Fourth Progress Report on Research Grant #04-05, *Effects of Seed Predators on Vegetation Distribution and Natural Habitat Recovery*

*Principal Investigator: Cathy Schwemm*

**Background**

This research investigates the role that herbivores, and in this case deer mice (*Peromyscus maniculatus elusus*), play in facilitating or preventing the re-establishment of native plants. Santa Barbara Island (SBI) is a small (1 $mi^2$) island occurring within Channel Islands National Park, and during the last century and up until the early 1980's, several species of feral herbivores, including rabbits and sheep, occupied the island and severely damaged the native vegetation community. Grazing by sheep and rabbits resulted in the loss of most of the stands of *Coreopsis gigantea* (Coreopsis), a semi-succulent native shrub, and the dominance of exotic annual grasses. Following the removal of the non-native herbivores many plant species began to recover, and increases in Coreopsis distribution as well as population increases of some more rare species, previously relegated to cliffs and other areas inaccessible to sheep, were noted. On a landscape scale, however, exotic annual grasslands still dominate the island, and some shrub and native plant species have increased little in distribution over the last 20 years.

Deer mice are the only mammal native to the island, and consume primarily seeds and some plant tissue. Mouse numbers on the island are at times extremely high, and during peak population years densities can reach over 900 mice per hectare. Prior work on mouse food habits on the island has examined the types of foods consumed by mice, however no attempt has been made to specifically investigate the levels of seed predation or to determine whether seed loss to mice ultimately affects plant population dynamics. This project will attempt to quantify mouse impacts on island plant diversity by measuring levels and composition of seed consumption. By better understanding the relationship between seed predation and the importance of seed reproduction for native plant species we hope to better explain the observed patterns of plant distribution and abundance on the island, and evaluate the larger role of herbivory within this relatively simple island system.

Additionally, the results from this research will be provided to restoration practitioners so that they might best implement vegetation restoration projects in the presence of mice. Because these mice are native and are at times extremely abundant, it is reasonable to assume that vegetation restoration efforts that consider potential mouse impacts will be more successful than those that do not.

**Project Status**

*Exclosure construction*

Study sites utilizing fenced exclusion plots were designed to investigate whether deer mice have measurable impacts on vegetation composition and shrub recruitment. To do this exclosures were constructed using ¼-inch hardware cloth with aluminum flashing around the top, and these fences were supported by rebar stakes. Five exclosures were constructed in areas where exotic annual grasslands integrate with stands of Coreopsis. Vegetation sampling plots (2 x 4 meters), used to measure species abundance and diversity and seedling recruitment, were established within the exclosures, and paired control plots established outside the exclosures. A total of five exclosures and associated control plots were constructed, three in the spring of 2004 and two in 2005.

For several reasons exclosure construction and maintenance proved to be more challenging than first anticipated. Difficult logistics of getting supplies and personnel to the island, weather and wind conditions that weakened fences, and the extremely high densities of mice on the island in 2005 all resulted in conditions that allowed mice to enter the exclosures, and trapping for mice inside and outside the exclosures in August 2005 revealed that mice were in fact present in all the plots. Some mice went through cracks in the soil that developed below the fence line as the island dried out during the summer, some went through tears in the fence caused by wind damage, and at least one was observed jumping from below the flashing to the top of the fence (clearly having learned that it couldn't climb directly on the aluminum).

After evaluating the options for fence repair and examining all of the access methods that mice had used, it was determined that continued maintenance of these fences was simply impractical given existing conditions of weather, transportation availability, and time. Modifications to the exclosures would have required new trenching (during a period when the ground is very hard from summer drought), possibly installing new fences using galvanized hardware cloth, possibly moving all the rebar supports to the inside of the fences, and other modifications. It wasn't clear that even given all these improvements that mice wouldn't still be able to breach the fences; there are literally hundreds of mice that live in proximity to any of the exclosures, and the presence of even one would negate the results. In addition, even if the fences could be made completely secure, in essence we would be starting the experiment over, since the presence of mice at any time in the past two years essentially violated the assumption that mice are not eating seeds or plants in those plots.

Anecdotally, trapping inside similar exclosures on San Miguel Island (SMI) several weeks later resulted in no mouse captures, although one trap did show mouse sign. Several factors on SMI may suggest why those exclosure fences have been successful while the SBI ones have not. First, the soil composition in the two areas is quite different; the soil at the SMI site is generally sandy while the soil at the SBI site has a much higher clay content and hardens and cracks when it dries. Consequently the SMI soil has held the fences in the ground much more securely than has the SBI soil. (The fences on both islands were constructed similarly and fencing material installed to the same depth.)

Secondly, most of the hardware cloth used on SMI was galvanized, while that used on SBI was not. This discrepancy was not intentional, but for whatever reason different materials were purchased for each island. The non-galvanized cloth is susceptible to rust, and in the humid, saline, and windy conditions present on SBI the fences simply weakened much more quickly than anticipated. The SMI study site is less exposed than the SBI site, and it appears that the combination of less wind and galvanized fencing has allowed the SMI exclosures to perform much better. Clearly it would have been worth the trouble and added expense to use galvanized materials on SBI, and this is a recommendation that will be made for future projects.

Finally, and maybe most importantly, the numbers of mice on SBI are much greater this year than on SMI. As mentioned above and in the proposal, SBI experiences mouse densities that are as high as recorded anywhere else in the world. While these conditions do not occur every year, when they do, pressure by the increasing population for all available space is intense. Under this pressure even a small breach in the fence will likely result in complete occupation of the plot in a very short period of time.

*Vegetation Data Collection*

To measure possible changes in vegetation communities when mice are excluded we collected relative species abundance and numerical seedling data from 4-meter transects from all plots in the spring of both years. Sometime during this period, probably in the early summer of 2005, mice entered all the exclosures, eliminating the power of the data to suggest changes in vegetation communities that may be attributable to mouse exclusion. The data are nevertheless valuable for describing annual changes in inter-annual changes in species composition and seedling abundance in these microhabitats over the course of the research.

We will also compare relative abundance data for each plant species obtained from transect sampling to results from faecal and soil sampling (see below) to aid in describing the relationships between levels of seed predation, seed bank potential for each species, and species abundance and reproduction.

*Seed bank Sampling*

Soil samples were collected from each plot (n = 10) in February, and August 2005 to investigate seed bank composition. Two analysis methods, greenhouse germination (Figure 1) and seed extraction, are being used to determine seasonal changes in the diversity and abundance of seeds present in the soil. To facilitate both methods, samples collected in the field are subsequently divided into two sub-samples so that each method is applied to each sample. Germination analysis for both sets of samples began this summer, and continues as of this writing. Tables 1 and 2 list the plants that have so far germinated from each of the samples.

The results to date suggest that the number of exotic seeds present in the seed bank far exceeds the number of native seeds. These results are generally reflective of the existing plant diversity on the plots, i.e. exotic species dominate, however there are relatively more exotic seedlings than native seedlings at this point than there are exotic relative to native plants on the ground. For example after two weeks of germinating the samples collected in August, 100% of the identifiable seedlings are exotic species. Also of interest is the total absence of Coreopsis seedlings from any of the SBI soil samples. (Coreopsis seeds did germinate from some of the SMI samples, so greenhouse conditions appear to be supportive for this species.)

This observation, combined with the almost total absence of Coreopsis seedlings in the study plots this spring, suggests that Coreopsis plants did not produce seed last year, or that seeds weren't fertile. It is also possible that mice (or other seed predators) consumed all of the available seeds prior to germination in the wild (and before we collected soil samples in February). These conditions were in contrast to April 2004, when we counted hundreds of Coreopsis seedlings on several of the plots.

*Mouse food habits assessment*

The use of seed trays as described in the proposal was intended for use as a tool to measure food preferences of mice in relation to the available foods on the island. Initial trials of seed tray methods were not successful for several reasons, and a new approach for assessing mouse food habits has been adopted. Instead of artificially providing food for mice, we are collecting faecal samples and analyzing those for relative abundance of food types consumed. Plant cells identified in faeces, which are unique to each species of seed, will be compared with prepared reference slides of known seed types. Faeces have been collected throughout the past year, and preliminary analysis of these samples began in spring 2005 (Table 3). Faecal samples have been collected coincident with the collection of soil samples, so that comparisons can be made between available seeds and seed consumption.

*Mouse population dynamics, 2004 – 2005*

In November of 2004 and March and April of 2005 we continued to sample mouse populations to obtain estimates of abundance. Mouse populations fluctuate greatly between seasons, between years, and between habitat types. Understanding mouse dynamics as they relate to plant recruitment is an important element of this project. The sample plots where we collect faecal and soil samples are located in the transition area between homogeneous exotic grassland habitat and an area of mixed Coreopsis and grassland, and we sample mice in both of these habitat types to estimate the relative changes in consumer abundance coincident with measurements of plant growth and recruitment. Population sampling for this fall is planned for November, and Table 4 presents density estimates obtained for mice since the project began.

**Timeline**

Table 5 presents the schedule of data collection to date. Generally, vegetation data are only collected in the spring due to the drought conditions that persist for much of the summer and fall seasons that make species identification difficult. Mouse population sampling is conducted twice each year, in the spring and fall, on each grid, and faecal and soil samples are collected coincidentally when possible.

**Recommendations and future work**

*Practicality of mouse exclusion for restoration projects*

Given the results from the exclosure portion of the project, at this time it seems reasonable to suggest that planning for any future restoration or management projects on the island should include within the planning an evaluation of impacts that mice might have. The alternative approach, of suggesting that mice might be kept out of or removed from any particular study or restoration site, seems impractical given our results and those of others on the island. For example seabird biologists have at times suggested that because mice are egg predators for some seabird species, that efforts be made to exclude mice from nesting areas. Our results illustrate the extreme level of effort that would be required for such a project, and the high likelihood that exclusion would ultimately fail, particularly in years when mouse numbers are high. Because we can't yet predict with certainty what combination of factors results in mouse population cycles on the island, we suggest that future projects should simply be designed to accept the presence of mice.

*Alternative methods for investigating impacts of mice*

Beginning this fall (2005), we will begin several new experiments to investigate mouse impacts on native plant survival. The exclosures were intended to examine impacts on vegetation communities, however given the challenges of that approach, we will instead focus on direct impacts of mice on seeds and possibly seedlings. To do this we will construct much smaller exclosures (cages), also made of hardware cloth, approximately 15 cm on a side, 5-10 cm high and covered on the top. (These cages will likely be constructed from the existing fence material.) Sets of cages will include one closed to mice and one open, and will test 1) direct levels of seed consumption by mice or other seed predators, 2) potential differences in seed consumption by mice in different habitats, 3) potential differences in seed consumption by mice under shrub cover and in open habitats, and 4) seed preferences of mice. If possible, the presence of seedlings in the spring in both open and closed cages will be documented as well.

**Interpretive Component**

As required by the grant award, the results of this work have been shared with the park's interpretive staff. A copy of this report was sent to them, and a follow-up meeting will include a discussion of what types of information would be most helpful to them and in what form they would like to receive information (i.e. Word document, PowerPoint presentation, poster, etc.). It is likely that at least one more year of data collection will be needed before results are apparent and of interest to visitors, but we will discuss that with the interpretive staff.

**Summary**

Funding provided by WNPA facilitated the initiation of this project, and future work will build upon what has been accomplished to date. Modifications to experimental methods and continued sampling of vegetation, soils and mouse food habits will provide more information on the dynamics of seed production and survival of several native plant species on the island and hopefully relate those variables to mouse population dynamics and behavior.

We are confident that the data collected over the next several years as a result of these efforts will greatly improve the likelihood of success of future natural resource restoration and management projects on the island.

**Table 1. Germination results from soil samples, Santa Barbara Island, collected February 2005**

| Species | Plot # | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1_b | 1C_b | 2_b | 2C_b | 3_b | 3C_b | 4_b | 4C_b | 5_b | 5C_b | **Totals** |
| ***Ansinckia intermedia*** | | | 1 | | 1 | | | 1 | 1 | | **4** |
| *Atriplex semibaccata* | 2 | | 3 | | | 1 | | | | | **6** |
| *Avena spp.* | | | 7 | 5 | 4 | | | | 3 | | **19** |
| *Bromus diandrus* | | | | 1 | | | | | | | **1** |
| *Bromus hordaceus* | | 1 | 1 | 1 | 2 | 1 | | | 8 | | **14** |
| *Bromus madritensis* | | | | 2 | | | | | | | **2** |
| *Bromus spp.* | | | | 3 | | 1 | | 1 | | | **5** |
| *Erodium cicutarium* | 1 | 1 | 2 | | 3 | | | | | | **7** |
| *Malva parviflora* | 7 | | | 1 | | 1 | | 1 | | 4 | **14** |
| *Mesembryanthmum crystallinum* | 18 | 1 | 45 | | | 20 | 9 | | | 7 | **101** |
| *Medicago polymorpha* | | | | | | | | | 1 | | **1** |
| ***Phacelia spp.*** | | | | | 1? | | | | | | |
| *Sonchus oleraceus* | | | | | 3 | 3 | | 6 | 1 | 1 | **14** |
| *Vulpia sp.* | | | | | | | | | 8 | | **8** |
| Totals | **28** | **3** | **59** | **13** | **13** | **27** | **9** | **9** | **23** | **12** | **196** |

**Table 2. Germination results from soil samples, Santa Barbara Island, collected August 2005**

| Species | Plot # | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1_b | 1C_b | 2_b | 2C_b | 3_b | 3C_b | 4_b | 4C_b | 5_b | 5C_b | Totals |
| *Avena spp.* | | | | 3 | 1 | | | | 1 | | **5** |
| *Bromus spp.* | 120 | 81 | 70 | 20 | 54 | 50 | 74 | 200 | 23 | 80 | **772** |
| *Erodium cicutarium* | | 1 | 2 | | 3 | | | 2 | | | **8** |
| *Malva parviflora* | | | | | | 2 | | | | | **2** |
| *Sonchus oleraceus* | | 9 | | | 2 | | 15 | 3 | 7 | 7 | **43** |
| *Vulpia sp.* | | | | | | | | | | | |
| Totals | **120** | **91** | **72** | **23** | **60** | **52** | **89** | **205** | **31** | **87** | **830** |

**Table 3. Mouse faecal samples collected from Santa Barbara Island study plots.**

| Date | Samples (#) |
|---|---|
| 4.4.04 | sb1_04 – sb7_04 (7) |
| 6.9.04 | sb20_04 – sb22_04 (3) |
| 2.26.05 | sb1_05 – sb8_05 (8) |
| 8.11.05 | sb11_05 – sb17_05 (7) |

**Table 4. Mouse density estimates, 2004-2005, on 2 sample grids on Santa Barbara Island.**

| Date | Grassland (mice/hectare) | *Coreopsis* (mice/hectare) |
|---|---|---|
| April 2004 | 251 | 453 |
| November 2004 | Very few, < 10/ha | 160 |
| March 2005 | | 63 |
| April 2005 | 91 | |

**Table 5. Timeline of project activities**

| Dates | Exclosure construction | Vegetation sampling | Mouse population sampling | Faecal sample collection | Soil sample collection |
|---|---|---|---|---|---|
| Feb.-June 2004 | x | x | x | x | |
| July-Dec. 2004 | | | x | | |
| Jan.-July 2005 | x | x | x | x | x |
| August-Dec. 2005 | | | Planned | x | x |

**Figure 1a. Greenhouse germination trays**

**Figure 1b. Sample tray with seedlings**