $27 \pm 1.06$  achenes per flower head while plants in the control treatment produced an average of  $24 \pm 1.06$  achenes per flower head (Table 4).

There was a significant effect of pollination treatment on the percentage of viable achenes produced ( $F_{4,45}=3.87$ ,  $P=0.009$ ) (Fig. 8). A Tukey's pairwise comparison test showed that the average percentage of viable achenes was significantly greater for flower heads in the pollen addition and outcross treatments than for stems in the bagging control treatment ( $P=0.010$  and  $P=0.021$ , respectively). Pairwise comparisons of all other pollination treatments were not significant.

Selection analyses was performed to examine the relationship between stem height, flower phenology (bloom date and bloom time) and flower production and the percentage of viable achenes produced by plants at the Big site and in Madaket. Sample size for this analysis was quite low,  $n=18$ , because plants in the Potato Field site were excluded as data on stem heights and stem numbers were not available. We found no significant effect of any of the characteristics examined on the percentage of viable achenes

produced by plants and there were no apparent trends suggesting strong correlations of traits to filled achene production (Fig. 9).

## Discussion

The increased number of flowering stems (Fig. 2), larger weekly floral display (Fig. 5), and, in some cases, increased flower production (Fig. 3 and Fig. 4) by plants in areas that were burned in the early spring is consistent with the idea that burning can stimulate growth in a disturbance adapted grassland species such as *S. concolor*. Increased plant productivity in some fire-adapted grasslands is attributed to increases in limiting resources such as nutrients, sunlight, and temperature (Bennett et al. 2002). Although the plants in the burn treatments exhibited fire stimulated increases in some traits, the percentage of filled achenes produced and seed set of plants in the burn treatment areas were not significantly greater than that of the plants in the control areas (Table 4). Thus, fire effects were observed at the whole plant level (i.e. total number of flowering stems, weekly flower production, and total number of flowers produced) and not generally evident at the level of flower head (i.e. number of filled achenes, percentage of filled achenes, and seed set). As there was no significant effect of fire on either of the measures we use to establish reproductive success, percentage of filled achenes or seed set, our results do not show a clear benefit of prescribed fire to reproductive fitness. In addition, our studies have been limited to disturbance impacts on the reproductive effort of established plants. We have not addressed the effects of disturbance on seed germination or seedling establishment.

Although there was no significant effect of fire on the percentage of filled achenes or seed set, on a per flower head basis, the cumulative number of filled and unfilled achenes produced per flower head was significantly greater in the burn areas than in the control areas (Table 4). This would suggest that there must be either an increase in unfilled achenes or an increase in filled achenes, or both, to account for the overall total being significantly greater. Yet, there were no statistical differences in either the seed set (number of filled achenes per flower head) or the number of unfilled achenes per flower head between plants in the burn and control areas. Furthermore, there was no significant difference in the percentage of filled achenes produced by plants in the burn and control treatments, yet there were significantly more flowers produced by plants in burn treatment areas.

Our data show the following two results for which there are not clear explanations:

1) There are more total seeds produced by plants in the burn treatment but neither the total number of filled or unfilled seeds were effected by management, and 2) that plants in the burn treatment produced more flowers and had a similar percentage of filled seeds to control plants but did not produce significantly more filled seeds per plant. One plausible explanation for these observations is that our small sample size is leading to a lack of statistical power. To avoid negatively impacting the *S. concolor* plants that we have on Nantucket, estimates of filled achenes and seed number were performed using a subset of flower heads (as mentioned in the methodology, seed numbers were estimated

using flower heads collected from only one stem on a plant) from a small number of plants. Therefore, the variability within samples is frequently high. It may be the case that counts of total achenes provides sufficient numbers to elucidate an effect of prescribed fire but a high level of variability resulting from a small sample size is overarching any effect on the total number of filled achenes per plant and the two components of total achenes, seed set and the number of unfilled achenes per flower head.

Similarly, small sample size may be confounding the results of the selection analysis. Traditional selection analyses have a minimum of 40 to 50 samples (Eric VonWettberg, *personal communication*) and we had only 18. However, the lack of any noticeable trends in figure 9 suggests that the traits measured may not be highly influential in the production of viable achenes.

Our results suggest that differences in habitat characteristics may have a greater effect on flower production than fire. As previously mentioned, due to a lack of contiguous large populations, the control and burn sites at the Potato Field were discrete occurrences separated by approximately 100m. The separation of the treatments areas was not ideal as the control plants were growing in an area with a greater density and height of surrounding vegetation than the plants in the burn area. Plants in the control area were taller and produced more flowers, which is likely a response to habitat (see appendix for figures depicting the effects of management treatment within site).

When measures of flower production are compared between the three control areas, plants in the Potato Field ( $67.4 \pm 12.03$ ) produced more than two times as many flowers as plants at Madaket ( $28.0 \pm 10.8$ ) or the Big site ( $33.1 \pm 12.6$ ). In contrast, when measures of flower production are compared between the three burn areas, plants in the Potato Field ( $69.21 \pm 12.64$ ) produced somewhat similar numbers of flowers as plants at Madaket ( $63.0 \pm 11.7$ ) and at the Big site ( $44.3 \pm 12.3$ ) (see appendix). Flower production was assessed within the Potato Field site in 2003, prior to the initiation of treatment, for both control and burn areas. Pre-treatment data from 2003 indicates that the plants used as the control treatment produced an average of  $105.4 \pm 15.8$  flowers while plants in the burn treatment area produced an average of  $72.7 \pm 15.8$  flowers. Flower production in the control and burn treatment areas in 2004 was  $67.4 \pm 12.1$  and  $69.2 \pm 12.6$ , respectively. Thus, between 2003 and 2004, flower production in the control treatment area decreased while flower production in the burn area was maintained. However, the initial rate of flower production measured in 2003 is not reflected in the analysis comparing flower production of plants in the 2 management treatments in 2004. By examining flower production at the Potato Field control and burn sites using data from 2003 as reference, there is some indication that burning positively influenced flower production.

Plants in the burn treatment areas bloomed earlier and the cumulative flowering distribution was significantly effect by prescribed fire. The change in flowering phenology that results from burning may influence seed set. Plants in the burn treatments had a greater percentage of flowers in bloom at one time which may serve to attract more pollinators. However, a shorter bloom time may make the plants in the burn treatments more susceptible to environmental (i.e. weather-related) limitations on pollinators. In

addition, the shorter flowering period may increase or decrease overlap with the flowering of other plant species. Our observations of pollinator behavior in 2003 indicated that most pollinators spent the majority of their time pollinating other more common asters and only occasionally visited *S. concolor*. Concentrating flowering when other asters are also flowering may increase the likelihood of pollination because more pollinators are drawn to the area. On the other hand, abundant flowers of other species may detract a limited number of pollinators from visiting *S. concolor*. By blooming and reaching peak bloom earlier than control plants, plants in the burn treatment areas may increase or decrease overlap with pollinators, altering the potential for pollen limitation. Changes in flowering phenology have been linked to pollen limitation and reductions seed set for a number of species (Freeman et al. 2003, Juenger and Bergelson 1997, Gutian and Sanchez 1992). Although *S. concolor* is not significantly pollen-limited, average seed set of pollen addition plants was consistently higher over two years of study. A slight change in overlap with natural pollinators in a mildly, though not significantly, pollen limited species, may interact with the seemingly positive effects of prescribed fire on seed set.

Browsing and seed predation were not consistently effected by management or by site. The percentage of browsed stems was between 34 % and 43 % for all sites and treatments with the exception of plants in the burn treatment in the Big study site, where the average number of browsed stems was only 20 % (Fig. 7). The average rate of seed predation was 6.43 % and this was consistent across both management treatment and site.

Similar to results in 2003, the percentage of filled achenes varied substantially among pollination treatment (Fig. 8). The average percentage of filled achenes from the bagging control treatment was 2.74 %. This value is extremely low in comparison to the percentage of filled achenes from the control, pollen addition, outcross, and incross treatments. Although there was no significant difference in the percentage of filled achenes produced in the control, pollen addition, outcross and incross treatments, with the exception of the bagging control, the incross treatment produced the lowest percentage of filled achenes (13.4%). Furthermore, the control, pollen addition, and outcross treatments all produced a significantly higher percentage of filled achenes than the bagging control treatment whereas there was no statistical difference in the percentage of viable achenes produced by the incross treatment and the bagging control treatment. This suggests that inbreeding depression has the potential to reduce the percentage of filled achenes produced in some populations.

Most incompatibility in the Asteraceae is the result of a sporophytic self-incompatibility mechanism. Inbreeding is particularly detrimental in small populations of plants that exhibit sporophytic self-incompatibility, as a certain number of S-alleles must be maintained within a population for the breeding system to function. Declines in population size may lead to a reduction in the number of different S-alleles within the population, which can result in decreased compatibility (de Nettancourt 1977, DeMauro 1993, Luijten et al. 2002). For example, the last remaining population of *Hymenoxys acaulis* var. *glabra* (Asteraceae) in Illinois is effectively extinct because this species demonstrates a sporophytic incompatibility mechanism, and repeated inbreeding in the

population of 30 plants resulted in a loss of mating type S-alleles. The adult population persisted on account of the perennial life form, but no longer produced viable seeds (DeMauro 1993).

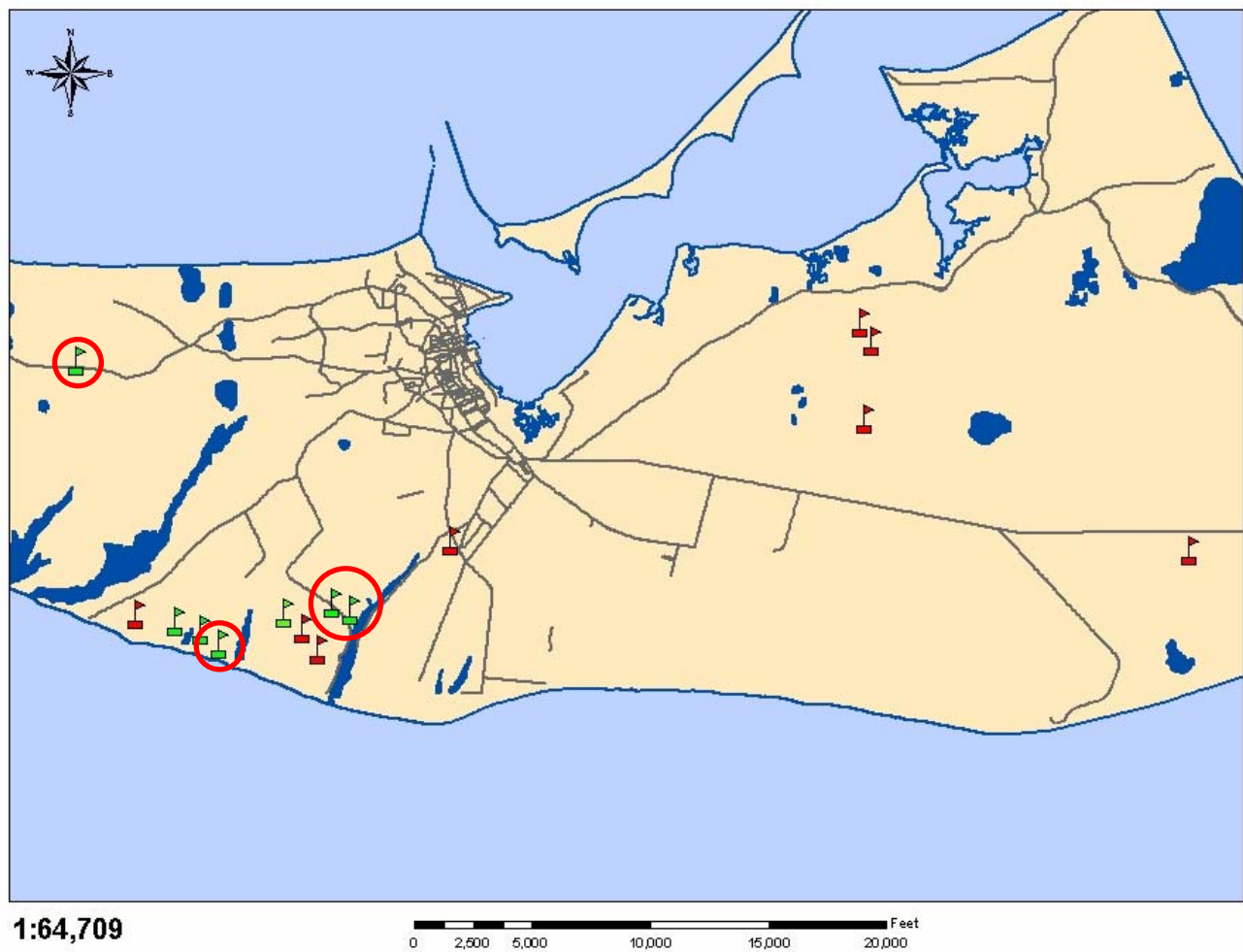
The potential for inbreeding depression to limit self-incompatible species remains one of the greatest conservation concerns for *S. concolor*. Over half of the *S. concolor* individuals in our study areas were found in the three largest populations, indicating the importance of protecting these populations. The remaining half of the plants occur in small populations where low seed viability may place these populations at risk of extirpation.

Our results from 2004 indicate that outcrossing and pollen transfer may play a major role in the reproductive success of *S. concolor*. We are currently addressing issues of genetic variation within and between occurrences of *S. concolor* on Nantucket and throughout the species range. We expect studies of genetic variability to add to the results of our hand-pollination studies by providing additional insight into the possibility for inbreeding depression to limit the persistence of this species on the island. In addition, we will attempt to clarify some of the remaining questions regarding the response of *S. concolor* to prescribed fire by further examining the reproductive success of plants 1-year post-management. We hope that our findings are providing and will continue to provide land managers with sufficient data to insure the survival of *S. concolor* on Nantucket Island.

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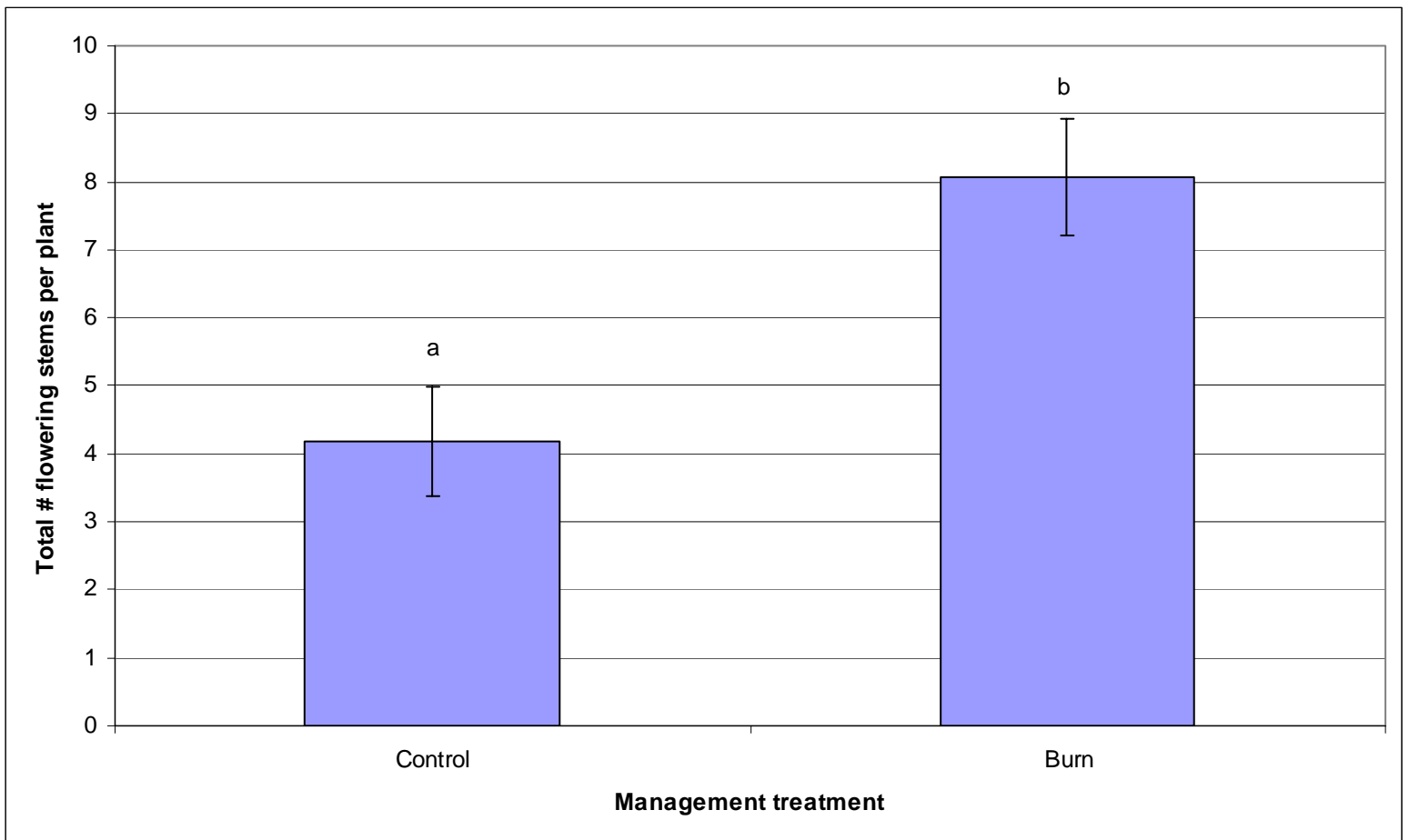
## Literature Cited

- Bennett L.T., Judd T.S. and Adams M.A. (2002) Growth and nutrient content of perennial grasslands following burning in semi-arid, sub-tropical Australia. *Plant Ecology* 164: 185-199.
- de Nettancourt, N. (1977) Incompatibility in angiosperms: Monographs on theoretical and applied genetics. Springer-Verlag, New York, New York, USA, 230 pp.
- DeMauro, M.M. (1993) Relationship of breeding system to rarity in the lakeside daisy (*Hymenoxys acaulis* var. *glabra*). *Conservation Biology* 7: 542-550.
- Dunwiddie, P.W. (1989) Forest and Heath: The Shaping of the Vegetation of Nantucket Island. *Journal of Forest History* 33: 126-133.
- Dunwiddie, P.W. (1994) Martha's Vineyard landscapes: the nature of change. The Vineyard Conservation Society and P.W. Dunwiddie, Edgartown, MA.
- Dunwiddie, P., Zaremba, R., and K. Harper (1996) A classification of coastal heathlands and sandplain grasslands in Massachusetts. *Rhodora* 98: 117-145
- Freeman, R.S., Brody, A.K., and C.D. Neefus (2003) Flowering phenology and compensation for herbivory in *Ipomopsis aggregate*. *Oecologia* 136:394-401.
- Freeman, R.S., Steinauer, E.M., and S.A. Treanor (2003) Aspects of the population biology of the state-endangered species *Symphotrichum concolor* (Asteraceae) on Nantucket Island. Report to Natural Heritage.
- Gutian, J, Sanchez, J.M. (1992) Flowering phenology and fruit set of *Petrocarptis grandiflora* (Caryophyllaceae). *International Journal of Plant Science* 153:409-412.
- Juenger, T., Bergelson J. (2000) Pollen and resource limitation of compensation to herbivory in Scarlet Gilia, *Ipomopsis aggregata*. *Ecology* 78:1684-1695.
- Luijten, S.H., Kery, M., Oostermeijer, J.G.B., and H.C.M. Den Nijs (2002) Demographic consequences of inbreeding and outbreeding in *Arnica Montana*: a field experiment. *Journal of Ecology* 90:593-603.
- Polloni, P. (2001) Aster concolor L. (Eastern Silvery Aster) Conservation and Research Plan. New England Wild Flower Society, Framingham, Massachusetts, USA.
- Sokal R.R., Rohlf F.J. (1995) Biometry, 3rd edn. Freeman, San Fransisco.
- Zar, J.H. (1999) Biostatistical Analysis, 4th edn. Prentice Hall, New Jersey.

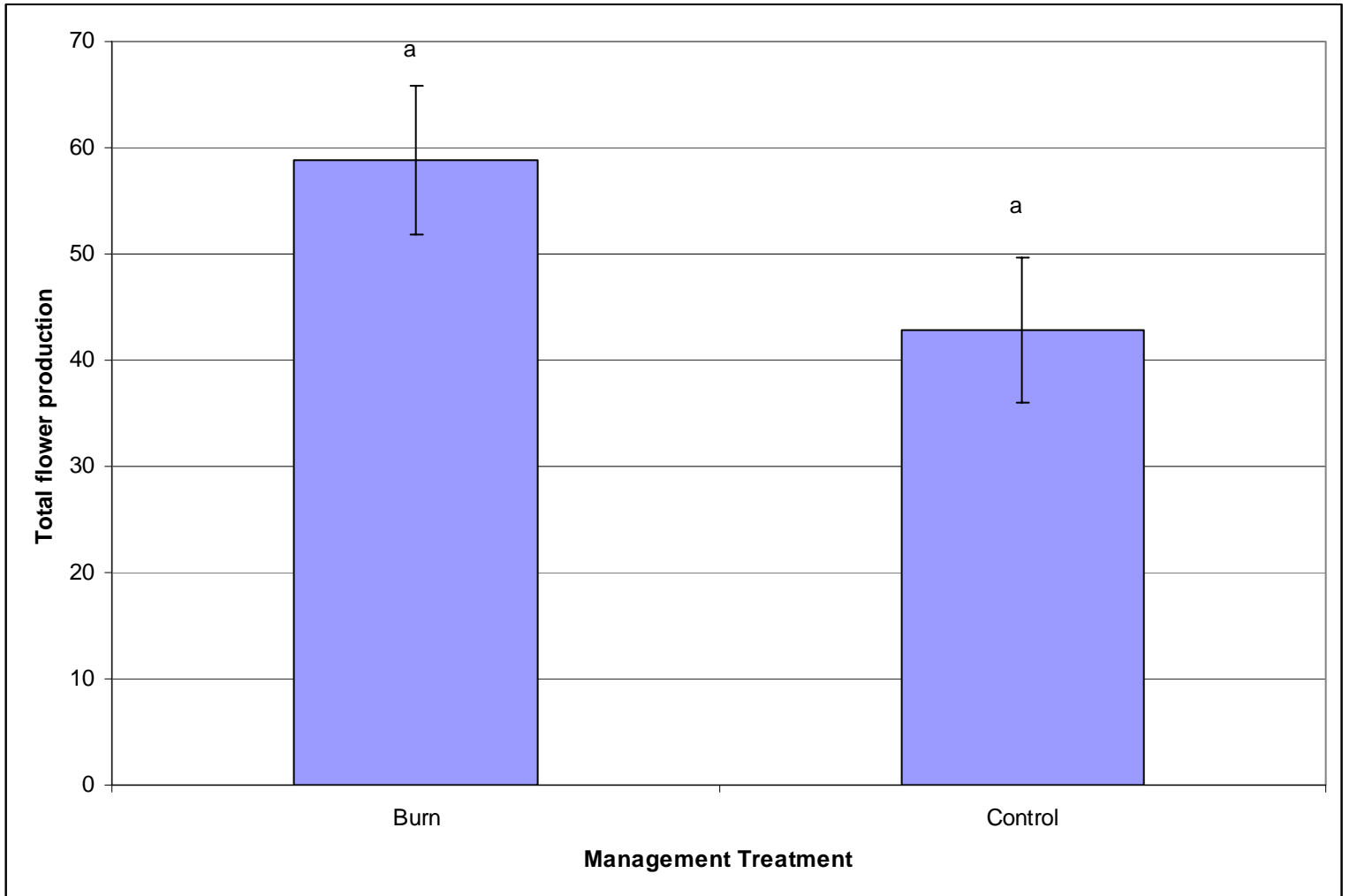


**Figure 1.** Map of *Symphyotrichum concolor* occurrences on Nantucket Island. Fifteen occurrences, totaling approximately 2000 plants, were located during surveys in the fall of 2003. Red flags denote occurrences that were surveyed but not used as study sites and green flags indicate occurrences used as study sites during 2003. Circles indicate sites used to examine the effects of management on *S. concolor* during 2004.

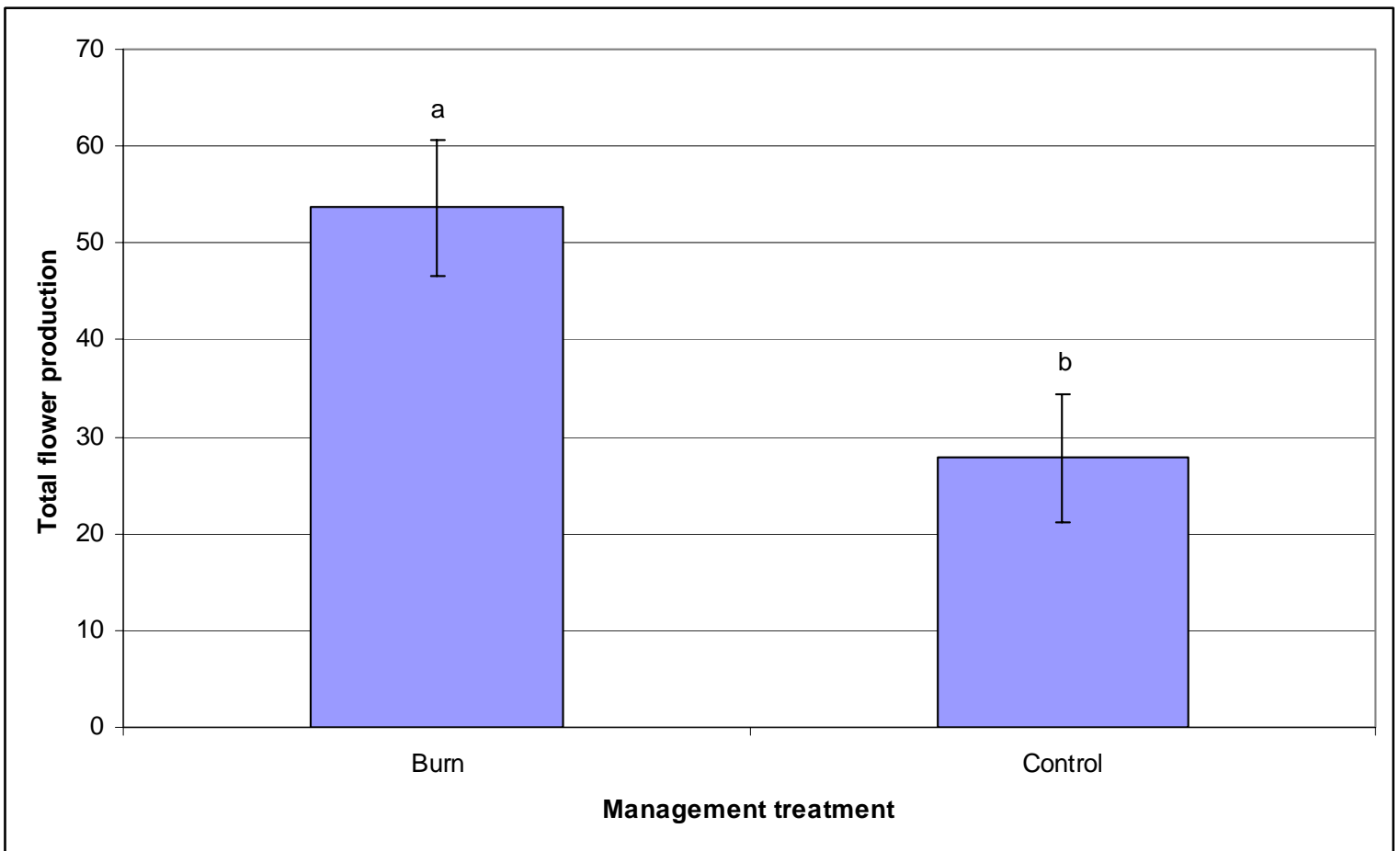
**Figure 2.** The total # of flowering stems on plants in the control and burn treatment areas. Plants in the burn treatment produced a significantly greater number of flowering stems than plants in the control area. *Error bars* represent standard errors calculated using the least squares means generated in SYSTAT. *Letters* indicate significant differences ( $P < 0.05$ ) between means compared using a Tukey-Kramer HD multiple comparisons test.



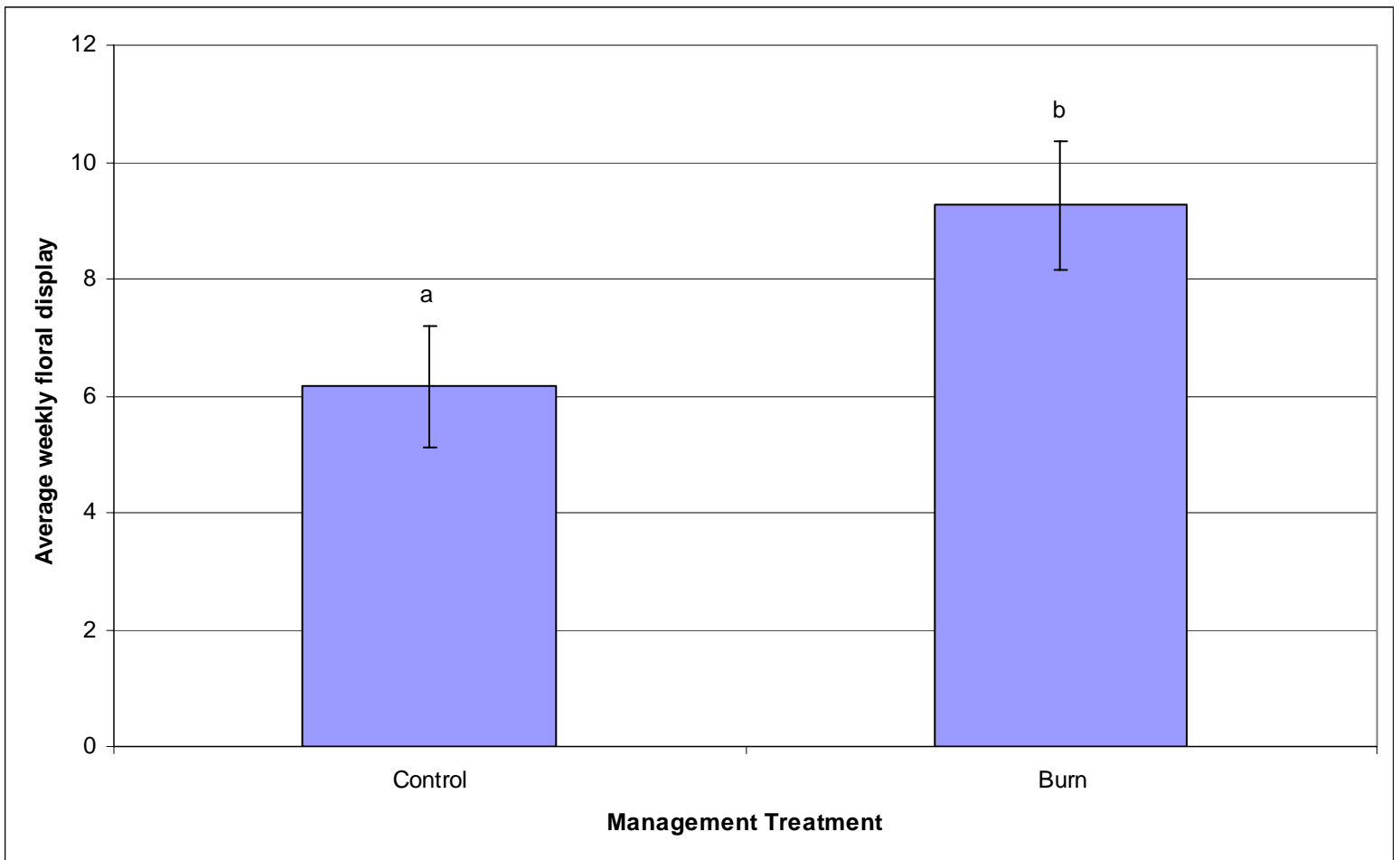
**Figure 3.** The total # of flowers produced by plants in the control and burn treatment areas at the three sites (Big, Madaket, and Potato Field). There was no significant difference in the total number of flowers produced by plants in the burn and control treatments. *Error bars* represent standard errors calculated using the least squares means



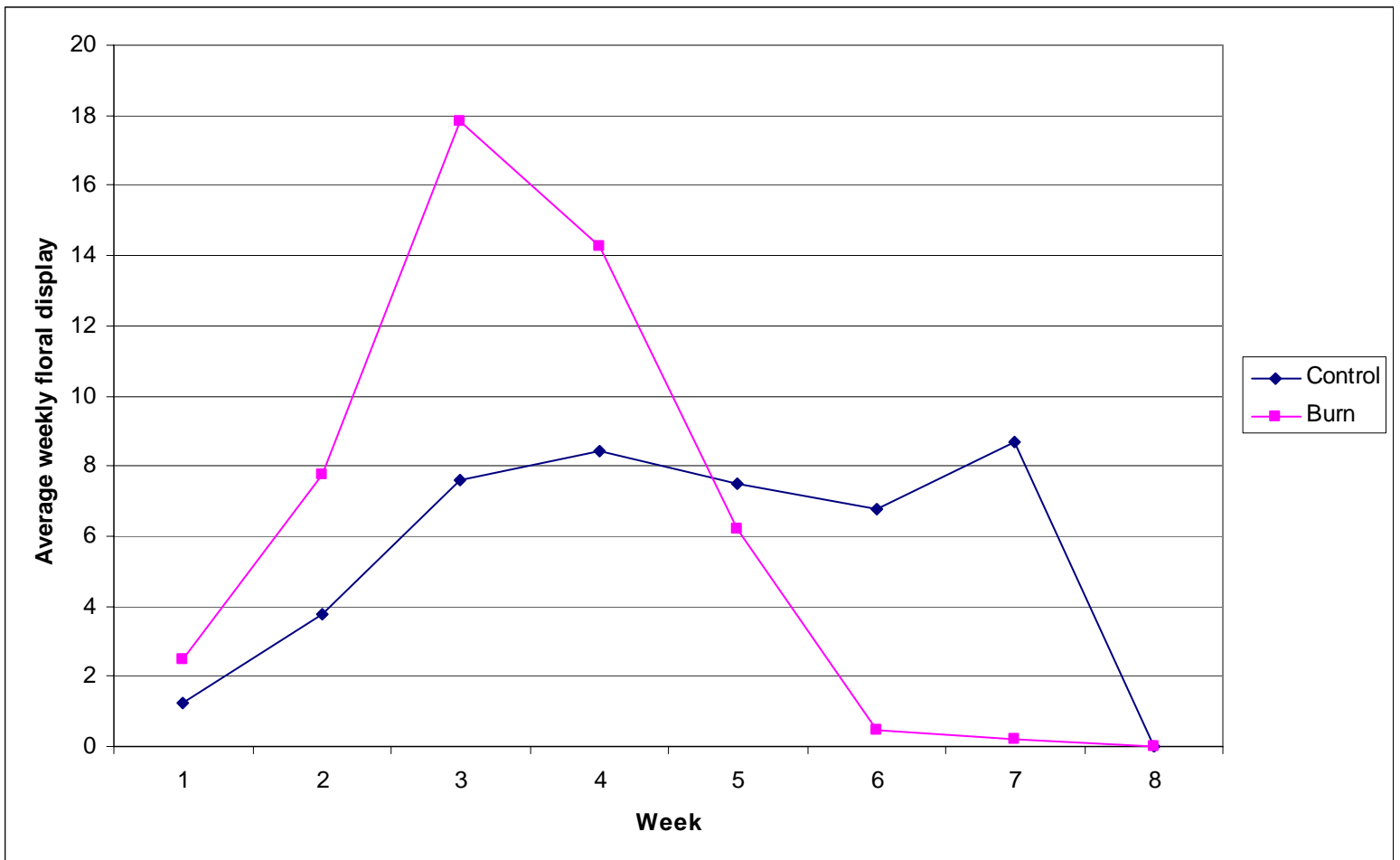
**Figure 4.** The total # of flowers produced by plants in the control and burn treatment areas at the Big and Madaket sites. There were significantly more flowers produced by plants in the burn treatments areas. *Error bars* represent standard errors calculated using the least squares means generated in SYSTAT. *Letters* indicate significant differences ( $P<0.05$ ) between means compared using a Tukey-Kramer HD multiple comparisons test.



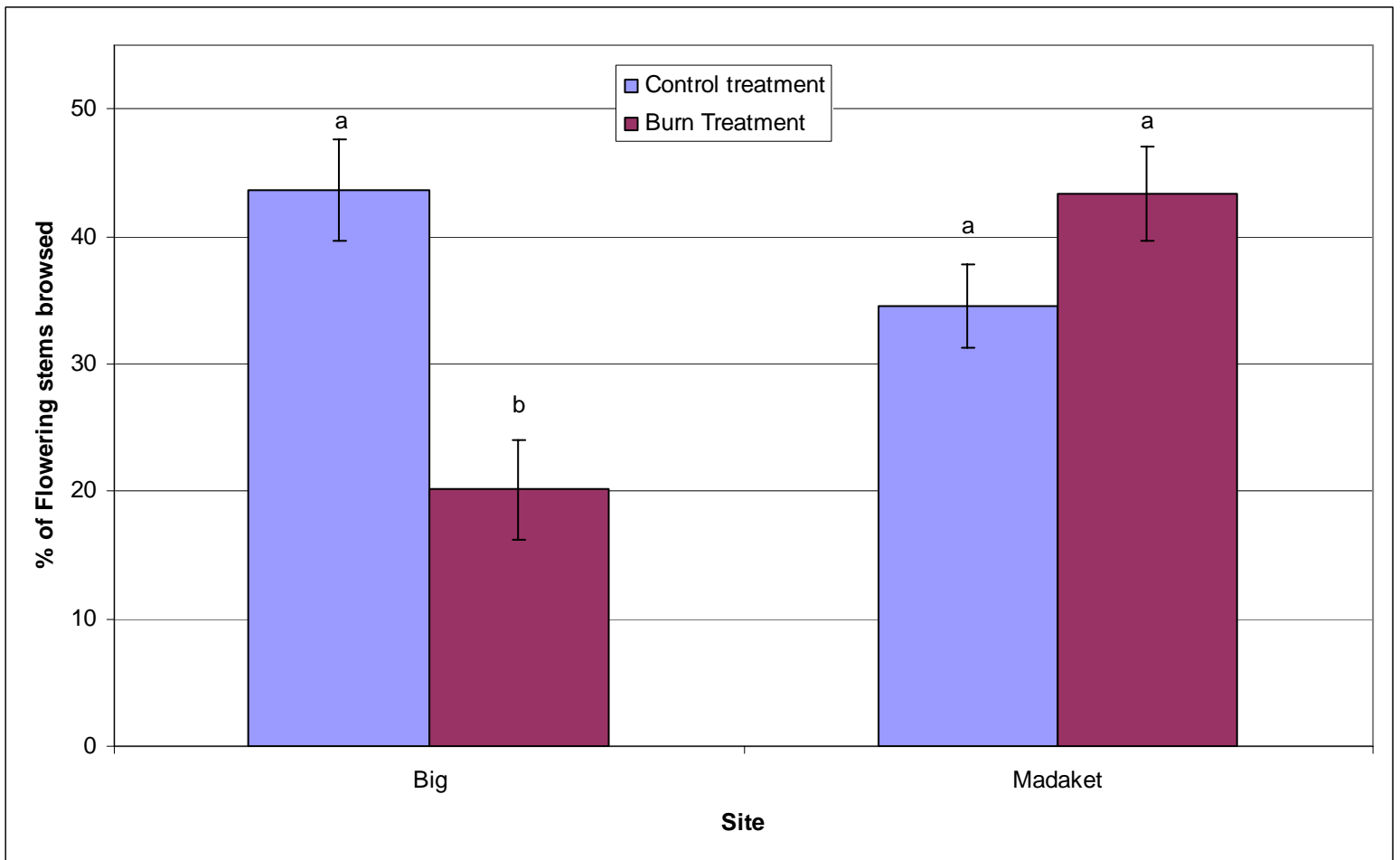
**Figure 5.** The average weekly floral display in the burn and control treatments. The average number of flowers on display was significantly greater for plants in the burn treatment than in the control treatment. *Error bars* represent standard errors calculated using the least squares means generated in SYSTAT. *Letters* indicate significant differences ( $P < 0.05$ ) between means compared using a Tukey-Kramer HD multiple comparisons test.



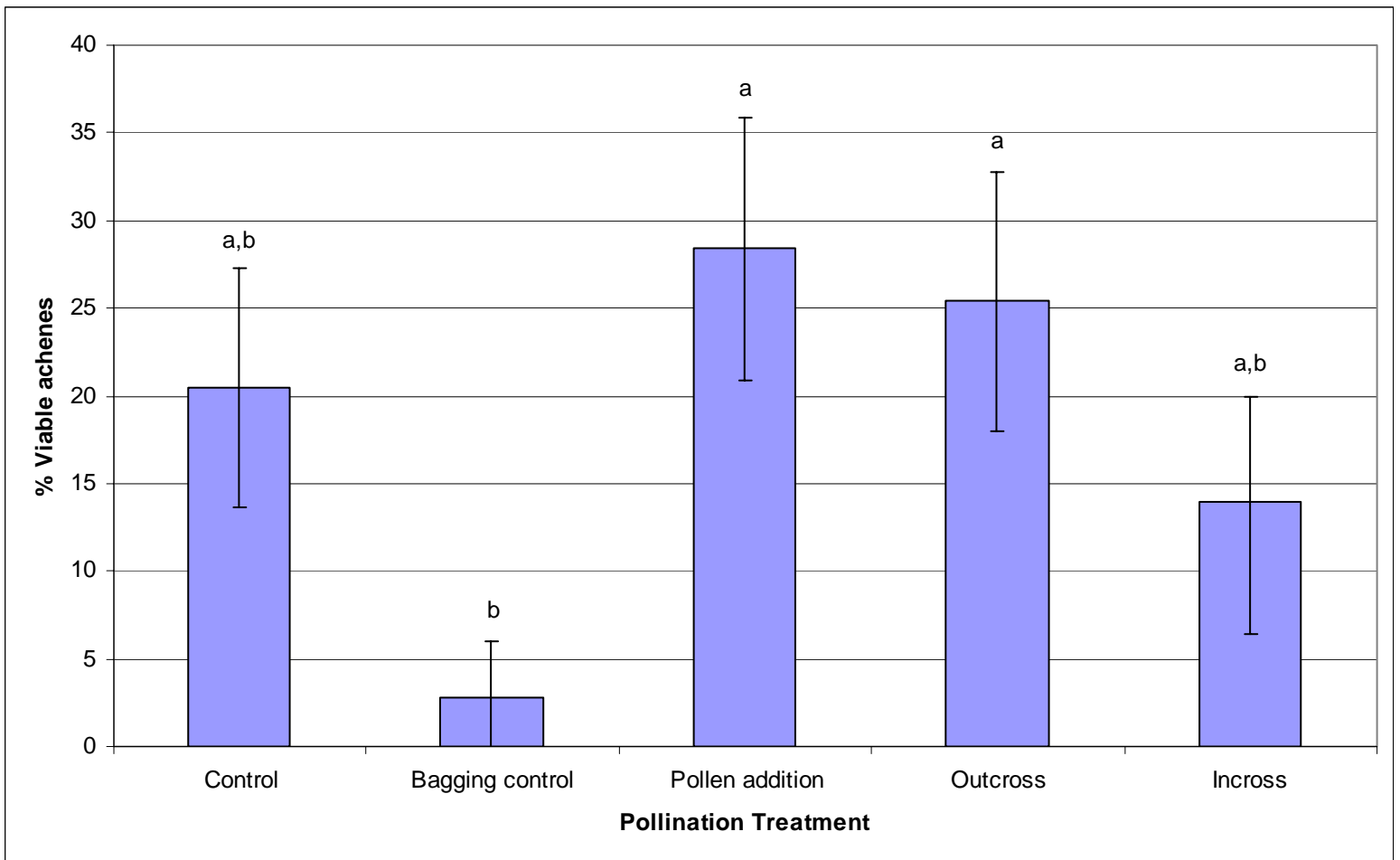
**Figure 6.** Seasonal course of flowering depicted as the average weekly floral display of plants in the two management treatments. Kolmogorov-Smirnov maximum differences ( $D$ ): burn vs. control  $D=0.265$ ,  $P<0.0001$ .



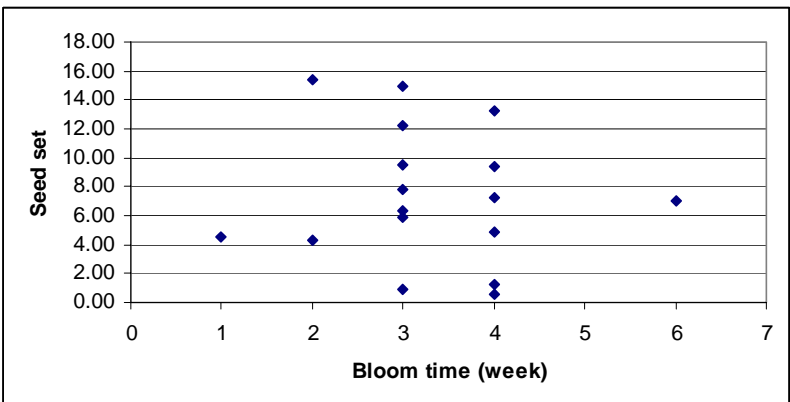
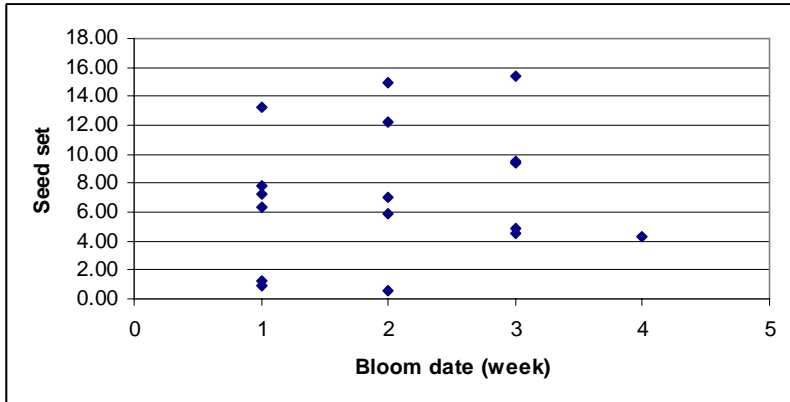
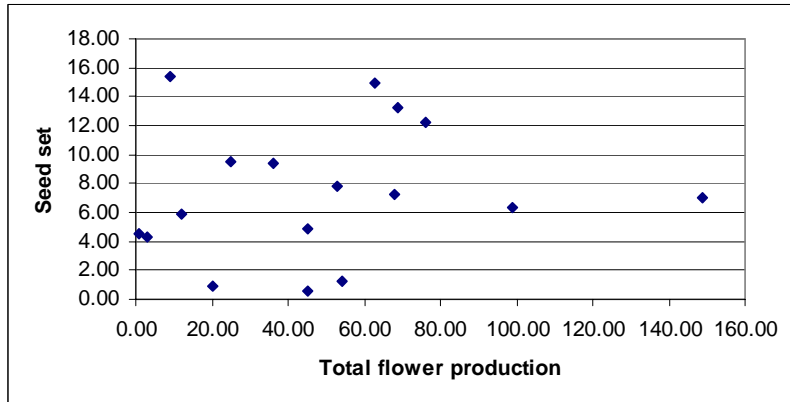
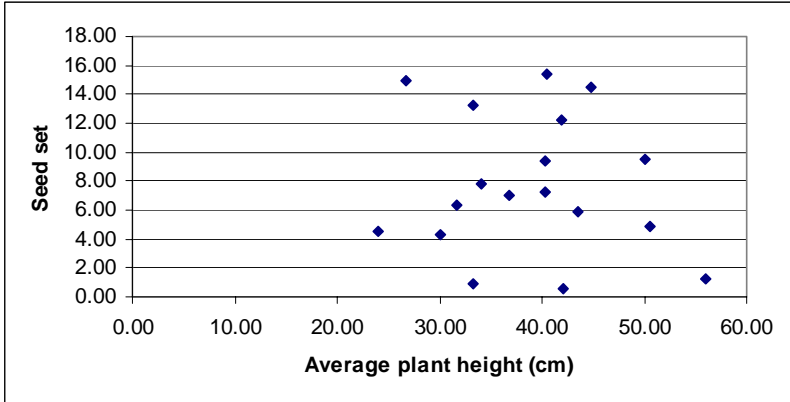
**Figure 7.** The average percentage of flowering stems browsed on plants at the Big and Madaket study sites in the burn and control treatments. The percentage of flowering stems browsed was significantly lower on plants in the burn treatment area at the Big study site than on plants in the control and burn treatment areas in Madaket or the control treatment area at the Big study site. *Error bars* represent standard errors calculated using the least squares means generated in SYSTAT. *Letters* indicate significant differences ( $P < 0.05$ ) between means compared using a Tukey-Kramer HD multiple comparisons test.



**Figure 8.** Average percentage of filled achenes produced by plants in the 5 pollination treatments at the Big site. *Error bars* represent standard errors calculated using the least squares means generated in SYSTAT. *Letters* indicate significant differences ( $P < 0.05$ ) between means compared using a Tukey-Kramer HD multiple comparisons test.



**Figure 9.** Relationship between phenotypic traits used in selection analysis and reproductive fitness, measured as seed set.



**Table 1.** Occurrence and status of *Aster concolor* in the United States based on information from Natural Heritage Programs. Table reproduced from the New England Plant Conservation Program Conservation and Research Plan for *Aster concolor* L. prepared by Pamela Polloni (2001).

Occurs & Listed (as S1, S2, or T & E)	Occurs & Not Listed (as S1, S2, or T & E)	Occurrence Unverified	Historic (likely extirpated)
Massachusetts (S1;E) -6 current and 9 historic occurrences New York (S1)	North Carolina (S5) -locally common  South Carolina (SR)*	Alabama (SR)  Georgia (SR)	Rhode Island  Delaware
New Jersey (S2)	Tennessee (SR)**	Florida (SR)	District of Columbia
Maryland (S1)		Louisiana (SR)	
Kentucky (S2)		Mississippi (SR)	
		Virginia (SR)	

\* Occurrence verified by personal communication between Bruce Sorrie and Pamela Polloni

\*\*Occurrence verified by personal communication between Ronald Jones and Pamela Polloni

**Table 2.** Average unbrowsed stem heights for plants at Madaket and the Big site and in the control and burn treatments. Standard errors were calculated using the least squares means generated in SYSTAT. Letters indicate significant differences ( $P < 0.05$ ) between means compared using a Tukey-Kramer HD multiple comparisons test.

		Average Stem Height (cm)	± SE
<b>Site</b>	Madaket	38.56 <sup>a</sup>	1.03
	Big	32.27 <sup>b</sup>	1.13
<b>Management Treatment</b>	Burn	31.05 <sup>a</sup>	1.05
	Control	39.8 <sup>b</sup>	1.12

**Table 3.** Seed set and percentage of filled achenes for plants in the three study sites, Big, Madaket, and the Potato Field. Standard errors were calculated using the least squares means generated in SYSTAT.

Site	Seed Set		% Filled Achenes	
	LS Mean	±SE	LS Mean	±SE
Big	7.32	1.36	31.14	5.33
Madaket	6.49	1.31	28.32	5.33
Potato Field	4.25	1.06	17.33	4.48

**Table 4.** Total number of seeds per flower head, seed set and percentage of filled achenes for plants in the burn and control management treatments. Standard errors were calculated using the least squares means generated in SYSTAT.

Management Treatment	Total Seeds / Flower Head		Seed Set		% Filled Achenes	
	LS Mean	±SE	LS Mean	±SE	LS Mean	±SE
Control	23.93	1.06	5.72	0.04	25.46	4.16
Burn	26.96	1.06	6.17	0.04	25.22	4.17





