LAND RETIREMENT DEMONSTRATION PROJECT

YEAR FOUR

2002 ANNUAL REPORT

PREPARED FOR:
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INTERAGENCY LAND RETIREMENT TEAM
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EXECUTIVE SUMMARY

INTRODUCTION

Vast tracts of once productive farmlands located on the west side of the San Joaquin Valley are characterized by a high groundwater level and high selenium content. The application of irrigation water to these lands has resulted in accumulation of poor-quality drain water. The elimination of drain water is a chronic problem on these lands and has been the subject of environmental concern. One way to reduce the accumulation of drain water and to lessen problems associated with its disposal is to retire the land from agricultural production to prevent accumulation of drain water. The Central Valley Project Improvement act (CVPIA) of 1992 authorized a land retirement program as recommended in the San Joaquin Valley Drainage Program Final Report. An interagency team consisting of federal representatives from the United States Bureau of Reclamation (USBR), the United States Fish and Wildlife Service (FWS), and the United States Bureau of Land Management (BLM) has been assembled to accomplish the goals of the CVPIA Land Retirement Program. This program may purchase land, water, and other property interests from willing sellers who receive Central Valley Project water allocations. Although land retirement may provide solutions to some problems associated with agricultural drain water, land retirement is equipped with its own set of challenges including: land acquisition, redistribution of acquired water, land management, and habitat restoration.

Prior to implementation of land retirement to a larger scale area, a 15,000-acre demonstration project was designed to test various potential impacts of land retirement. The objectives of the demonstration project are to:

- Assess the effects of land retirement on drain water and groundwater levels,
- evaluate the potential of land retirement to decrease bioavailable selenium and other toxic compounds,
- develop and determine costs of effective restoration technologies for establishing native biota on the sites, and
- determine the responses of wildlife to restoration efforts.

Two study sites, one in western Fresno County (Tranquillity site) and the other in Tulare and Kings counties (Atwell Island site) have been established to investigate these aspects of land retirement. The California State University Stanislaus, Endangered Species Recovery Program (ESRP) is leading the biological studies at both sites, and conducting restoration efforts and managing the Tranquillity site. The BLM is conducting restoration efforts and managing the Atwell Island site. The physical impacts of land restoration are being examined by USBR at both sites.

This annual report summarizes information collected in 2002 from both the Tranquillity and Atwell Island study sites and compares results from 1999 through 2002 of the Habitat Restoration Study. This report also describes and presents information from site-wide biological surveys, restoration trials and restoration efforts at both sites, and explains impacts of land retirement on physical properties (groundwater, soils, geology, etc.). Data collected from the Habitat Restoration Studies include plant cover and survivorship, invertebrate richness and abundance, amphibian and reptile richness and abundance, avian richness and abundance, small mammal richness and abundance, and avian nest monitoring. Data were collected from 20, 10-acre plots in 5 replicated Blocks at the Tranquillity site. At Atwell Island, similar data were collected from 48, 2-acre plots; 16 plots in 4 replicated Blocks in each of 3 separate study areas. Site-wide data collection included night spotlighting surveys, track station surveys, winter raptor surveys, contaminants monitoring, and plant cover and survivorship on various test plots. Data on the physical impacts of land retirement that were collected include soil type and soil chemistry, groundwater levels, and groundwater contaminants.

PHYSICAL IMPACTS

PHYSICAL IMPACTS AT TRANQUILLITY

The Tranquillity Land Retirement Demonstration Project site is underlain by flood basin deposits consisting of moderately to densely compacted clays that range in thickness from 5 to 35 ft. The flood basin clays have low permeability and provide poor drainage conditions for irrigated agricultural production. The U.S. Department of Agriculture soil types found at the site in order of abundance include the Tranquillity clay (80%), the Lillis clay (10%) and the Lethent silt loam (10%). Data on baseline soil chemistry, collected during 1999, indicate that the site soils are moderately to highly saline (mean Electrical Concuctivity (EC) 1:5 = 7.2 ds/m), and contain elevated concentrations of selenium (mean total Selenium = 1.05 mg/kg) and boron (mean soluble Boron = 32.7 mg/kg) when compared to other soils in the San Joaquin Valley. Comparison of soil chemistry data collected in 2001 with baseline data collected in 1999 for change detection analyses, indicate that soil salinity and total selenium concentrations are decreasing at the site, while boron concentrations in the subsoils are increasing.

Groundwater monitoring data collected to date support the conceptual model of a declining, shallow water table in response to land retirement. The average decline in water level observed in 10 monitoring wells for the period between August 1999 and July 2003 was approximately 6 feet (an average decline of 1.5 feet per year). The area of the site underlain by a shallow water table within 7 feet of the land surface decreased from 600 acres (30% of the site) to 0 acres during the time period from October 1999 to October 2002. Large vertical groundwater gradients measured at the site indicate perched water-table conditions in the shallow groundwater system.

Baseline groundwater quality data taken during 1999 indicate that the shallow groundwater is a highly saline, sodium sulfate type of water that contains high concentrations of selenium and boron (median electrical conductivity = 43,260 micro-siemens/cm, median selenium concentration = 1280 μg/L, median boron concentration = 46 mg/L). Stable isotope data indicate that the shallow groundwater has undergone evaporation resulting in high salinity and trace element concentrations. Selenium concentrations observed in deep wells completed in the underlying Sierra Nevada deposits at the site are below the analytical detection limit for this study (less than 0.4 µg/L). Reducing geochemical conditions in the Sierran deposits underlying the northern portion of the site may account for this observation. Tritium data from the shallow monitoring wells indicate that the shallow groundwater consists of a mixture of water recharged before and after 1952. Tritium data from the deep wells completed in the Coastal Range deposits at the site indicate that the groundwater was recharged before 1952. No ephemeral pools resulting from accumulation of rainfall on the land surface were observed at the site during 2002.

PHYSICAL IMPACTS AT ATWELL ISLAND

The Atwell Island demonstration site lies on the southwestern margin of the Tulare Lake bed. The site is underlain by lakebed and marsh deposits consisting primarily of clay and silt with some sand. Soils in the Atwell Island study area consist of silt and sand loams that are formed from alluvium derived from igneous and sedimentary rocks. The U.S. Department of Agriculture soil mapping units found at the site in order of abundance include the Posochanet silt loam, Nahrumb silt loam, Westcamp silt loam, Excelsior fine sandy loam, and Lethent fine sandy loam. Baseline soil chemistry data from three research areas at the site were collected during 2002. The surface soils (0-12 inch depth) at the research sites are moderately to highly saline (mean ECe 3.85-9.25 ds/m) and contain low selenium concentrations (mean total Selenium 0.097-0.114 mg/kg). By comparison, the mean Selenium concentration in western U.S. soils is about 0.34 mg/kg.

Monitoring wells were installed at the site in the fall of 2001 to establish baseline groundwater conditions. Initial groundwater level measurements indicate the presence of a perched water table beneath much of the site. Groundwater levels observed in 2002 in the shallow groundwater system range from approximately 4 – 15 feet below land surface. The water table is generally shallowest (nearest to the land surface) in the northeast portion of the site and becomes deeper to the southeast. A declining shallow water-table in response to land retirement has been observed on portions of the site where irrigation has ceased or been greatly reduced.

The shallow groundwater underlying the Atwell Island site is moderately saline in nature. Salinity in the shallow groundwater samples, expressed as electrical conductivity (EC), ranged from 575 to 52,925 micro-siemens/centimeter (µS/cm), with a median value of 13,740 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm. The shallow groundwater at the site is best described as a sodium sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 469 to 15,100 milligrams/Liter (mg/l), and a median concentration of 4,500 mg/L. Sulfate is the dominant major anion found in the shallow groundwater with sulfate concentrations ranging from 261 to 22,200 mg/L, and a median concentration of 5,700 mg/L. Selenium concentrations measured in the shallow groundwater wells at the site during the baseline year of monitoring range from less than the detection limit of 0.4 to 208 micrograms per liter (µg/L), with a median concentration of 8.56 µg/L. The USEPA water-quality criteria for long-term exposure to selenium in aquatic environments is 5 µg/L (USEPA 1988). Approximately 50% of the groundwater samples (35 of 72 samples) collected during the baseline year of sampling had selenium concentrations that were less than the USEPA aquatic life criteria.

No ephemeral surface water pools resulting from rainfall were observed at the site during 2002. Selenium concentrations in three surface water samples taken from the artificial wetland at the site are below the USEPA aquatic life criteria, and ranged from below the detection limit (less than 0.4 μg/L) to 0.6 μg/L.

SELENIUM ACCUMULATION IN BIOTA ON LRDP LANDS

A tiered monitoring program developed in consultation with the U.S. Fish and Wildlife Service was used to determine the level of sampling that would be conducted at the two project sites for each biotic group. Plants, terrestrial invertebrates, and small mammals were collected and analyzed for selenium levels over a 4-year period (1999 to 2002) at the Tranquillity site and for a 3-year period (2000 to 2002) at the Atwell Island site. At the Tranquillity project site there were 229 plant samples, 95 invertebrate samples, and 73 small mammal samples that were analyzed. At the Atwell island project site there were 149 plant samples, 83 invertebrate samples, and 17 small mammal samples analyzed.

TRANQUILLITY SITE

Mean (geometric mean) selenium concentrations in vegetation on the Tranquillity project site were between 0.307 and 0.405 mg/kg during all 4 years of sampling and the variances among years were not significantly different. Selenium levels are less than the population-level performance standard of 2.0 mg/kg established by the U.S. Fish and Wildlife Service for project lands and approximately an order of magnitude less than the selenium levels of plants collected from Kesterson National Wildlife Refuge. Most of the outliers (data points that exceeded the 90^{th} percentiles) exceeded the performance standard, but were within or below selenium levels of plants collected from Kesterson National Wildlife Refuge. Outliers included 7 species; *Atriplex argentea, Brassica nigra, Heliotropium curassavicum, Sonchus sp., Hordeum vulgare, Sisymbrium irio, and Suaeda moquinii.* Although outliers were grouped in Block 4 and in the northern portion of the project site, there is not adequate data to conclude that bio-accumulation of selenium is problematic in these areas.

Mean selenium concentrations in terrestrial invertebrates varied from 0.81 to 1.65 mg/kg from 1999 to 2002 at the Tranquillity study site. The mean selenium concentration in invertebrates from 2002 was significantly lower than in 2000 and 2001. Selenium in terrestrial invertebrates was below the performance standard of 2.0 mg/kg established for project lands and approximately an order of magnitude below selenium in invertebrates collected at Kesterson National Wildlife Refuge. Isopods and spiders contained higher selenium levels than beetles and crickets. Most of the data outliers were collected from blocks 4 and 5.

Mean selenium concentrations in deer mouse bodies varied from 0.89 to 1.09 mg/kg from 1999 to 2002 and there were no significant differences in selenium concentrations between years. The mean selenium concentrations in deer mouse bodies were below the background selenium level found in small mammal body tissues from non-seleniferous soils in the western United States (generally less than 2.0 mg/kg). No performance standards were set by the FWS for small mammal body tissues. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from deer mouse bodies exceeded those established for blood, but were lower than those established for hair. Geometric means of selenium concentrations in deer mouse whole bodies collected from 1988 to 1992 at Kesterson NWR varied from 4.8 to 11.0 mg/kg and exceeded the values from the Tranquillity site by approximately an order of magnitude. Data outliers were scattered over the site and not clumped.

Mean selenium concentrations in deer mouse liver tissues varied from 2.27 to 3.89 mg/kg from 1999 to 2002 at the Tranquillity site. Selenium concentrations in 2001 were significantly lower than in 1999 or 2002.

Mean selenium concentrations in shrew bodies varied from 1.95 to 2.51 mg/kg from 1999 to 2002 at the Tranquillity site and there were no significant differences in selenium concentrations between years. The mean selenium concentrations in shrew bodies, the standard deviations of the data, and the data outliers were all near the published upper level of background selenium concentrations for small mammal body tissues (generally less than 2.0 mg/kg; USDI 1998). This is not unexpected because shrews are insectivores and bioaccumulation of selenium in shrews is expected to be greater than in most other small mammals. There were 2 data outliers; both were collected from Block 4.

Mean selenium concentrations in shrew livers varied from 2.00 to 4.18 mg/kg from 2000 to 2002 at the Tranquillity site (livers were not extracted from the bodies of shrews in 1999). The selenium concentration in shrew liver tissues in 2002 was lower than in 2000, but the small sample size in 2002 (n = 1) makes this questionable.

ATWELL ISLAND SITE

Mean selenium concentrations in vegetation on the Atwell Island site was between 0.199 and 0.213 mg/kg during the 3 years that samples were collected (2000 to 2002). Variances among years were not significantly different and selenium levels were slightly below the mean selenium concentrations of plants collected from the Tranquillity site. However, some of the data points that exceed the 90th percentiles (outliers) did exceed the mean selenium concentration of selenium in plants from the Tranquillity site. The mean concentrations of selenium in vegetation at the Atwell Island site are below the performance standard of 2.0 mg/kg established by the U.S. Fish and Wildlife Service for project lands. Most of the outliers were collected from two areas: the extreme western portion of the project site and south of Study Area 2.

Mean selenium concentrations in terrestrial invertebrates varied from 0.167 to 0.715 mg/kg from 2000 to 2002 at the Atwell Island site. The mean selenium concentration in invertebrates collected in 2000 was significantly greater than in 2001. The mean concentrations of selenium in terrestrial invertebrates collected from the Atwell Island site were below the means observed at the Tranquillity site. Selenium levels in terrestrial invertebrates collected from the Atwell Island site were below the performance standard of 2.0 mg/kg established for project lands. Seven of the 83 invertebrate samples collected exceeded the 90th percentiles (outliers). These samples were collected from native lands in the western portion of the project site and from study areas 1 and 2.

Mean selenium concentrations in deer mouse bodies collected from the Atwell Island site in 2000 were between 0.62 and 0.68 mg/kg. There were no differences in selenium concentrations between years. The mean selenium concentrations in deer mouse bodies collected from the Atwell Island site are below the selenium concentrations found in deer mouse bodies collected from the Tranquillity site. The U.S. Fish and Wildlife Service did not set a performance standard for small mammal body tissues. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from deer mouse bodies slightly exceeded the values established for blood, but were much lower than the values established for hair. Two deer mouse body samples exceeded the 90th percentiles . Both samples were from the western portion of the project site.

HABITAT RESTORATION ON LRDP LANDS

Tranquillity Site

In 2002, two rounds of vegetation monitoring (spring monitoring and shrub monitoring) were conducted on the HRS plots. Results from the spring monitoring suggested a decrease in richness and abundance of imprinted species relative to levels in the preceding two years. Generally, non-native species were most abundant on the plots; imprinted herbaceous species were less successful than imprinted woody species. *Sisymbrium irio* (London Rocket) and *Bromus madritensis* (red brome) constituted the most abundant non-native species, with the latter dominating the more saline portions of the site. Due in part to the abundance of non-native species, blocking effects among the replicates exceeded treatment effects. Much of the restoration effort appeared to have been strongly influenced by the tumbleweed, *Atriplex argentea*. The stems and leaves of this annual herbaceous species persist on the site for a number of years and limit the germination of other, more desirable species.

During the 3 years of monitoring since imprinting, 9 of the 13 species included in the seed mixture have been observed on at least some of the plots. Nevertheless, only a few of these species have become well-established. Few native species appear to have become established from the existing seed bank; with only a single species (*M. coulteri*) being present in any abundance.

Species in the barley buffer frequently appeared to be less stressed than in the plots. Furthermore, barley was fairly successful at excluding weeds. Hence, inter-planting of native species with barley may prove to be a useful strategy for initially establishing native vegetation.

Results from the shrub monitoring were very positive. Two imprinted shrubs, *Atriplex polycarpa* and *Suaeda moquinii*, were well-established on the plots. A third imprinted shrub, *Isocoma acradenia*, was also noted, however, in lower abundance than the latter two species. Shrub establishment appeared to be positively linked to the created microtopography (berms and trenches); however, blocking effects were too great for this association to be demonstrated statistically. Nevertheless, a strong relationship between shrub establishment and microtopography was very evident in the field. No native shrubs were encountered on the non-imprinted plots. As with the observations from the spring monitoring, this absence of natives suggests a paucity of remaining viable native seed in the seedbank.

Atwell Island Site

Restoration efforts at the Atwell Island HRS were characterized by extreme differences in response to treatments among the three study areas at the site. The study areas were situated within a few miles of each other, all had received essentially the same pre-treatment, and all had received the same treatments, yet vegetative development was vastly different on Study Area 1 than on the other two study areas. The large differences in responses should serve as a clear warning to anyone hoping for a single, broadly applied approach to restoration.

Some aggressive weedy species, particularly *Bassia hyssopifolia* and *Atriplex argentea*, were fairly abundant at Atwell Island; however, these species tend to germinate in mid- to late-spring. This delayed germination of the dominant weeds appeared to allow the imprinted species—many of which germinate during the same period—to compete. For example, on Study Area 1 woody perennials were generally quite successfully established. This success appears to have been partially attributable to a surfeit of open ground during this period. By contrast, the weed flora of the Tranquillity HRS contained a large portion of early-germinating winter annuals. These species characteristically created a dense cover, thereby reducing the suitable habitat for the later-germinating native species.

Restoration trials

To date, the primary focus of the Tranquillity Habitat Restoration Study has been the monitoring of the effects of land retirement on the biota. Nevertheless, as the project developed, an increased emphasis has been placed on developing and evaluating restoration methods. To this end, research in 2001-2002 concentrated on developing techniques for establishing and identifying appropriate native vegetation. Studies undertaken during this year were: 1) Berm and mycorrhiza Trial; 2) Marsh Area seeding Trial; 3) Suitability trial; 4) Succession trial; and, 5) *Atriplex spinifera* planting. In most trials, the target native plants germinated successfully. Nevertheless, the vegetation was generally dominated by introduced species. Hence, interpretation of the experimental results was often problematic.

It was evident from this research that improved weed-control measures need be developed. Therefore, the majority of the trials that were developed for 2002-03 were primarily concerned with weed control. These were: 1) Growth form and herbicide Trial; 2) Mowing Trial; 3) Section 10 Burn Trial; 4) Pre-irrigation Trial. An additional experiment, the Section 23 restoration Trial, was designed to assess the performance of two mixtures of species. Additionally, a series of hedgerows were installed along the edges of some of the buffer areas in the HRS site and along the northern edge of the

Manning Avenue Parcel. These activities will be monitored through 2003; if warranted, monitoring may continue beyond this period.

Native Plant Nursery

A native plant nursery was established in 2001 with 17 native species. Subsequently (the winter of 2001), the nursery was relocated to a 10-acre site on Section 23. The nursery beds were installed in November 2001. The 17 species that were grown in the original nursery will also be planted in the new nursery. These will be augmented by an additional 13-15 species. On 12 December, 2.3 acres of the nursery site were planted using seeds collected during the previous 2 years. For the 2002-03 growing season, it is anticipated that approximately 4 acres of the nursery site will be put into production, with the remaining 6 acres managed for weed control. To date, the nursery has provided much useful information concerning the growth requirements of many species. Furthermore, it is hoped that the nursery will serve as a first step in augmenting the seed types (i.e., local genotypes) required for successful restoration.

WILDLIFE DIVERSITY AND ABUNDANCE ON TRANQUILLITY LRDP LANDS

INVERTEBRATES

The fourth annual invertebrate pitfall survey was conducted from 16-19 April 2002 by collecting invertebrates from the five pitfall-arrays established on each of the 20 HRS plots. The number of orders (richness) among study blocks ranged from 9 to 13. There were significant differences in richness of invertebrates between blocks, but there was no significant variation in richness between treatments. There were significant differences in mean abundance of invertebrates across blocks within specified study years, when Hemiptera and Thysanoptera are both included and excluded from the data. There were no significant differences in mean abundance of invertebrates between treatments, both including hemipterans and thysanopterans and excluding hemipterans and thysanopterans. Mean abundance by treatment varied significantly among years, both including and excluding hemipterans and thysanopterans, yet no specific year was significantly different from any other year (Student’s *t*-test).

From a management perspective, the fluctuations in richness and abundance of invertebrate orders may be significant. The orders showing the greatest fluctuations are typically considered to be agriculturally beneficial and include Lepidoptera, Neuroptera, Mantodea, Scolopendromorpha, and Opiliones. Species in these orders that were found on the Tranquillity plots have been confirmed to be generally beneficial. The species identified in the orders Homoptera and Acari are considered pests. The highest overall invertebrate abundance as well as the greatest contribution of these orders, and hence the greatest pest load, occurred in 2000. In 2001 the highest pest load was observed on Block 3, and in 2002 on Block 2.

REPTILES AND AMPHIBIANS

Reptile and amphibian surveys were conducted on 8-10 June, 29 April and 2-3 May, and 9-11 July 2002. Transect surveys were conducted along the small mammal trapping lines, and four 4 by 4-ft cover boards per plot were inspected for presence of amphibian and reptile species. In addition, pitfall traps were opened for the survey conducted 8-10 January 2002 and data also were compiled from incidental sightings.

No reptiles or amphibians were observed during focused surveys, but western toads were observed during spotlighting and avian surveys, and California king snakes were observed during vegetation surveys. Western fence lizards also were seen on the study plots. While the number and variety of amphibian and reptile species on the study plots and in the surrounding area continues to be low, there have been increases since retirement of the lands. This is likely the result of continued, although slow, colonization from adjacent lands. Pacific rattlesnake, western fence lizard, western whiptail lizard, and coast horned lizard have been observed on, or are known to have inhabited adjacent lands in the recent past. As these study lands stabilize and mature over the coming years, it is likely that colonization by reptiles and amphibians will continue.

AVIAN

Avian richness, abundance, and species composition were monitored on the study plots on 16-18 January, 2-4 April, 22-24 July, and 8-10 October, 2002. Four point counts on variable circular plots and two parallel north-south transects were used on each study plot. All blocks were concurrently sampled by synchronizing starting times between blocks. Each circular-plot was censused for 5 minutes and each transect was censused for 5 minutes, resulting in 30 minutes of observations per plot.

Total species richness remained relatively constant across seasons and years, except in summer 2001 and 2002 when richness was lowest. Mean species richness for 2002 ranged from 1.25 to 6.55 species/plot and varied significantly by year and season. Mean richness was significantly greater in 1999 than in all other years. Winter, spring, and fall (all years combined) had significantly higher richness than summer.

The site-wide number of birds (birds/day) excluding blackbirds varied annually. Site-wide bird abundance was highest in 2001 compared to all other years. However, summer of 2001 had the lowest site-wide abundance of birds among all years at 13.3. Mean abundance of birds (birds/plot/day) varied significantly among years and among seasons. The mean abundance of birds was significantly less in 1999 than in all other years and avian abundance in 2001 was significantly greater than in 2000 and 2002. There were significant differences in the mean abundance of birds between blocks and between years by block. However, the mean abundance of birds did not significantly vary by treatment within each year or among all years.

Species composition varied seasonally as residents, migrants, and wintering birds used the plots. Five species that were either of species of special concern in California (CSC) or on the federal candidate list (FSC) used the study plots in 2002. The loggerhead shrike

(*Lanius ludovicianus*) and the burrowing owl (*Athene cunicularia*) were among the top five most abundant species in summer 2002. The horned lark (*Eremophila alpestris*), loggerhead shrike, and the northern harrier (*Circus cyaneus*), which is federally proposed for threatened listing (FPT/CSC), ranked in the top five most abundant species in fall 2002.

In 2002, we implemented a program to monitor avian nesting success on the HRS plots to provide another measure of avian responses to restoration treatments. We searched for ground-nesting birds and their nests by dragging a 60-meter, 0.375 inch nylon rope across sections of each plot. Nest searching began the first week of March and continued through the second week of April 2002.

There were 23 nests located during 2002: 1 horned lark (*Eremophila alpestris*), 2 loggerhead shrike (*Lanius ludovicianus*), 3 western meadowlark (*Sturnella neglecta*), 3 short-eared owl (*Asio flammeus*), and 14 mallard (*Anas platyrhynchos*). We observed copulation by song sparrows (*Melospiza melodia*) on the study plots although no nest was located. Six of the 23 nests were found outside of the study plots. Approximately 70% of the nests that were located on the plots were found on plots where contours had been added. Approximately 65% of the nests discovered on the study plots were located in Block 2.

The annual winter raptor survey for the Tranquillity site was conducted on 10-12 December 2002 by conducting a windshield survey along a predetermined survey route. Five species of raptors were recorded during the 2002 survey: red-tailed hawk (*Buteo jamaicensis*), northern harrier (*Circus cyaneus*), white-tailed kite (*Elanus leucurus*), American kestrel (*Falco sparverius*), and peregrine falcon (*Falco peregrinus*). Two additional species were observed at the site, but not during the survey: ferruginous hawk (*Buteo regalis*) and prairie falcon (*Falco mexicanus*). Species richness of wintering raptors has declined slightly between 1999 and 2002 but abundance of raptors has steadily increased.

SMALL MAMMALS

Trapping for small mammals was conducted on 29 January-1 February, 6-9 May, 15-18 July, and, 28-31 October 2002. Thirty Sherman live-traps were used on each of the 20 study plots in three lines of 10 traps each, with an inter-trap spacing of 15m. Pitfall traps also were used to capture small mammals. Data from the pitfall traps were used to augment the assessment of species richness and some small mammals captured in the pitfalls were sacrificed for selenium analysis. The four-day pitfall survey was conducted on 16-19 April and was concurrent with the invertebrate survey.

A total of 1,842 small mammals were captured in 2002 during live-trapping on the Tranquillity HRS plots. The majority (1,828 out of 1,842 captures) were deer mice (*Peromyscus maniculatus*). Other species captured included 12 Heermann's kangaroo rats (*D. heermanni*), one western harvest mouse (*Reithrodontomys megalotis*), and one house mouse (*Mus musculus*). There were no significant differences in the number of animals captured between 2001 and 2002, but there were some important seasonal differences in numbers of captures. For example, captures in spring and summer were relatively high and the abundance of small mammals during the fall sampling period increased on all blocks except on Block 1 from 1999 to 2001. There were 20 shrews, 2 voles, and 2 pocket gophers captured in the pitfall traps in 2002. Most of the shrews (70%) were captured on plots seeded with native vegetation. This is similar to results found in 2000 and 2001, but not in 1999. Numbers of other species caught in the pitfall traps were not abundant enough to show trends in treatments or time.

SITE-WIDE SURVEYS

Spotlighting surveys

Spotlighting surveys at the Tranquillity site were conducted on 4-5 and 11-12 March, 24-26 June, 9-11 September and 9-11 December 2002 following established methods. The highest rates of observations of animals during spotlighting were in summer 2002, summer 2000, and fall 2001 when there were 2.29, 2.14, and 1.93 observations per mile, respectively. The lowest rate of observation was in winter of 2001 when only 0.68 animals per mile were seen. Barn owls (*Tyto alba*), desert cottontails (*Sylvilagus auduboni*), and black-tailed hares (*Lepus californicus*) were seen during 12 of the 13 census periods. Western toads (*Bufo boreus*) and red-tailed hawks (*Buteo jamaicensis*) also were present during most census periods. The fewest number of species was observed in winter 1999 and winter 2001.

There were some notable species-specific fluctuations in abundance. The three owl species present on the Tranquillity site exhibited great fluctuations in rate of observation. There were generally a greater number of barn owls in summer and fall. Western burrowing owls were absent from fall 2000 to spring of 2002. Short-eared owls (*Asio flammeus*) were not observed from winter 2001 to winter 2002 and they were infrequently observed during all other survey periods. Leporids and small mammals tended to be most abundant in the spring and summer and least abundant in the winter. The abundance of leporids was uncommonly high in summer of 2002.

Track station surveys

Track station surveys were conducted at the Tranquillity site concurrent with the spotlighting surveys on 5, 12-13 March, 25-27 June, 11-13 September and 10-12 December 2002 utilizing methodology previously presented.

The number of visits to track plates by small mammals and invertebrates was greater than birds, reptiles, and amphibians during each survey period. The mean number of visits of all taxa was significantly variable across years. Visits by birds were significantly lower in 1999 than in 2000 and visits by mammals were significantly lower in 1999 than in 2000, 2001, and 2002. Additionally, small mammal visits were significantly lower in 2000 than in 2001 and 2002.

OTHER TASKS ACCOMPLISHED

NORTH AVENUE PARCEL SURVEY

The USBR augmented the amount of land dedicated to the Land Retirement Program at the Tranquillity site with the acquisition of a parcel known as the "North Avenue Parcel". This property was purchased in May of 2002 and is located across from the western boundary of the Mendota Wildlife Management Area. The North Avenue Parcel consists of 440 acres of recently fallowed land. A baseline inventory consisting of spotlighting, small mammal trapping, avian surveys, track stations, invertebrate sweeps, and a broad-scale vegetation survey was preformed to assess habitat quality and to document presence of all plant, invertebrate, herpetological, avian, and mammalian species.

Vegetation monitoring on the North Avenue Parcel took place on 13 and 29May, 27 June, and 2 July 2002. Sampling incorporated a walking census of the property along with point sampling (non-random). No fixed transects were walked; rather, distinctive looking areas were continually sought out; as the route from "area" to "area" was walked, a running list of all species was compiled. Periodically, areas were identified as being "representative" of the characteristic vegetation type (e.g., red brome dominated habitat), and were selected for more "comprehensive" sampling. Sampling was conducted within a circular area with a radius of 15 ft. All species within this "plot" were noted. Species were ranked in decreasing order of abundance (estimated visually); however, no attempt was made to assign actual cover values. In all, 33 such quadrats were sampled.

Thirty-two species in fourteen families were noted during the vegetation survey. Generally, the flora was typical for fallowed lands in the western side of the San Joaquin Valley. About 21.8% of the flora (7 spp.) corresponded to "desirable" native species; of these, only *Amsinckia menziesii* (Menzie's fiddleneck) was encountered with any great frequency. Nevertheless, later in the season, two perennial native herbs, *Heliotropium curassavicum* (seaside heliotrope) and *Sesuvium verrucosum* (western sea purslane) were observed in abundance along one portion of the eastern edge of the property. *Phacelia ciliata* (Great Valley phacelia), a valuable native species was fairly abundant in the southeastern section of the property.

Species richness was fairly low and was extremely variable, ranging from 2 to13 species. The poorest areas were those that were dominated by non-native grasses, some of which were formerly cultivated on the site.

The spotlighting survey was preformed on 28-30 May 2002 and was conducted along the tertiary roads encompassing the property. The most common species encountered was the barn owl (*Tyto alba*), although desert cottontails (*Sylvilagus audubonii*) were also numerous.

The track station survey was conducted on 29-31 May 2002. Ten track stations were established along the tertiary roads surrounding the property. The tracks of twelve animal species were documented on the track plates. Desert cottontail (*Sylvilagus audubonii*), mice tracks (presumably *Peromyscus maniculatus*), and beetle species (Order Coleoptera) were prevalent throughout the 3-day effort.

The small mammal census was conducted on 28-30 May 2002. One hundred and twenty Sherman live-traps were systematically placed near active burrows or areas on the property with small mammal sign. Three species of small mammals were documented to occur on the property. The most commonly trapped species was the deer mouse (*Peromyscus maniculatus*), but kangaroo rats (*Dipodomys heermanni*) and house mice (*Mus musculus*) also were captured. Sign of other small mammal species included California ground squirrel (*Spermophilus beecheyi*) burrows and pocket gopher (*Thomomys bottae*) mounds.

The avian survey for the North Avenue Parcel was preformed on 29-31 May 2002. A total of 26 bird species were observed during the 3-day census. The most common species recorded included: mallard (*Anas platyrhynchos*), red-winged blackbird (*Agelaius phoeniceus*), and horned lark (*Eremophila alpestris*).

RECREATION

The California Department of Fish and Game has held an annual dove hunt on 60 acres of land in the northwest corner of Section 10 in a safflower field. The hunt is held on 1 September. Approximately 43 hunters attended the hunt and 128 dove were taken (average 3 per person).

TOURS, PRESENTATIONS, CONFERENCES, AND WORKSHOPS

The annual spring tour that is typically held at the project site was not conducted in 2002. Instead, site tours at Tranquillity and Atwell Island were given to US Fish and Wildlife Service and US Bureau of Land Management personnel. These tours were conducted on consecutive days in fall, 2002. ESRP biologists, GIS specialists, and senior staff members attended a variety of conferences in 2002. Biologists attended the annual western section meeting of The Wildlife Society (TWS), which was held in Visalia, CA. Senior staff members presented preliminary results of the Demonstration Project at that conference. Two presentations were also given at a joint conference sponsored by the Ecological Society of America (ESA) and Society for Ecological Restoration (SER) held in Tucson AZ. GIS specialists attended the Annual Society for Conservation GIS (SCIS), and the annual ESRI International User conference. One staff member presented a poster on avian response to restoration practices at the Partners in Flight conference held in ??. Two notes were published in the Central Valley Bird Bulletin.

MANAGEMENT ACTIVITIES AND RESTORATION AT THE ATWELL ISLAND SITE

RESULTS OF STUDY PLOT RESTORATION

Small Test Plots

During November 2001, BLM established a series of 456, 1/1000-acre (6.58 ft by 6.58 ft) test plots in the southwest quarter of Section 23. Seed from 29 species of shrubs, forbs, and grasses were planted in the plots. Four types of site preparation were used: scraping the surface, disking to 8 inches, harrowing to 4 inches, and no preparation. Within the disked area, plots with supplemental phosphorus and bone meal were established. Seeding rates of 10, 40, 80, and 160 lbs/acre were used. There was no replication of plot treatments because the test plots are being used as a screening technique to look for broad effects and are the first step of a tiered study approach.

The test plots were monitored on 7 January and 20 February 2002. No seedlings of the seven shrub species were found of any on either date. Of the six grass species, none were found on 7 January, but in February, a few seedlings of alkali sacaton, few-flowered fescue, and slender-hair grass were found. These were found primarily in the disked area. Of the 16 forb species that were planted, 6 were found during the January check. Only goldfields and tomcat clover had more than 10% coverage. During the February check, only 5 species of forbs were found. The goldfield and the caterpillar phacelia had the best coverage, with over 20%. The goldfield plants grown from commercially purchased seed died without blooming or setting seed, while plants from the locally collected seed was blooming and setting seed. The *phacelia* did best in the plowed areas, while the goldfield did best in the scraped areas. Broad trends showed that higher seeding rates led to better germination and establishment. Very few plants of any species were found in the untreated control, indicating very poor germination and survival of native plants in areas with heavy competition. There were no obvious trends in the amended plots.

Hedgerows

During February 2002 BLM formed and planted 37 hedgerows in the southeast quarter of Section 10. Hedgerows were planted in 2 forms, single curved lines and groups of 4 or 5 straight lines. We planted rows 1-6 with a commercial S&S hedgerow mix consisting of 60% bran and 40% native seed. We planted rows 7-17 with a combination of 10% commercial hedgerow mix, 40% locally collected common sunflower, 25% locally collected valley salt bush, and 25% locally collected quail bush. We planted rows 18-37 with a combination of 10% commercial alkali sacaton, 45% quail bush and 45% valley salt bush.

A survey of the hedgerows was done in early August 2002. Rows 1-6, which were planted with the commercial hedgerow mix were nearly a total failure. The other 31 rows were much more successful with a total of 1,835 valley saltbush, 863 quail bush, and 3,809 alkali sacaton plants counted.

Statistical comparisons for the three primary species were made between single curved rows (n = 3), inside straight rows (n = 9), and outside straight rows (n = 8). There was no significant differences in the amount of valley saltbush, but the number of shrubs was highest on the inside grouped straight lines (mean = 108 shrubs) and lowest on the single curved lines (mean = 64 shrubs). The grouped rows had significantly higher number of quailbush shrubs (mean = 37 shrubs) than single rows (mean = 13 shrubs). In addition, inside rows (mean = 52 shrubs) had a significantly higher number of shrubs than outside rows (mean = 19 shrubs). The difference in number of clumps of alkali sacaton between single and grouped rows was not significant, but the number of clumps on inside rows (mean = 310 clumps) was significantly higher than the number of clumps (mean = 62 clumps) on the outside rows. These results show that it may be advantageous to plant hedgerows in groups of rows rather than in single rows.

Seeding Restoration Mix

On 28 November 2002, BLM planted 80 acres in the southwest corner of Section 23. Forty acres was planted using a commercial seed mix containing 11 native species and 56% bran. Seeding rate was 11.1 lbs/ acre. The other 40 acres was planted with locally collected spikeweed at a similar seeding rate. Both areas were planted with an imprinter.

The area was monitored during the winter and spring. In January, many seedlings of goldfield, spikeweed, fescue, and gilia were found in the field, but were overtopped by the non-native annuals. On 4 March 2002, the area was browning out from lack of moisture. None of the shrubs had sprouted and none of the planted annuals had set seed. The site was totally dominated by introduced exotic annual plants, which profoundly out-competed the planted natives.

Propane Flaming for Weed Control

Immediately before planting the restoration mix on 40 acres in Section 23, two small areas approximately 50 ft by 30 ft were flamed with a propane weed flamer. Residual dry matter was burned off and the remaining green non-native annual forbs and grasses cooked. On 4 March 2002, the planted vegetation was still green in the flamed area, while non-flamed areas were desiccating. Many planted native species were found to be blooming. Several natives that had not been planted also were found including ranchers' fireweed and California mustard (*Guillenia lasiophylla*). These findings show the importance of control of competing non-native vegetation when attempting native plant establishment.

Planting Shrubs and Trees along Canals

On 21 March 2002, BLM planted 130 Gooding's yellow willows (*Salix gooddinggii*) and 20 Fremont cottonwoods (*Populus fremontii*) in a ditch along the Alpaugh Canal in Section 10. Planting was done using a hydro-auger. On 1 May 2002, BLM planted 70 potted trees and shrubs along the Alpaugh Canal on the north side of the project area in sections 4 and 5. On 25 November, in the same area, we planted an additional 60 trees and shrubs.

Quail bush shrubs planted along the Alpaugh Canal in spring 2001 had 100% survival during 2002. These plantings were not watered during 2002, but showed good growth with the largest shrubs reaching over 5 ft in height and 7 ft in diameter.

Shrub Islands with Drip Irrigation

During January 2002, a drip irrigation system was placed on the 80 acres that had been planted with the range drill in Section 23. Twelve lines, each 1,000 ft long with a total of 1,400 emitters, were installed. Seedlings (120 goldenbush; 120 valley salt bush, 10 quail bush, and 300 alkali sacaton) were planted at approximately 550 emitters including. Seeds of golden bush, valley salt bush, and alkali sacaton were planted at the remaining 850 emitters. The southern 3 lines, which had most of the planted seedlings, have done well, with nearly 100% survival. The 130 plants on the northern 9 lines and the seeds planted on those lines had nearly a 100% failure rate. The 300 plus plants that survived have grown, even though they were not watered after 1 July 2002. The advantages to using drip irrigation are that there are almost no weed problems and the success rate is very high. The disadvantages are the high cost of materials for the drip system and the high labor demand for installing the drip system, planting the plugs, and running the irrigation system.

Native Seed Collection

During 2002, BLM contracted with seed collectors to collect native seed in the southern San Joaquin Valley. A total of 1,270 lbs of 7 species of native shrubs was collected. Also collected were 1,227 lbs of 11 species of annual forbs and gasses.

INCIDENTAL WILDLIFE SIGHTINGS

During 2002, a total of 3,120 sightings found on the Atwell Island site were recorded in the database of incidental wildlife sightings. Included were 155 species of birds, 11 mammal, 6 reptiles, 3 amphibians, and 15 butterflies. Of special interest is a road-killed kit fox was found along the paved road on the project area south of Alpaugh. A breeding population of San Joaquin Valley coachwhips and coast horned lizards also was located in the newly acquired unfarmed area.

SITE MANAGEMENT EFFORTS

During 2002, BLM repaired and upgraded one well and pump on the northern half of the project area. This upgrade will ensure a continued supply of water for the restoration activities on the site.

CHRISTMAS BIRD COUNT

An annual bird count was conducted at Atwell Island on 16 December 2002. Data compiled during this survey was intended for the National Audubon Society Christmas Bird Count (CBC), which is an annual survey conducted simultaneously in the Western Hemisphere during December (early winter).

A total of 96 species were observed and 11,381 individuals were recorded. Unusual sightings included: 1 American bittern, 1 ross goose, 53 cinnamon teal, 57 common mergansers, 13 white-tailed kites, 1 merlin, 1 peregrine falcon, 1 prairie falcon, 280 black-bellied plovers, 15 mountain plovers, 4 short-eared owls, 2 burrowing owls, 2 greater roadrunners, 1 chipping sparrow, and 1 vesper sparrow. The most common species recorded were red-winged blackbird (5,640), savannah sparrow (840), horned lark (771), white-crowned sparrow (603), and house finch (540), black-bellied plover (380), western meadowlark (299), and American pipit (291).

RECREATION

Game Bird Heritage Program Dove Hunt

During the summer of 2002, BLM, in cooperation with the California Department of Fish and Game and our cooperating farmer, Jackson Farms, planted 40 acres of safflower in sections 4 and 5. Two dove hunts in 2002 occurred on 1 September, 2002. These hunts can accommodate a maximum of 40 hunters, 20 in the morning and 20 in the afternoon. The hunt on opening day of dove season (1 September, 2002) drew the maximum number of hunters. Nearly all hunters in the morning session and many in the afternoon session reached their limit of dove. After 1 September, the area was open to dove hunting and a permit was not required.

TOURS AND PRESENTATIONS

The following tours and presentations were conducted by BLM staff.

- Presentation on Atwell Island project accomplishments for BLM State Office Staff.
- Presentation on Atwell Island project for the Tulare County Audubon Society.
- Gave presentation on Atwell Island project for The Wildlife Society Western Section meeting in Visalia.
- Gave tour of Atwell Island project to a group from The Wildlife Society Western Section.
- Gave tour of Atwell Island project to representatives of the California Department of Corrections and EDAW.
- Gave tour of Atwell Island project to CVPIA Restoration Group from FWS.
- Gave tour of Atwell Island project area to Patagonia's Sustainable Cotton Tour.
- Gave tour of Atwell Island project area to BLM Bakersfield FO management team and interagency Land Retirement Team.

Workshops and conferences attended by BLM staff include:

- Attended Seed for Success workshop in Sacramento – Instruction workshop on seed collecting.
- Attended workshop and open house at ConservaSeed in Courtland.
- Attended tour of Union Slough restoration project in Yolo Co.
- Attended Ecological Farming Conference and Wildfarm Alliance Workshop at Asilomar.

1. INTRODUCTION

1.1. BACKGROUND

Large tracts of land on the west side of the San Joaquin Valley are characterized by a high groundwater level and high selenium content. The application of irrigation water to these lands results in an accumulation of poor quality drain water. The elimination of drain water is a chronic problem on these lands and has been the subject of environmental concern. One way to reduce the accumulation of drain water and to lessen problems associated with its disposal is to retire the land from agricultural production. The Central Valley Project Improvement Act (CVPIA) of 1992 authorized a land retirement program to retire up to 200,000 acres of land as recommended in the San Joaquin Valley Drainage Program Final Report. An interagency team consisting of federal representatives from the U.S. Bureau of Reclamation (USBR), the U.S. Fish and Wildlife Service (FWS), and the U.S. Bureau of Land Management (BLM) has been assembled to accomplish the goals of the CVPIA Land Retirement Program. The Land Retirement Team (LRT) is entrusted with the task of implementing the CVPIA Land Retirement Program. Through this program, the U.S. Department of the Interior (DOI) may purchase land, water, and other property interests from willing sellers who receive Central Valley Project (CVP) water allocations and are located in areas where there are significant drainage problems (Figure 1-1). Condemnation of land is not a part of the program. However, willing sellers are numerous because of the low productivity and high cost of agricultural production on drainage impaired lands.

The broad goals of the Land Retirement Program are to:

reduce the volume of drain water by retiring land from irrigated agricultural production on the west side of the Valley,

- acquire water for CVPIA purposes, and
- enhance fish and wildlife resources.

Additional background information on the CVPIA Land Retirement Program can be found in a variety of reports (USDI 1997, USDI 1999, Selmon et al. 2000, Uptain et al. 2001) and web sites (see http://www.usbr.gov/mp/cvpia).

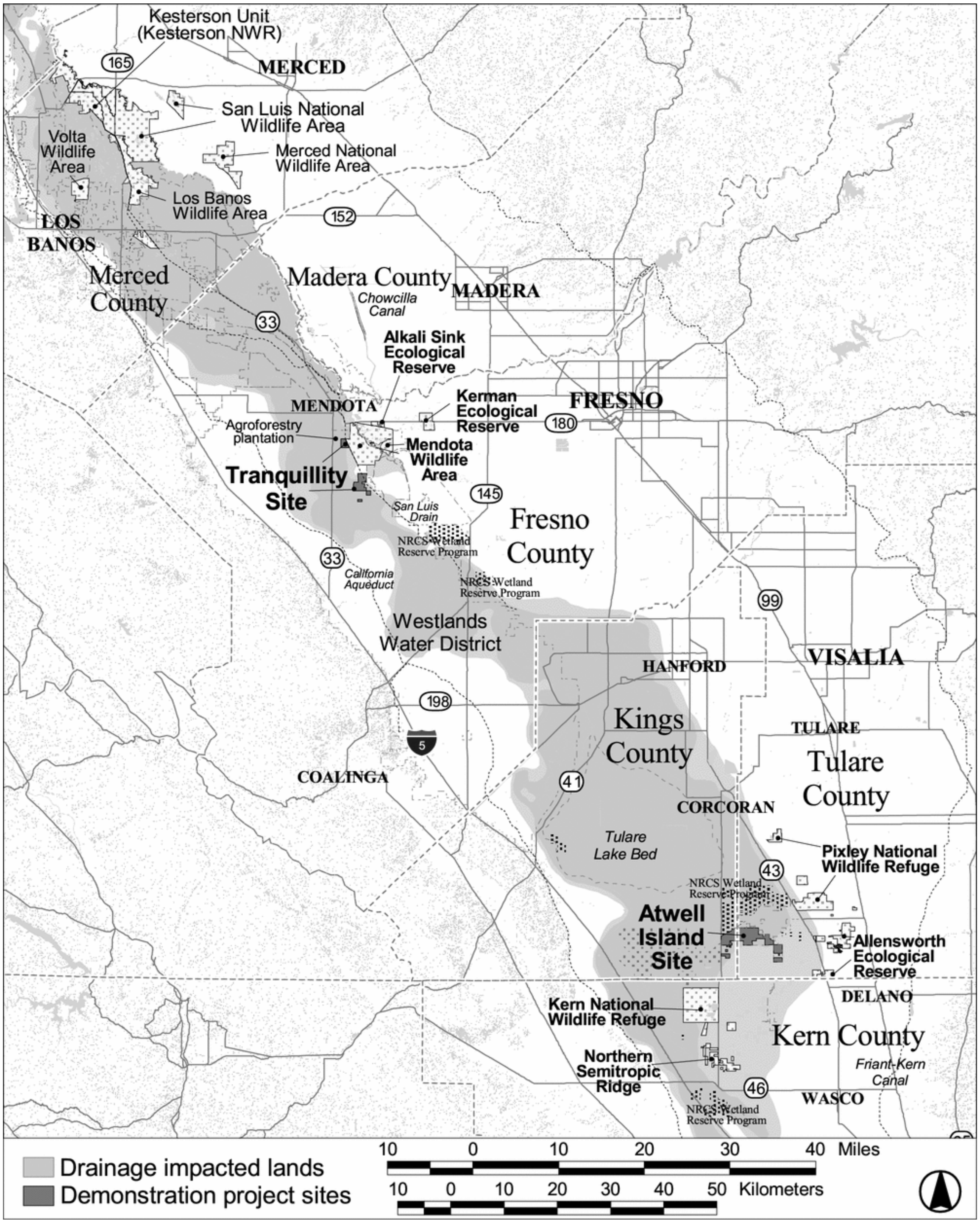

Figure 1-1. Drainage impaired lands in the San Joaquin Valley.

1.2. DEVELOPMENT OF THE LAND RETIREMENT DEMONSTRATION PROJECT

During the comment period for the Land Retirement Program Draft Environmental Assessment (EA), concerns were raised about the magnitude of the project and the lack of knowledge about the potential positive and negative effects of retirement of agricultural land on a large scale (USDI 1999). A Biological Opinion was issued by the FWS that raised specific concerns about the potential for bio-accumulation of selenium on retired lands and its effects on wildlife (FWS 1999). Also of concern was the disposition of retired lands; without appropriate management or habitat restoration, retired lands could become infested with weeds and pests. This condition could impact neighboring farming operations as well as creating undesirable wildlife habitat. Land managers have an obligation to ensure that these conditions do not persist on retired lands.

Historically, the conversion of native habitat to agriculture greatly contributed to a loss of wildlife habitat and to the endangerment of a number of species that are endemic to the San Joaquin Valley. The restoration of retired lands could contribute to the recovery of endangered and threatened plant and animal species by providing connecting linkages and corridors between existing habitat areas or through restoration of large blocks of land that would provide habitat for new core populations of sensitive species. In fact, agricultural land retirement is prominently featured in the FWS recovery plan for upland species of the San Joaquin Valley (FWS 1998).

Accordingly, the Land Retirement Demonstration Project (LRDP) was initiated to address concerns about the scope and degree of impacts of land retirement on drainage volume reduction, wildlife, socio-economics, and overall cumulative effects of removal of land from irrigated agriculture.

Specifically, the goals of the Land Retirement Demonstration Project are to:

- Provide site-specific scientific data to determine if land retirement is an effective way to reduce drain water volume and concurrently to provide habitat for wildlife. Results are expected to guide implementation of a larger Land Retirement Program;
- Research cost-effective means of restoring self-sustaining communities of native upland plants and animals on LRDP land that will be applicable to larger acreages;
- Use adaptive management principles (Holling 1978, Walters and Holling 1990) to maximize efficiency of the restoration research program;
- Educate stakeholders about the Land Retirement Program; and
- Evaluate the need for continued use of acquired water on Demonstration Project lands. If not needed for habitat restoration or continued management of these lands, USDI may sell the water to another user within the water district or the water may be used for other CVPIA purposes (USDI 1999).

A monitoring plan was prepared which describes sampling and analysis of physical factors including surface water, groundwater, and soils (CH2M Hill 1999). That plan is being implemented by the USBR. The California State University Stanislaus, Endangered Species Recovery Program (ESRP), prepared a resource-monitoring plan that outlined the focus of habitat restoration research and established monitoring protocols (Selmon et al. 1999). The 5-year plan included establishing a Habitat Restoration Study (HRS) to monitor the level of success of four levels of restoration treatments and monitor the responses of wildlife to those treatments. The plan also outlined a program to monitor the selenium levels in plants and wildlife. Although habitat restoration research and active site restoration efforts are included in the plan, those tasks are only accomplished with funds in excess of the funds required to conduct the Habitat Restoration Study. The research and monitoring described in the plan were implemented in 1999.

1.3. Demonstration Project Site Locations and Descriptions

The Demonstration Project consists of project sites in two geographically and physiographically different drainage-impaired basins, in order to generate data representative of large-scale land retirement. The Tranquillity site, formerly called the Westlands site or Mendota site, is located in western Fresno County (Figure 1-2). The Atwell Island site formerly called the Alpaugh site, is located in Kings and Tulare counties (Figure 1-3).

1.3.1. Tranquillity Site

In the fall of 1998, the Land Retirement Team purchased 1,646 acres in western Fresno County. An additional 440 acres were added to the site in late 2001, bringing the total to 2,086 acres (Figure 1-2). Much of the land initially purchased in 1998 had previously been in agricultural production. In 1999, a cover crop of barley was planted on approximately 1,200 acres for weed and erosion control. The remaining acreage had been idled for longer than 5 years and contained sufficient plant cover. The 440-acre North Avenue Parcel was obtained in late 2001 and was previously fallowed and grazed. Wildlife surveys and some restoration efforts were conducted in 2002 on the North Avenue Parcel.

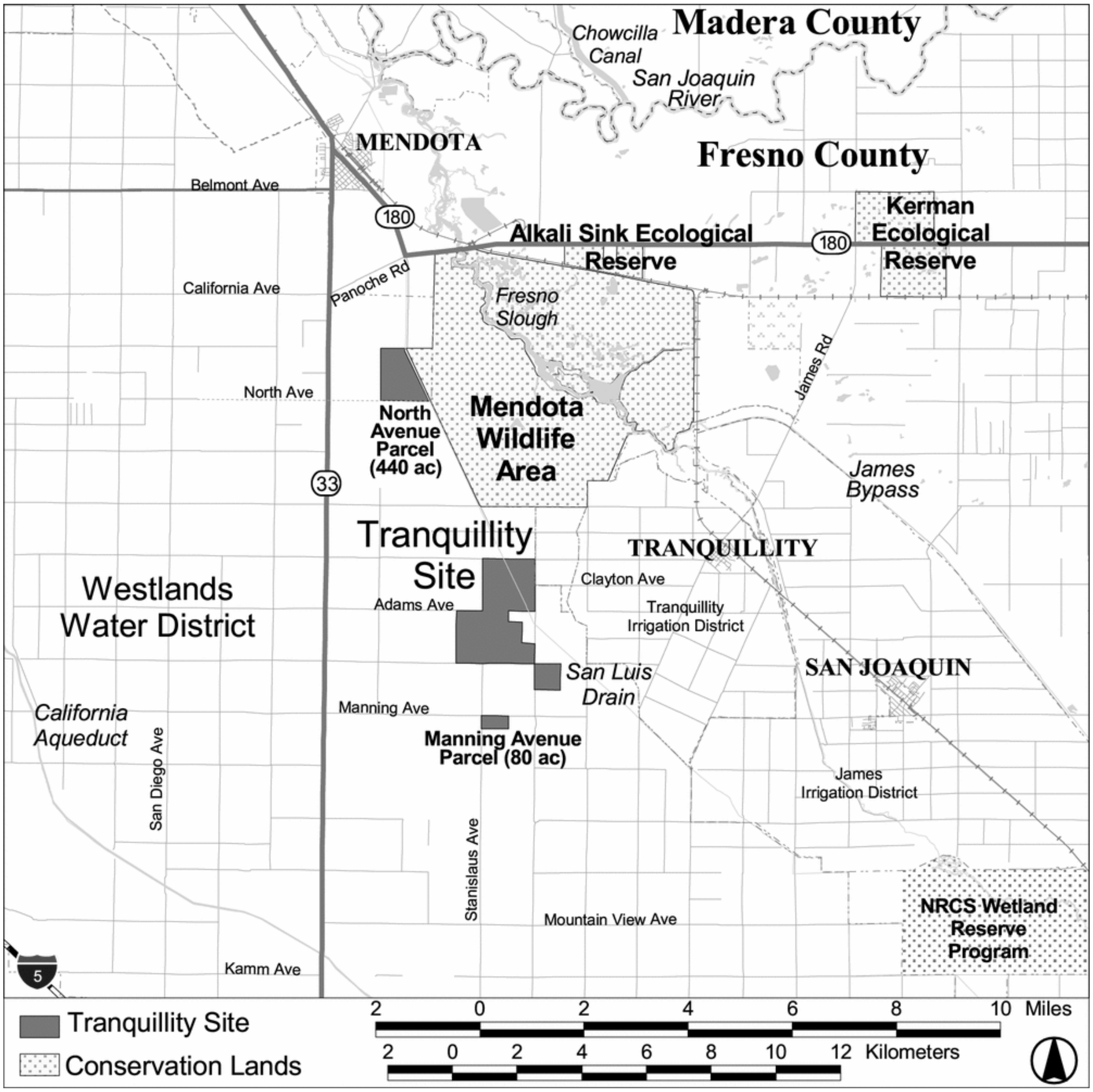

Figure 1-2. Location of the Tranquillity Site including the additional 440 acres known as the North Avenue Parcel.

1.3.2. Atwell Island Site

As of the end of December 2002, The Atwell Island site consisted of 5,530 acres located in the Tulare Lake Basin in Kings and Tulare counties near Alpaugh (Figure 1-1). This includes 1,502 acres that were purchased during 2002. An additional purchase of 617 acres was made in March 2003, bringing the total to 6,147 acres. The project site is authorized to increase to 8,000 acres.

Of the 6,147 acres currently owned and managed by the BLM, approximately 360 acres (6%) has never been farmed, 1400 acres (23%) has not been farmed for 16 years, 1300 acres (21%) has not been farmed for 6 years, 340 acres (6%) has not been farmed for 2 years, and 2747 acres (45%) is currently being farmed. Farming is being used as a placeholder until the land can be restored to native habitat. On the farmed areas, water intensive crops (such as alfalfa) are being replaced by crops with lower water needs (such as oats).

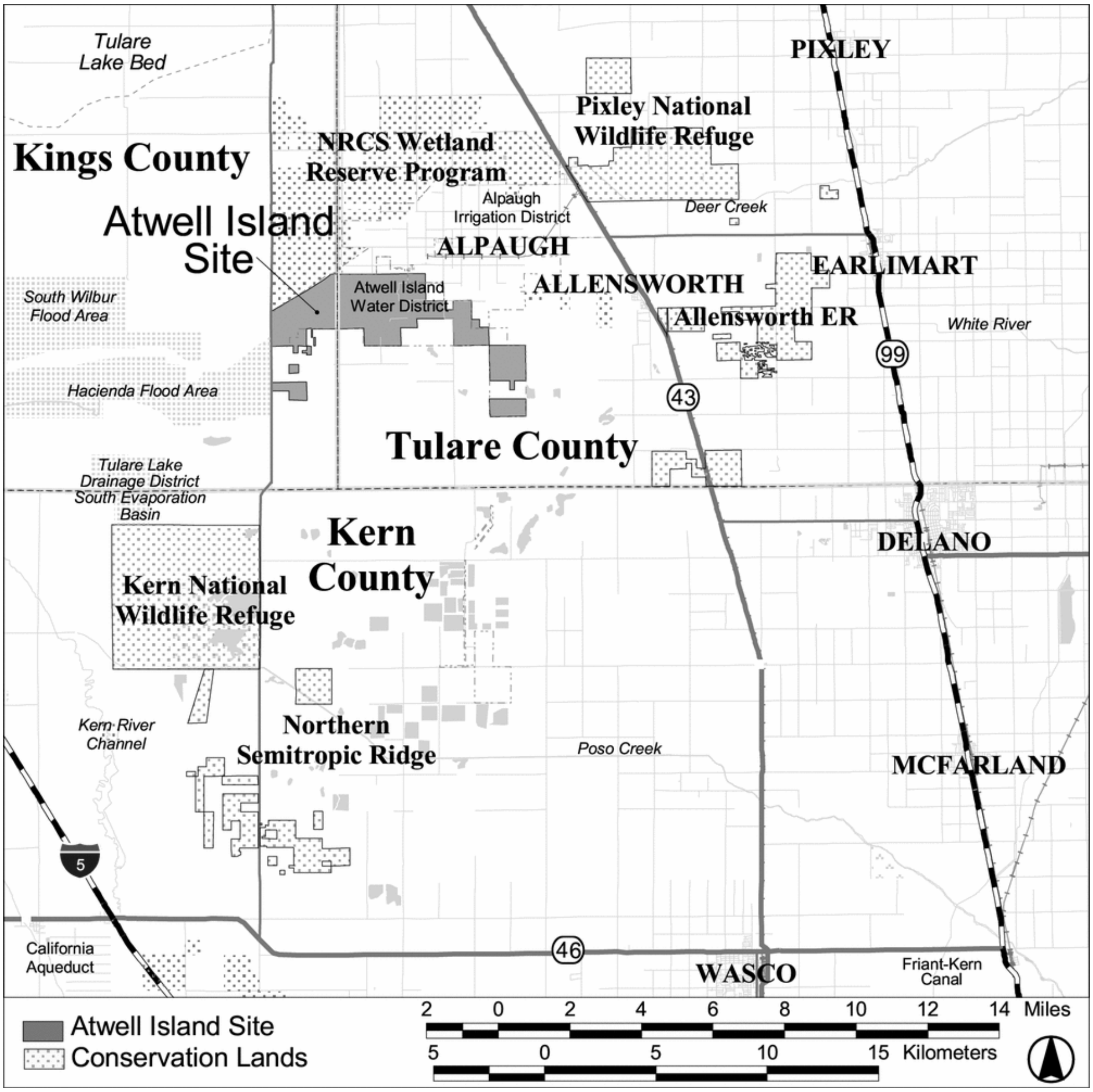

Figure 1-3. Location of the Atwell Island site.

1.4. PROJECT SCOPE

Although the primary goal of land retirement is drainage reduction, it is also imperative that retired lands be restored to an established, self-sustaining matrix of upland plant communities such as California Prairie, Valley Sink Scrub, and Valley Saltbush Scrub (*sensu* Holland 1986). Virtually no information is available on upland community restoration of retired agricultural land in the San Joaquin Valley and restoration technologies developed elsewhere are generally of marginal applicability. Accordingly, the Land Retirement Demonstration Project provides an opportunity to develop restoration techniques specifically applicable to retired agricultural lands at various locations in the San Joaquin Valley and to study the effects of habitat restoration and its importance to wildlife prior to implementation on a larger scale.

A variety of research, monitoring, restoration, and management activities have been implemented on retired lands at both the Tranquillity and the Atwell Island sites since 1999. Some of these activities include:

- monitoring groundwater levels and groundwater quality in relation to reduction of applied irrigation water;
- monitoring the level of bio-accumulation of selenium in plants and wildlife,
- performing a study to determine the responses of wildlife to restoration efforts (Habitat Restoration Study);
- performing site-wide monitoring of wildlife;
- restoration-related experimentation to gather information on appropriate native plants to use in restoration efforts
- performing restoration related experiments to gather information on appropriate uses and types of cover crops, seeding methods, seeding rates, seedling planting, weed control, microtopographic relief, and mycorrhizal inoculation;
- installating a native plant nursery to facilitate the investigation of ways to efficiently grow native plant species, amplify locally collected seed stock, determine the potential usefulness of species for future inclusion in restoration strategies, allow an assessment of species' applicability for mechanized seed production, and develop mechanized seed production technologies for selected species.
- implementating wildlife-friendly farming practices, and;
- managing lands for recreational use.

This report describes the accomplishments and preliminary results obtained by the Land Retirement Team in calendar year 2002. This report is structured differently from previous annual reports (Selmon et al. 2000, Uptain et al. 2001, Uptain et al. 2002) because the Land Retirement Team decided that the two highest priorities are to present results of the physical impacts of land retirement (Chapter 2) and to present the results of selenium accumulation in biota on LRDP lands (Chapter 3). We also present information gathered on habitat restoration on retired lands (Chapter 4) and information on the richness and abundance of wildlife on restored lands (Chapter 5). Other tasks accomplished (e.g., site management, recreation, site tours, presentations, and workshops) are presented in Chapter 6. Management and restoration activities conducted by BLM at Atwell Island are presented in Chapter 7. The primary author (or authors) of each chapter is listed under the chapter title, but in most cases each chapter was a collaborative effort.

Introductory paragraphs and study designs and methodologies are presented in each section whenever necessary for clarity or when changes have been made from information presented in previous annual reports. Each section contains results of the research and a discussion. However, in a number of cases, results and discussions are not provided because complete analysis of the data has not been completed or sampling and data analysis did not occur until after the end of calendar year 2002. Because this is a project that is in progress, this should not be surprising. All data analysis and a complete synthesis of information will be contained in the final report that will be prepared in 2004.

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2. PHYSICAL IMPACTS

- Stephen Lee and Joseph Brummer

2.1. TRANQUILLITY SITE

2.1.1. Geology

The Tranquillity Demonstration Project site is located in the western San Joaquin Valley, an asymmetrical basin bounded by the Coast Ranges on the west, the Tehachapi Mountains on the south, the Sierra Nevada on the east and the delta of the San Joaquin and Sacramento Rivers on the north. The axis of the valley trough is closer to the Coast Ranges than to the Sierra Nevada. The basin is filled with alluvium overlying older Mesozoic and Cenozoic marine and continental sediments. Alluvial deposits underlying the central San Joaquin Valley were shed from the adjacent Coastal and Sierra Nevada ranges and vary in thickness from 900 to 3,300 ft (Miller et al. 1971). The Sierra Nevada consists mainly of granitic and metamorphic rocks of pre-Tertiary age. The Coast Ranges are composed primarily of folded and faulted beds of Cretaceous age marine shale and sandstone in the north and Cenozoic age sandstone and shale in the south (Prokopovich 1987). Bull (1964a and b) identified a series of alluvial fans derived from sediments from the coastal ranges that form the western margin of the San Joaquin Valley in the study area.

The Tranquillity demonstration site is located in the trough of the San Joaquin valley in Western Fresno County. The site is underlain directly by flood basin deposits derived from overbank deposition from the San Joaquin River and Fresno Slough. The flood basin deposits consist of fine textured, moderately to densely compacted clays that range in thickness from 5 to 35 ft (Belitz and Heimes 1990). The flood basin clays have low permeability and greatly impede the downward movement of water. On the northern part of the site (Section 10, Figure 2-1), the flood basin deposits rest upon well sorted micaceous sand derived from the Sierra Nevada . The Sierran sands are highly permeable, reduced in oxidation state, and vary in thickness between 400 to 500 ft in the project vicinity. On the southern part of the site (Sections 15 and 16, Figure 2-1), the flood basin deposits overlie sediments derived from the coastal ranges. The coastal range sediments inter-finger with Sierran sands in the project vicinity, and are oxidized and primarily fine grained. The Corcoran clay is a regionally extensive fine grained lake bed deposit that underlies the site at a depth of approximately 500 ft.

2.1.2. Soils

Soils in the Tranquillity Demonstration Project area primarily consist of clays, silty clays, and silty clay loams, which formed in alluvium, derived from igneous and sedimentary rock. Individual soil mapping units in the project area include (in order of abundance) Tranquility clay, Lillis Clay, and Lethent Silt Loam. The Tranquility mapping unit is the predominant soil type in the study area and covers approximately 80% of the site, while the Lillis and Lethent mapping units occur exclusively in Section 10 and cover the remainder of the site (Figure 2-1). The Tranquility clay is a very deep, poorly to moderately drained saline-sodic soil found on low-lying alluvial fans and flood plains with slopes between 0 and 1%. The permeability of this soil is slow and the unit is suited to growing irrigated, salt-tolerant crops, or for wildlife habitat (USDA 1996). Runoff is low, and the hazard of water erosion is slight. The depth to the water table varies and is commonly highest during irrigation applications in the winter and early spring. These soils generally require intensive management to reduce salinity and maintain agricultural productivity. The USDA took soil samples from the major soil horizons in a test pit located in the NW 1/4 of Section 16 (Figure 2-1) at the site in 1992. The samples were analyzed in the laboratory for particle size, chemistry and mineralogy. These soils consist predominantly of clay-sized particles less than 0.002 mm in diameter. The USDA reported that the clay fraction from 6 samples taken from the test pit ranged from 48 to 52% of the total samples. Silt size particles (0.002-0.05 mm in diameter) ranged from 36-37% of the total samples, and sand size particles made up from 11-16% of the total samples (USDA 1992). Total selenium concentrations ranged from 0.5 to 1.1 ppm, and the Electrical Conductivity (EC) of saturation extracts ranged from 3.7 to 10.9 deciSiemens/meter (dS/m). These soils are highly plastic with Plasticity Indices ranging from 23-52%. The predominant clay mineral is Montmorillonite, which can take on water in the crystal lattice, resulting in high shrink-swell potential and development of deep cracks at the soil surface upon drying.

The Lillis clay mapping unit covers about 10% of the study area in the eastern half of Section 10 (Figure 2-1). These soils are very deep, poorly drained, saline-sodic soils found typically on floodplains and basins. Permeability of the Lillis soil is extremely slow, water infiltration rate is high, and when the soil is dry the surface cracks open. As the soil becomes wet and the cracks close, the infiltration rate greatly decreases. Surface water runoff is low and the hazard of water erosion is slight. The unit is used mainly for wildlife habitat and recreation. The USDA took soil samples from the major soil horizons in a test pit located in the SW 1/4 of Section 10 at the site in 1992. The samples were analyzed in the laboratory for particle size, chemistry and mineralogy. These soils consist predominantly of clay sized particles less than 0.002 mm in diameter. The USDA reported that the clay fraction from nine samples taken from the test pit ranged from 59 to 66% of the total samples. Silt-size particles (0.002-0.05 mm in diameter) ranged from 29-36% of the total samples, and sand-size particles made up from 2-7% of the total samples (USDA 1992). Total selenium concentrations ranged from 0.3 to 0.7 ppm, and the EC of saturation extracts ranged from 9.6 to 38.6 dS/m. These soils are highly plastic with Plasticity Indices ranging from 33-61%. The predominant clay mineral is Montmorillonite, which can take on water in the crystal lattice, resulting in high shrink, swell potential.

The Lethent silt loam mapping unit covers about 10% of the site in the north half of Section 10 (Figure 2-1). These soils are deep, moderately well drained, saline-sodic soil found on low lying alluvial fans and basin rims. Permeability of this soil is very slow, runoff is slow, and the hazard of water erosion is slight (USDA 1996).

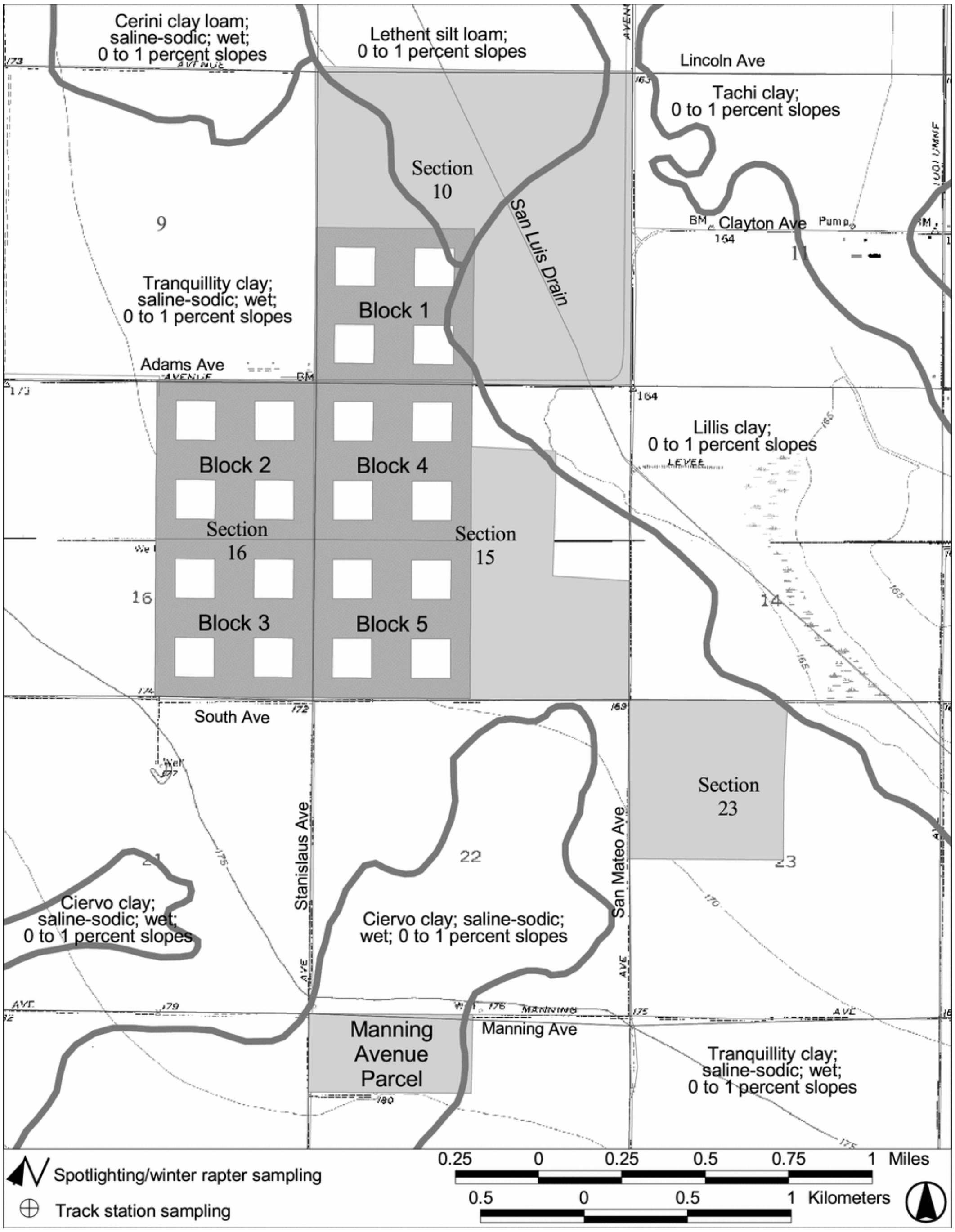

Figure 2-1. U.S. Department of Agriculture soil mapping units, Tranquillity site.

2.1.2.1. Soil monitoring

The objective of the soil monitoring program for the demonstration project is to detect changes in levels of soil selenium, boron, and salinity that may result from land retirement over the 5-year life of the demonstration project. Baseline soil sampling was carried out by members of the Inter- Agency Land Retirement team during September and October, 1999. Analyses of baseline soil data for the Tranquillity site can be found in the calendar year 2000 annual report.

2.1.2.1.1. Soil sampling

A partial resampling of soils at the Tranquillity Site was conducted in November of 2002. A complete resampling of the deep borings was completed and a resampling of shallow (0-12 inches) sites was completed on northern portions of the area where the highest soil salinity levels occurred in the fall-1999 baseline surveys. Surface (0-12 inches), 8-increment soil samples where collected within 10 feet of the original baseline sampling site. Deeper soil samples were collected from a single core located very close to the site where the baseline samples were collected in 1999. Identical sampling depths of 0-1, 2-3 and 4-5 feet were used for both surveys. Hand equipment was used to collect all the samples in the 2002 resampling event. The samples were tested for total selenium, soluble boron, soluble selenium, and soil salinity. Soil salinity analysis included the electrical conductivity of one part soil, 5 part water extracts (EC5) and the electrical conductivity of saturation extracts (ECe). The EC5 test was used to be consistent with the baseline sampling event while the saturation extracts were run in order to evaluate soil salinity in relation to plant growth response and adaptability. Figure 2-2 shows the relationship between the saturation extract (ECe) and the 1:5 (EC5) extract conductivity levels.

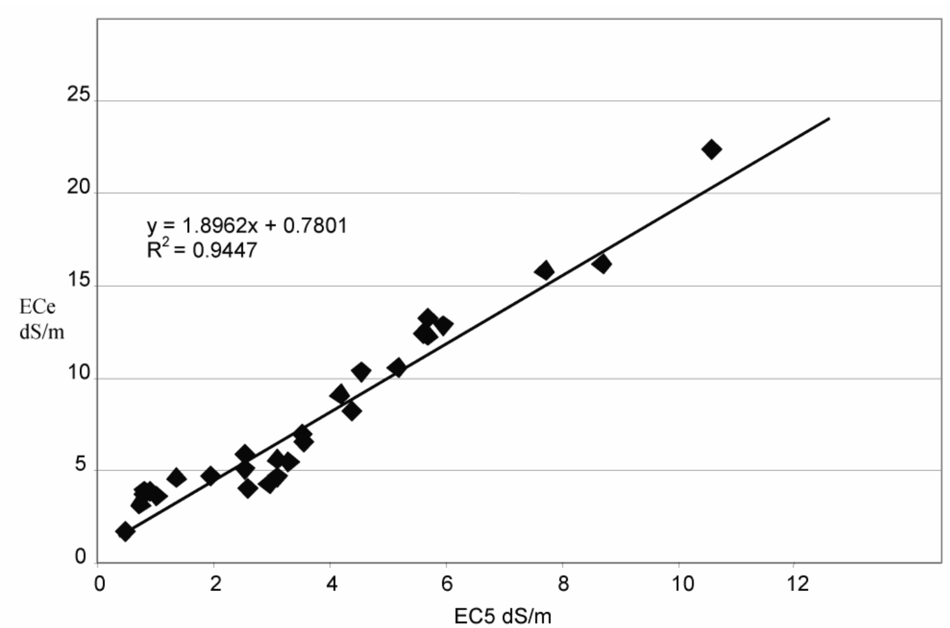

Figure 2-2. The relationship between the EC5 values and The ECe values for soils at the Tranquillity site.

2.1.2.1.2. Trend analysis

Comparisons of data collected at paired sites in 1999 and 2002 are presented in Table 2-1, Table 2-2, Table 2-3, and Table 2-4. All data presented in the following statistical summaries are on a dry soil weight basis except for the soil salinity data, which are the concentration of the extract. The Wilcoxon sign rank test was used to determine if the concentration changes at the paired sites where statistically significant at the 95% confidence level.

Table 2-1. Soil salinity (EC5 dS/m).

Depth (inches)	Sites increasing	Sites decreasing	Sites stable	1999 average	2001 average	Trend	Significant at 95%
0-12	6	51	0	3.69	1.9	Decrease	Yes
24-36	4	19	1	6.63	6	Decrease	Yes
48-60	3	21	0	7.79	6	Decrease	Yes

Table 2-2. Soluble boron 1-5 extract (mg/kg dry soil).

Depth (inches)	Sites increasing	Sites decreasing	Sites stable	1999 average	2002 average	Trend	Significant at 95%
0-12	34	19	4	11.66	10.88	Decrease	No
24-36	17	4	1	25.8	35.5	Increase	Yes
48-60	17	5	1	40.2	45.7	Increase	Yes

Table 2-3. Soluble selenium 1-5 extract (mg/kg dry soil).

Depth (inches)	Sites increasing	Sites decreasing	Sites stable	1999 average	2002 average	Trend	Significant at 95%
0-12	18	36	2	0.031	0.023	Decrease	Yes
24-36	18	5	0	0.084	0.13	Increase	Yes
48-60	21	3	0	0.144	0.264	Increase	Yes

Table 2-4. Total selenium (mg/kg dry soil).

Depth (inches)	Sites increasing	Sites decreasing	Sites stable	1999 average	2001 average	Trend	Significant at 95%
0-12	6	40	9	0.976	0.937	Decrease	Yes
24-36	6	13	5	1.036	0.985	Decrease	No
48-60	9	13	2	0.945	0.919	Decrease	No

2.1.2.1.3. Soil interpretive summary

The element most limiting plant growth in project surface soils probably is boron. Soil salinity was decreasing and average ECe values in the 2002 surveys were 4.9 dS/m in the top foot of soil. ECe levels increased below this depth but salinity levels were also decreasing in the substrata. Some of the soil salinity reduction in surface layers may be due to the beneficial leaching effects of rainfall. The magnitude of the soil salinity reduction may also be related to the soils tendency to form deep wide cracks upon drying. Before the land was retired from irrigation bare soil surface evaporation may have formed a salt concentration in the upper few inches of soil. Upon extended drying the soil cracked deeply while the saline surface layers developed a loose crumb structure. Much of the loose surface material dropped into the deep cracks and was deposited in the substrata. Some of the cracks observed at the Tranquillity Site were over 5 feet deep. These soils are commonly termed vertisols since they have the ability to invert over many wetting and drying cycles.

Total selenium concentrations appear to be slowly decreasing at the site. This is an important trend because this represents the total inventory of selenium in the soil and is not subject to seasonal or temporary concentration changes due to climatic factors or soil reaction changes.

The 2002 samples contained higher levels of soluble boron and soluble selenium than were present in the baseline samples, especially in subsoils. Although some of these elements were leached out of surface soils, the magnitude of the increases in the subsoils seems to suggest these elements where becoming more soluble in the soil solution. Changes in soil pH and redox potential may be responsible for the changes. Plants can also take up boron and selenium, which tends to reduce the leaching potential of these elements. Substrata pH values were currently in the alkaline range so far, which would tend to favor the soluble selenate species of selenium. The soils were dry for most of the year and oxidized conditions prevailed at the site.

Much of the soluble boron at the site was only sparingly soluble. Saturation extract boron concentrations, when expressed on a dry weight basis, are lower than the 1-5 extract concentrations when converted to a mg/ kg dry soil basis.

2.1.3. Weather

Data on hourly precipitation, temperature, wind, and relative humidity data were collected at the California Irrigation Management Information System (CIMIS) weather station # 105, which is located 1.5 miles west of the demonstration project site at the Westlands Water District (WWD) Tranquillity Field Office. The CIMIS station is operated and maintained by the California Department of Water Resources (CDWR), and can be used to guide crop irrigation scheduling and estimate consumptive water use for various crops. A total of 4.07 inches of rainfall was recorded at the CIMIS station (Table 2-5).

Table 2-5. Monthly CIMIS weather data and estimated water use by the barley crop at Station 105 in 2002.

Month (2002)	Reference evapotranspiration (inches)	Barley crop coefficient	Estimated evapotranspiration barley (inches)	Measured precipitation (inches)
January	1.18	0.3	0.35	0.52
February	2.61	1.18	3.08	0.05
March	4.36	1.18	5.14	0.64
April	5.98	1.18	7.06	0.18
May	8.61	0.40	3.44	0.15
June	9.66	0.20	1.93	0
July	9.59	Not applicable	Not applicable	0
August	8.27	Not applicable	Not applicable	0
September	6.66	Not applicable	Not applicable	0.02
October	4.45	Not applicable	Not applicable	0
November	2.15	Not applicable	Not applicable	0.86
December	1.22	Not applicable	Not applicable	1.65
Total	**64.74**			**4.07**

The following paragraph is an excerpt taken from the California Department of Water Resources website (http://www.dpla.water.ca.gov/cimis/hq/etoexpl.txt) that defines the concept of a reference evapotranspiration.

> A daily reference evapotranspiration (ETo) is calculated from the CIMIS weather data by CDWR. ETo is a term used to estimate the evapotranspiration rate of a reference crop expressed in either inches or millimeters. The reference crop used for the CIMIS program is grass, which is close clipped, actively growing, completely shading the soil, and well watered. ETo varies by location, time, and weather conditions. The main factors that influence ETo include incoming radiation (energy from the sun), outgoing radiation (sensible energy leaving the earth), the amount of moisture in the air, air temperature, and wind speed (CDWR 2000). The ET value can be used to estimate the consumptive water demand of an agricultural crop. ETo can be estimated quite accurately through the use of a "model" (a series of mathematical equations). The "model" that is used in CIMIS is a version of Penman's equation modified by Pruitt/Doorenbos (Proceedings of the International Round Table Conference on "Evapotranspiration", Budapest, Hungary 1977). It also employs a wind function developed at the University of California, Davis. The version used in CIMIS uses hourly weather data to calculate daily ETo instead of daily weather data. Hourly averages of weather data are used in the "model" to calculate an hourly ETo value. The 24 hourly ETo values for the day (midnight to midnight) are summed to result in a daily ETo (CDWR 2000). Hourly values of net radiation, air temperature, wind speed and vapor pressure are the inputs used to calculate ETo. Air temperature, wind speed, and vapor pressure are measured directly at each weather station. Hourly net radiation is estimated using a method developed by the University of California. This method uses solar radiation, vapor pressure, air temperature, and a calculated monthly cloud coefficient (CDWR 2000).

Monthly consumptive use by the barley crop exceeded precipitation at the site during the calendar year 2001 in all months except January (-0.17 inches), September, (-0.02 inches) November (-0.86 inches), and December (-1.65 inches; Figure 2-3, Table 2-5). Due to dry soil conditions, the timing of the rainfall, and evapotranspiration by plants, most of the moisture from precipitation probably either evaporated or was added to the soil moisture reservoir and thus did not contribute toward deep percolation (recharge) to the shallow groundwater. Continued declining groundwater levels observed in the shallow monitor wells and sumps at the site during calendar year 2002 support this inference.

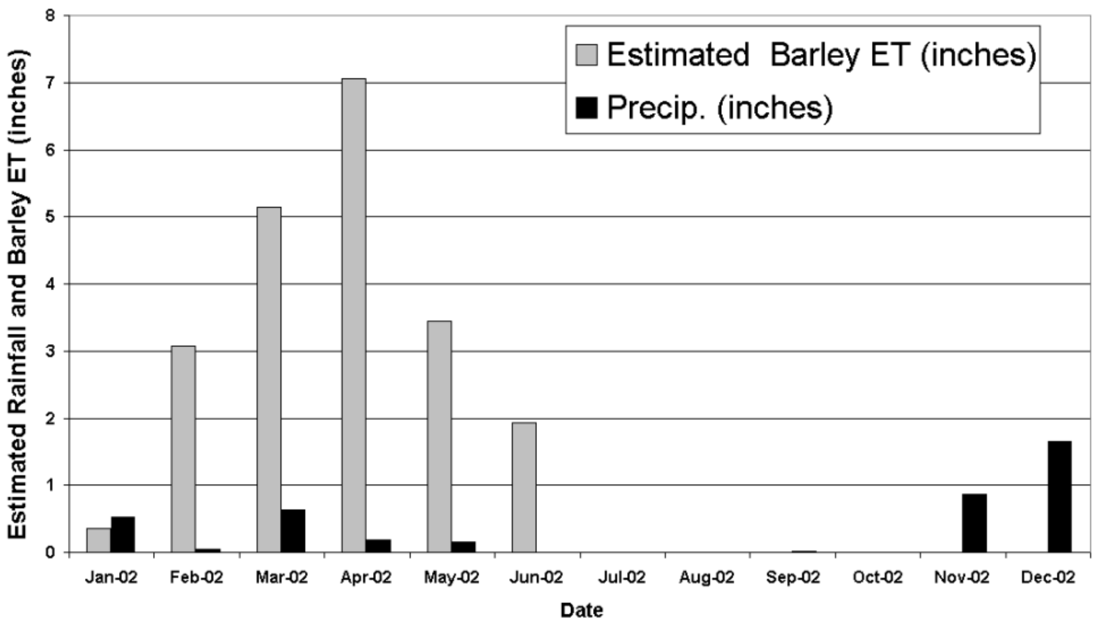

Figure 2-3. Monthly precipitation and estimated barley crop consumptive water use for calendar year 2002 at CIMIS Station 105.

2.1.4. Irrigation

No irrigation water was applied to the barley buffer or research plots in 2002. Approximately 6 inches of water was applied to the 60-acre safflower field in the northwest corner of the site.

2.1.5. Hydrology and Surface Water Monitoring

No surface water ponding was observed at the site during the calendar year 2002, thus no surface water samples were taken for chemical analysis. The natural drainage at the site is to the east and northeast with ground surface elevations ranging from 169 ft above mean sea level (AMSL), in the southwest corner of the site, to about 162 ft in the northeast portion of the site. The land surface in most of the study area has been laser leveled to facilitate irrigation of row crops. There are no perennial surface water bodies on the site. Shallow ephemeral surface water ponds may form on low lying portions of the study area due to localized sheet-flow of runoff during prolonged winter storm events. Surface water courses within the area consist principally of irrigation supply canals, and irrigation return flow ditches. Three irrigation tailwater ditches traverse the site on Sections 15 and 16 (Figure 2-1). Tailwater is irrigation water that does not penetrate the soil, and runs off the irrigated cropland. Tailwater is usually collected in a surface water pond and recirculated into the irrigation system. Fresno Slough, which is located approximately 1 mile east of the study area, is the largest perennial surface water body in the vicinity of the project. Fresno Slough receives flood flow releases from the North Fork of the Kings River and serves as a storage reservoir for irrigation water conveyed via the Delta Mendota Canal. Fresno Slough also occasionally receives flood flows from Panoche Creek, which rises in the Coast Ranges to the west, and flows out onto the Panoche Fan during winter storm events.

2.1.6. Groundwater Level Monitoring

One of the primary objectives of the Demonstration Project is to measure the response of the shallow water table to land retirement. There are approximately 50 monitor wells and three drain sumps in the project vicinity that are used to measure groundwater levels beneath the site on a quarterly basis. The well and sump locations are shown on Figure 2-4. Existing wells constructed prior to the 1998 purchase of the demonstration project lands were installed by Westlands Water District (WWD) and the U.S. Bureau of Reclamation (USBR) for the primary purpose of measuring depths to groundwater beneath drainage impacted lands in WWD. These existing wells are constructed of PVC casing ranging in diameter from 0.75 to 4 inches and vary in depth from 3 to 86 ft below the ground surface. These wells were installed using various construction techniques that range from jetting a short length of pipe into the ground to standard rotary drilling with hydraulic drill rigs.

During the summer of 1999, the USBR installed 15 additional wells for the purpose of measuring groundwater levels and obtaining representative groundwater samples for water quality analyses for the Land Retirement Demonstration. The new wells were installed using a hollow stem-auger drill rig and are constructed of 2-inch PVC casing. Well construction diagrams for the new wells are on file at the USBR office in Fresno, California. Well construction diagrams for the previously existing wells are unavailable.

There also are 18 subsurface drain water collection sumps located in a north to south alignment bisecting the northern half of Section 15 at the site. The sumps are part of an experimental drainage system that was installed at the site during the 1960's. Subsurface tile drains lines were installed beneath the northwest quarter of Section 15 at a depth of approximately 8 ft, with a drain spacing of approximately 150 ft. The drain lines are approximately 6 inches in diameter and discharge to 3-foot diameter concrete sumps that are open to the atmosphere. Water levels have been measured quarterly in three of the drain sumps at the site (Figure 2-5).

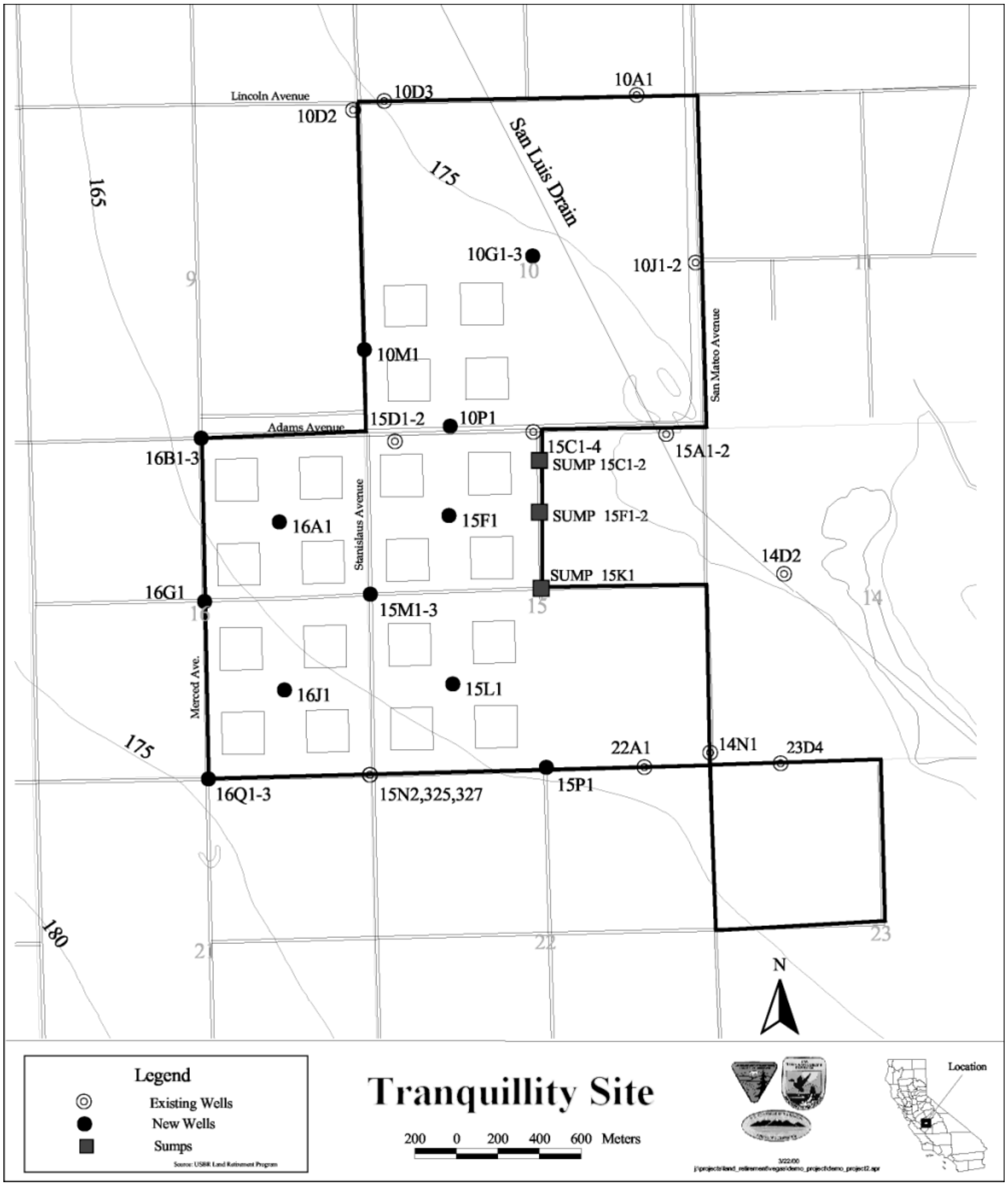

Figure 2-4. Monitor well and sump location map, Tranquillity site.

2.1.7. Groundwater Response to Land Retirement

Groundwater level data collected at the demonstration site as of this date supports the conceptual model of a declining shallow groundwater table in response to land retirement. Declining water level trends have been the norm for the wells used to monitor the system of shallow, perched groundwater at the site since the land was retired from irrigated agriculture in August, 1998. Hydrographs are time series plots of water levels measured in monitor wells. A declining trend in groundwater levels for the shallow perched groundwater system at the site is illustrated by the hydrographs shown in Figure 2-5. The hydrographs represent water levels measured in three drain sumps (15C1, 15F2, 15K1) during the time period from July 1998 to July 2000. The drain sumps are connected to tile drain lines that underlie the northwest quarter of Section 15, and are useful for measuring shallow groundwater trends in that portion of the site. The drain sump locations are shown in Figure 2-4. All three of these sumps show an overall declining trend in groundwater levels for the period of record. Total water-level declines observed in sumps 15C1, 15F2, and 15K1 are 4.5, 3.0, and 2.4 ft, respectively. Sumps 15C1 and 15 F2 were observed to be completely dry starting in January, 2000, while sump 15C1 was observed to be completely dry starting in October, 2000. The drain sumps have remained dry as of this date.

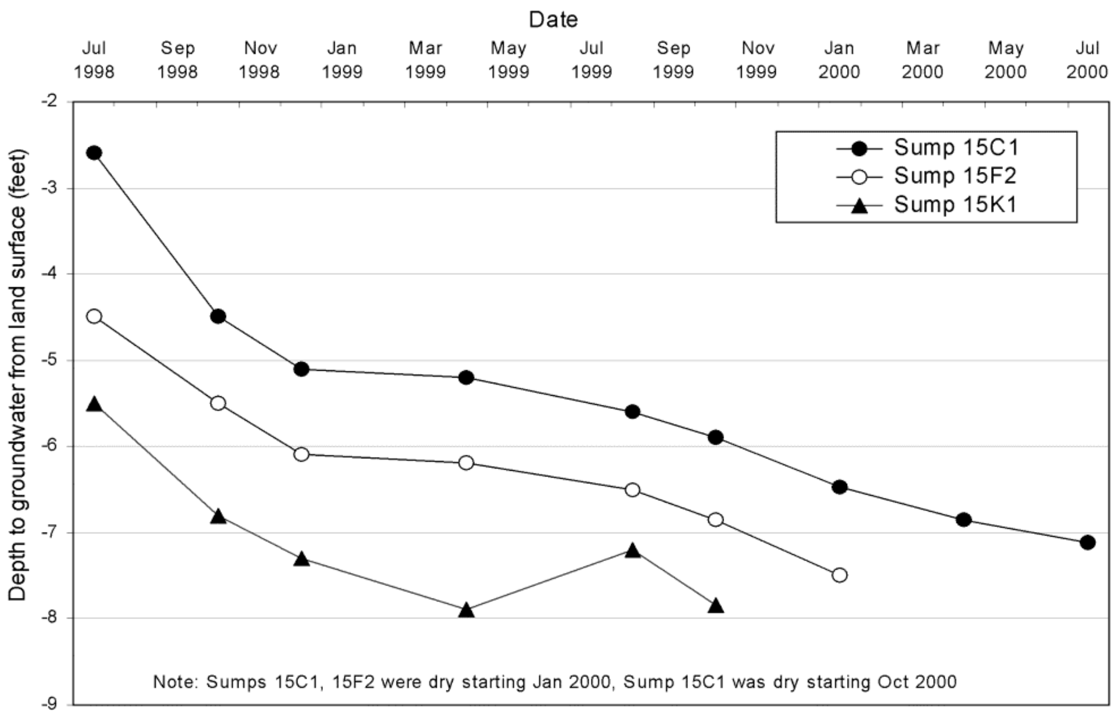

Figure 2-5. Hydrographs for three agricultural drain sumps at the Tranquillity site showing a declining shallow groundwater trend.

A trend of declining water level has been observed in the southwest part of the site at monitor wells 325 and 326. The hydrographs and locations for these wells are shown in Figure 2-6 and Figure 2-4, respectively. The total water-level declines observed in wells 325 and 326 for the period of record are 7.4 and 7.5 ft, respectively. A similar declining trend was observed in wells 15M1 and 16A1 (Figure 2-7). The total water-level declines observed in wells 15M1 and 16A1 were 5.2 and 6.1 ft, respectively.

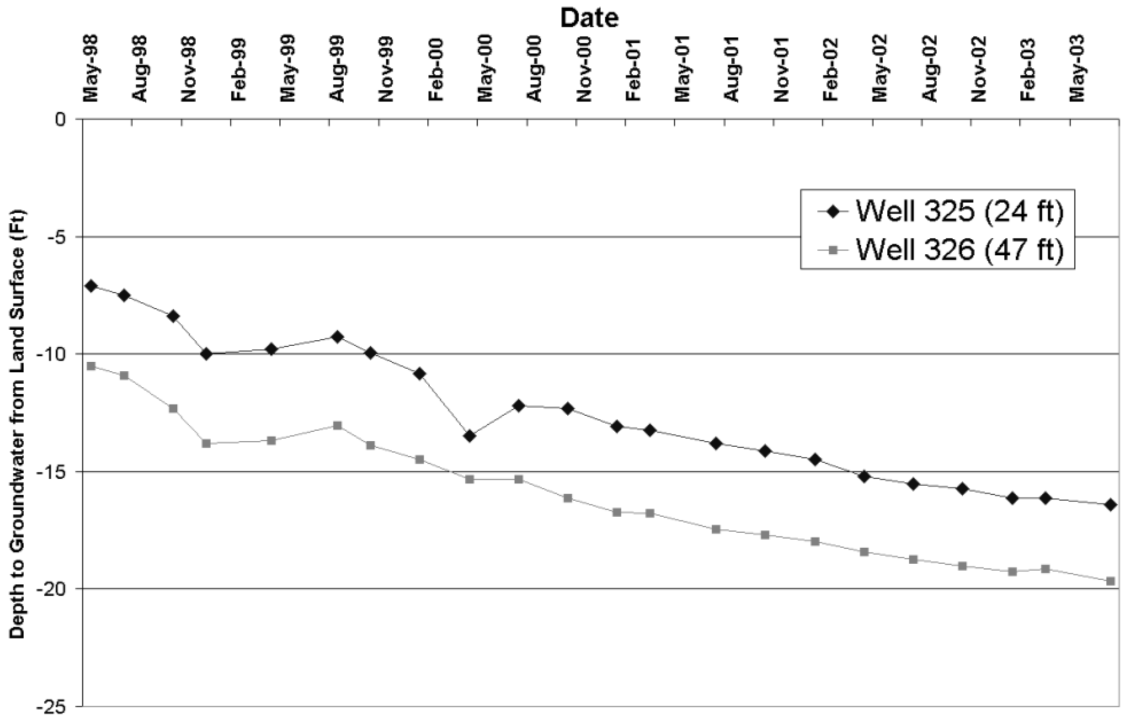

Figure 2-6. Hydrographs for monitor wells 325 and 326 at the Tranquillity site showing a declining shallow groundwater trend.

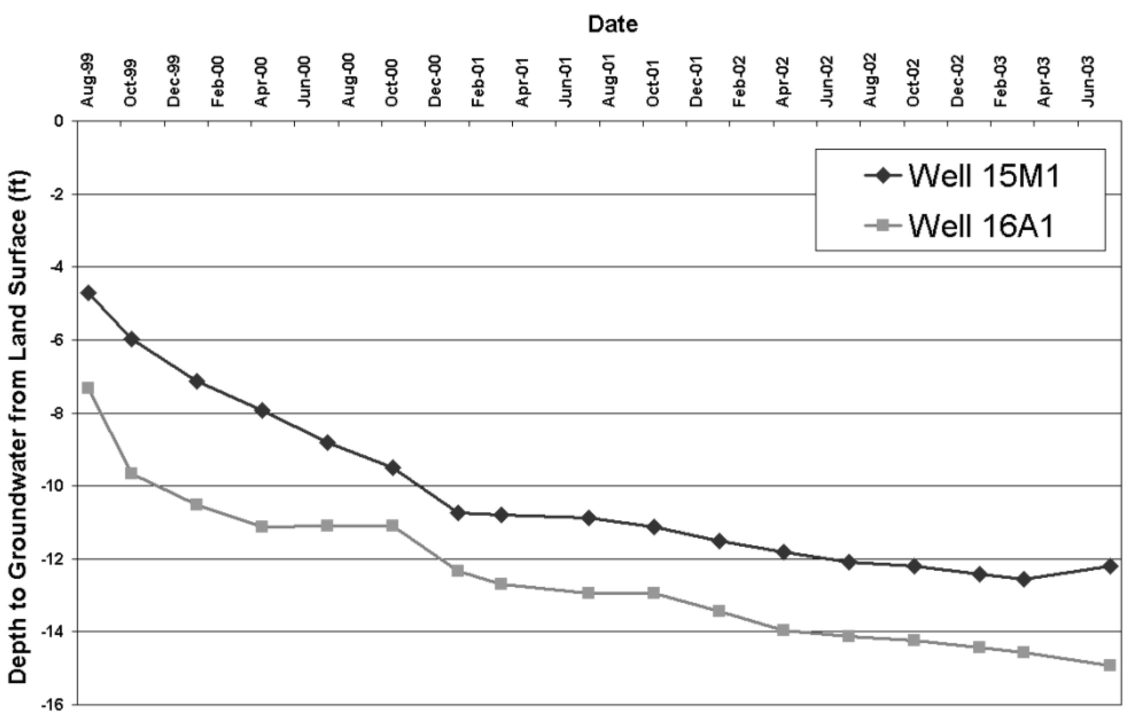

Figure 2-7. Hydrographs for monitor wells 15M1 and 16A1 at the Tranquillity site showing a declining shallow groundwater trend.

Maps of synoptic depth to groundwater are another useful way to portray the decline of the shallow water table beneath the Tranquillity site. Figure 2-8, Figure 2-9, and Figure 2-10 show the depth to groundwater from the land surface as measured in monitor wells at the site in October, 1999, 2000, and 2001. The measured depth to groundwater data was contoured using Environmental Systems Research Institute (ESRI) ArcView Spatial Analyst software to produce the maps. During October, 1999 approximately 30% (600 acres) of the site was underlain by a water table within 7 ft of the land surface. During October, 2000 approximately 3% of the site (55 acres) was underlain by a water table within 7 ft of the land surface. In October, 2001 the area of the site underlain by a water table within 7 ft of the land surface decreased to less than 2% of the site (34 acres). As of October, 2002, no part of the site had a shallow water table within 7 ft. of the land surface.

The site can be divided into two distinct areas based on the depth to groundwater observations (Figure 2-8, Figure 2-9, Figure 2-10). The depth to the water table north of Adams Avenue (Section 10) was significantly greater than that observed south of Adams Avenue. The differences can be attributed to two factors. This area of the site (Section 10) has been retired from irrigated agriculture since 1994, and has not received significant application of irrigation water (groundwater recharge) since that time. Section 10 is also underlain by more permeable Sierran sand deposits, which allow more rapid percolation of applied irrigation water.

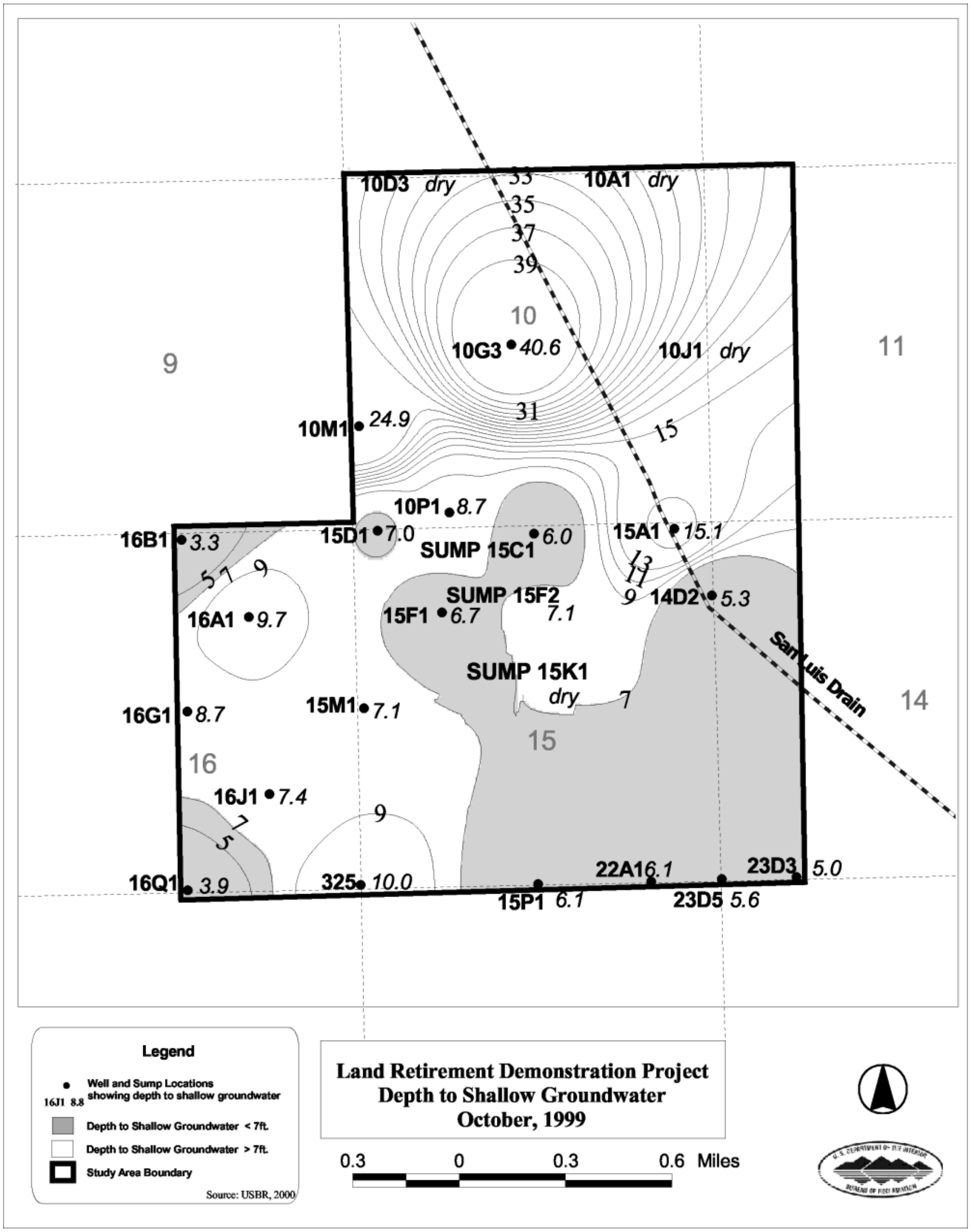

Figure 2-8. Depth to shallow groundwater, October, 1999. The project area underlain by shallow groundwater within 7 ft of the land surface is approximately 600 acres.

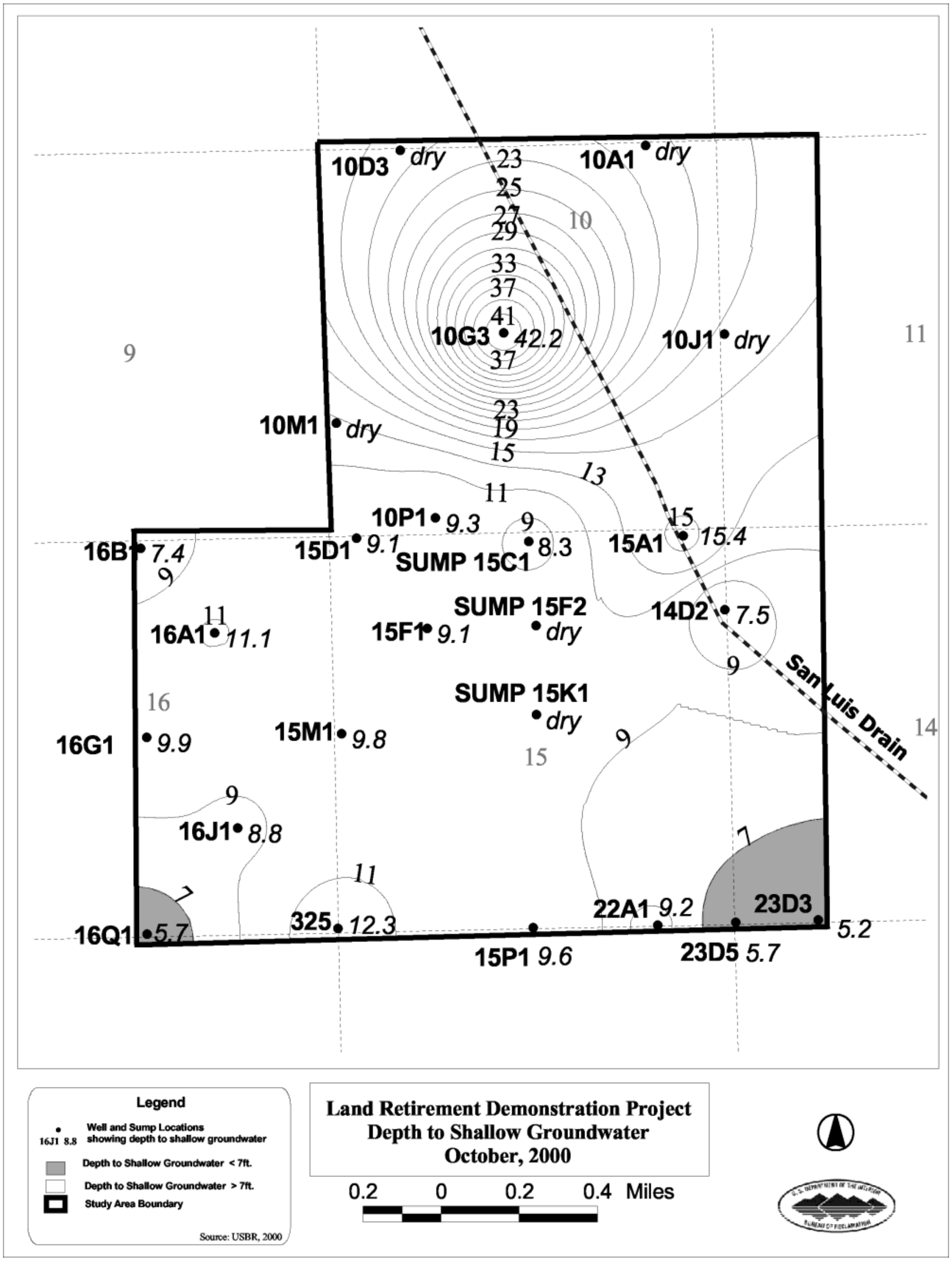

Figure 2-9. Depth to shallow groundwater, October, 2000. The project area underlain by shallow groundwater within 7 ft of the land surface is approximately 55 acres.

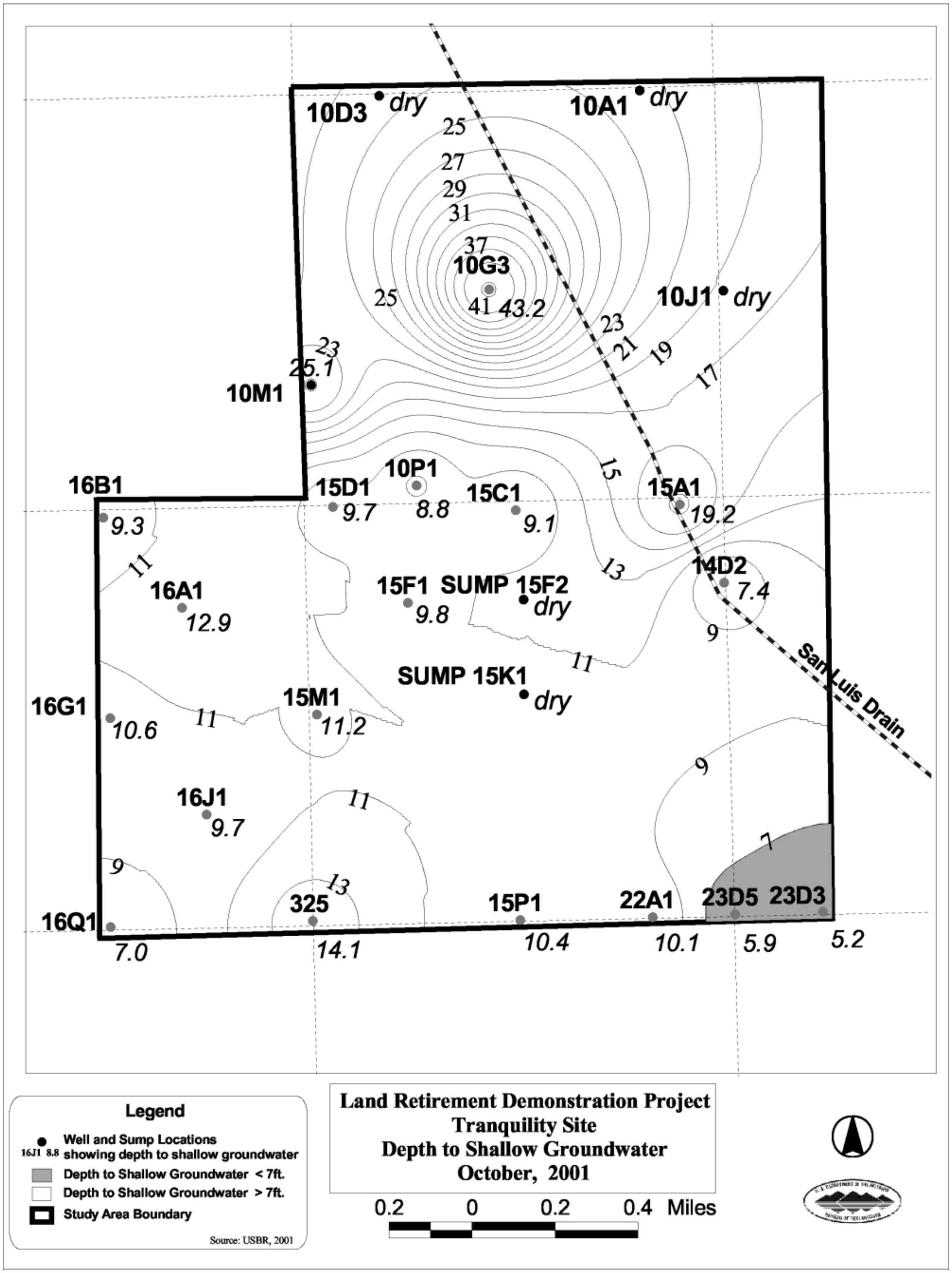

Figure 2-10. Depth to shallow groundwater, October, 2001. The project area underlain by shallow groundwater within 7 ft of the land surface is approximately 34 acres.

The combinations of dry climatic conditions and greatly reduced irrigation applications associated with land retirement have resulted in significant declines of the shallow water table at the Tranquillity demonstration site. Nearly all the monitor wells are showing a declining water level trend over time. The average drop in the shallow water table measured in 10 wells at the site during the first 4 years of monitoring is approximately 6 ft or 1.5 ft. per year (Table 2-6).

Table 2-6. Groundwater level decline observed in ten wells at the Tranquillity site for the time period from August, 1999 to July, 2003.

Well	Water level decline (feet)
15P1	7.26
15L1	1.64
15M1	5.87
15F1	4.17
16G1	7.64
16Q1	7.07
16A1	7.60
16B1	6.56
15N1	9.32
15C1	3.55
Minimum	**1.64**
Maximum	**9.32**
Average	**6.07**

2.1.8. Groundwater Quality Monitoring

The purposes for monitoring groundwater quality monitoring at the site are to establish baseline conditions that can be used as a basis for comparison of change-detection analyses, and to collect data that can be used to evaluate exposure risk to wildlife via the groundwater pathway. Baseline groundwater samples were taken on a quarterly basis during year 1 of monitoring at the Tranquillity site. The baseline groundwater quality samples were taken in October 1999 and February, May, and July 2000. Annual groundwater sampling began at Tranquillity in May 2001 and will continue for the 5-year duration of the project. The springtime sampling was chosen to coincide with the seasonal high water table in the region. The annual, groundwater-quality data will be compared to the baseline data set to evaluate changes in groundwater quality. Unfiltered groundwater samples were taken from 12 wells and two drain sumps to assess baseline groundwater quality at the site. Standard operating procedures for groundwater sampling used by the Mid-Pacific Region of the USBR and those outlined in the Quality Assurance Project Plan for the Land Retirement Demonstration Project (CH2M Hill 1999) were employed to obtain groundwater samples.

Unfiltered groundwater samples were analyzed for major ions (calcium, magnesium, potassium, sodium, chloride, sulfate, total alkalinity), trace elements (selenium, boron, iron, manganese) and isotopes (H^2, O^{18} and H^3). Specific conductance (electrical conductivity), pH, temperature, and turbidity of groundwater samples were measured in the field at the time of sampling. Fluorometric analyses of groundwater samples for selenium were performed by Olsen Biochemistry Laboratories, South Dakota State University. Analyses for isotopes (H^2, O^{18}) were performed by the U.S. Geological

Survey (USGS) Water Resources Division laboratory in Reston, Virginia. Analyses for tritium (H^3) were performed by the USGS Water Resources Division laboratory in Menlo Park, California. All other analyses were performed by Caltest Analytical Laboratory in Napa, California. The Quality Assurance Project Plan (QAPP) for the Land Retirement Demonstration Project describes in detail the analytical procedures and quality assurance measures taken to ensure groundwater data quality (CH2M Hill 1999).

2.1.8.1. Groundwater salinity

A general indication of the total dissolved ionic constituents in the groundwater can be obtained by determining the capability of a groundwater sample to conduct an applied electrical current. This property is reported as specific conductance (also electrical conductivity, EC), and is expressed in terms of the conductivity of a cube of water 1 square centimeter on a side. EC is expressed in units of microSiemens/cm (µS/cm).

Baseline EC data for the groundwater samples collected during the first year of monitoring are presented in Table 2-7 and Table 2-8. The shallow, perched groundwater is extremely saline in nature. Salinity in the shallow groundwater and drain sump samples, expressed as EC, ranged from 11,500 to 76,980 µS/cm, with a median value of 43,925 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm. The groundwater samples obtained from the underlying semi-confined aquifer is much less saline. Salinity in the groundwater samples obtained from the deep wells (> 50 ft deep), expressed as EC ranged from 5,630 to 18,580 µS/cm, with a median value of 7,675 µS/cm.

The extreme salinity of the shallow groundwater at the site is a result of the irrigation of saline soils. Naturally occurring salts have been leached from the soil profile under irrigated conditions. Salts also have been transported to the site in the applied irrigation water. Direct evaporation from the shallow water table and transpiration of applied water by crops has concentrated salts in the shallow groundwater, resulting in the high EC values observed in the shallow groundwater samples.

2.1.8.2. Groundwater major ion chemistry

Baseline major ion chemistry for the groundwater samples collected during year 1 of monitoring are presented in Table 2-9 and Table 2-10 The groundwater comprising the perched water and in the underlying semi-confined aquifer is best described as a sodium sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 2,300 to 25,000 mg/l, and a median concentration of 13,000 mg/l. Sodium is also the dominant major cation found in groundwater samples taken from the deep wells, with concentrations ranging from 760 to 3,800 mg/l, and a median concentration of 1,100 mg/l. Sulfate is the dominant major anion found in both the shallow, perched groundwater and in the underlying semi-confined groundwater at the site.

Table 2-7. Groundwater quality data for shallow wells at the Tranquillity site - major ions and field parameters.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	44	44	44	44	44	44
EC(field) (µS/cm)	11,500	32,620	43,260	52,350	76,980	41,987
pH (field)	6.74	7.54	7.78	7.9	8.37	7.73
Calcium (mg/l)	250	400	420	450	500	417
Magnesium (mg/l)	42	250	525	663	1300	515
Sodium (mg/l)	2,300	8,725	13,000	16,500	25,000	13,009
Potassium (mg/l)	7	20	30	42	94	32
Total Alkalinity (mg/l)	150	260	330	423	610	351
Chloride (mg/l)	380	1,150	2,700	3200	4,100	2,332
Sulfate (mg/l)	4,300		24,500	31,000	62,000	26,330

Table 2-8. Groundwater quality data for deep wells at the Tranquillity site - major ions and field parameters.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	12	12	12	12	12	12
EC(field) (µS/cm)	5,630	6,763	7,675	17,315	18,580	10,633
pH (field)	6.82	7.13	7.21	7.28	7.46	7.21
Calcium (mg/l)	280	300	320	360	390	327
Magnesium (mg/l)	280	300	310	328	350	315
Sodium (mg/l)	760	823	1,100	2,425	3,800	1,714
Potassium (mg/l)	6	9	13	14	20	12
Total Alkalinity (mg/l)	200	250	270	329	340	277
Chloride (mg/l)	300	410	540	1,700	1,900	924
Sulfate (mg/l)	2,100	2,750	3,100	5,525	7,300	4,067

Sulfate concentrations found in groundwater samples from the shallow wells (< 50 ft deep) ranged from 4,300 to 62,000 mg/l, with a median concentration of 24,500 mg/l. Sulfate concentrations in groundwater samples from the deep wells (> 50 ft deep) completed in the semi-confined aquifer ranged from 2,100 to 7,300 mg/l, with a median concentration of 3,100 mg/l (Figure 2-11).

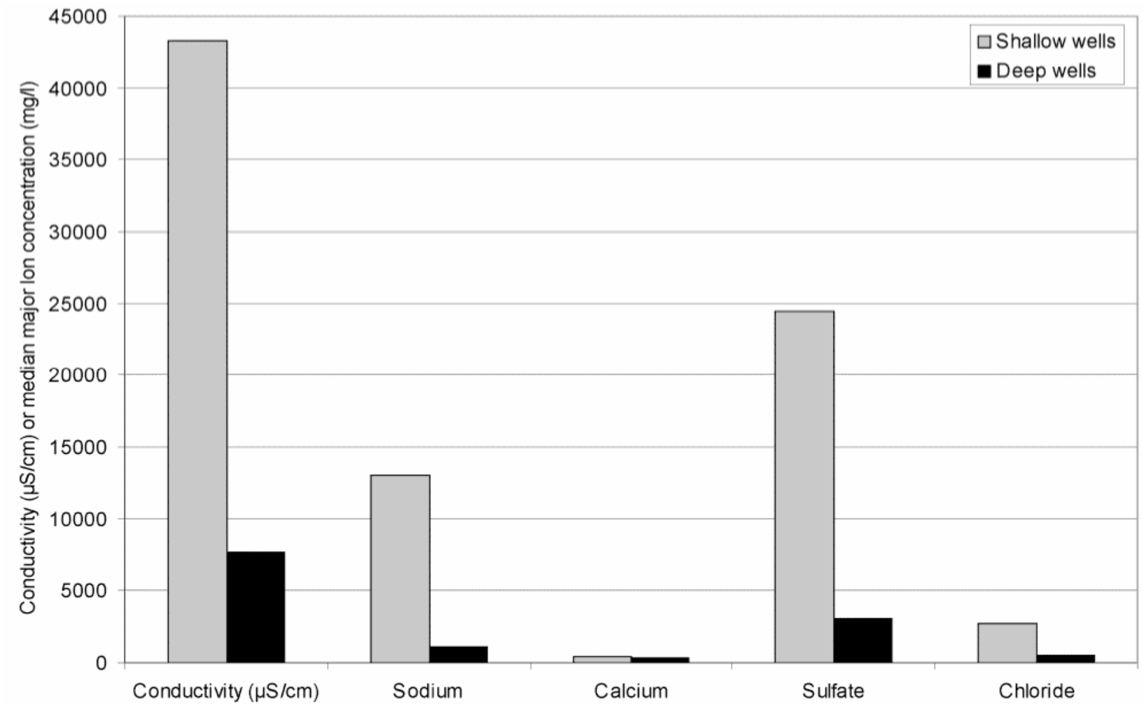

Figure 2-11. Comparison of dominant major ion concentrations and electrical conductivity for groundwater samples from shallow and deep wells.

High sodium and sulfate concentrations in the groundwater on the west side of the San Joaquin Valley result from weathering of sulfate rich rocks in the adjacent Coast Ranges. Davis (1961) hypothesized that the sulfate in groundwater in the study region originates from the oxidation of organic marine shales containing reduced iron sulfide minerals. Presser et al. (1990) reported oxidation of iron sulfide minerals for west-side streams in the study vicinity. Another probable source of sulfate in the shallow groundwater is gypsum (calcium sulfate) that has historically been applied to soils by farmers in the region as a method of salinity management.

2.1.8.3. Trace elements in groundwater

The trace elements of concern monitored for this study include selenium and boron. High concentrations of selenium and boron in the shallow groundwater are of concern due to potential toxicity to wildlife and plants. Iron and manganese concentrations were also monitored because they provide insight into geochemical conditions in the groundwater system. A summary of baseline trace element data for the first year of groundwater monitoring is presented in Table 2-9 and Table 2-10.

Table 2-9. Groundwater quality data for shallow wells at the Tranquillity site - trace elements and tritium.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	44	44	44	44	44	44
Boron (mg/l)	10	26	46	55	81	42
Iron (mg/l)	0.1	0.8	2.1	15	160	19.4
Manganese (mg/l)	0.008	0.11	0.23	1.1	3.9	0.757
Selenium (mg/l)	0.005	0.195	1.28	3.812	5.39	2.095
Tritium (TU)	0	0.9	2.4	3.7	6	2.3

Table 2-10. Groundwater quality data for deep wells at the Tranquillity site - trace elements and tritium.

Statistic	Min.	25th percentile	Median	75th percentile	Max.	Mean
Number of Samples	12	12	12	12	12	12
Boron (mg/l)	2.5	2.8	3.2	6.6	8.3	4.4
Iron (mg/l)	0.3	0.6	1.2	1.3	1.6	1
Manganese (mg/l)	0.25	0.318	1.75	2.5	4.3	1.718
Selenium (mg/l)	< 0.0004	0.0005	1.84	1.91	1.95	1.0873
Tritium (TU)	0	0.4	10.1	11.6	14	7.5

2.1.8.4. Selenium in groundwater

Selenium concentrations measured in the shallow groundwater wells and sumps (< 50 feet deep) at the site during the first year of monitoring (1999) varied spatially. In general, selenium concentrations in the shallow groundwater system were high, ranging from 5 to 5,390 μg/l (0.005 to 5.390 mg/l), with a median concentration of 1,280 μg/l (1.280 mg/l). By comparison, the U.S. Environmental Protection Agency (EPA) water-quality criteria for long-term exposure in aquatic environments is 5 μg/l (EPA 1988). It becomes clear why the conceptual model of a declining shallow water table is an essential element of land retirement in light of the extremely high concentrations of selenium observed in the shallow groundwater. If these waters were exposed at the land surface, wildlife could be exposed to potentially toxic conditions. Deverel and Millard (1988) concluded that the main factors affecting selenium concentrations in the shallow groundwater of the western San Joaquin Valley are the degree of groundwater salinity and the geologic source of the alluvial soils.

Selenium concentrations measured in the deep wells (> 50 ft deep) at the site also showed considerable spatial variation (Table 2-10). Selenium concentrations found in well 15M3 (69 ft deep), ranged from 1,840 to 1,950 μg/L during the first year of monitoring, while selenium concentrations found in Wells 15C3 and 10G3 (83 and 75 ft deep, respectively) ranged from the analytical limit of detection (< 0.0004 mg/l) to 0.0005 mg/l. The extreme variation in selenium concentration seen in the deep wells may be explained due to differing geochemical conditions found in Coast Range deposits and the Sierran sands underlying the site. Well 15M3 is perforated in Coast Range sediments, while wells 15C3 and 10G3 are perforated in sediments derived from the Sierra Nevada Range. Dubrovsky et al. (1993) noted high concentrations of selenium in shallow groundwater in Coast Range sediments, and low concentrations in underlying Sierra Nevada sediments in previous groundwater quality investigations in the western San Joaquin Valley. The authors hypothesized that the absence of selenium in groundwater from wells screened in the Sierra Nevada deposits may be due to a redox (chemical reduction or oxidation) process. Selenium can exist in four valence states; -2, 0, +4, and +6. The +6 and +4 valences occur as the oxyanions selenate (SeO^{42}) and selenite (SeO^{32}) under alkaline, oxidizing conditions. Selenate is the most oxidized form of selenium, is relatively mobile in aqueous environments, and does not associate with solid phase materials (Leckie et al. 1980, Frost and Griffin 1977, and Hingston et al. 1974). Deverel and Fujii (1988) reported that the selenium in soil solutions and shallow groundwater in the western San Joaquin Valley is in the selenate form, and a very small percentage of soil selenium is in the absorbed phase. Although no attempt has been made to speciate selenium in groundwater samples from the Land Retirement Demonstration Project, the selenium found in the shallow groundwater at the site probably occurs predominantly as selenate.

Under more reduced conditions, such as those found in the underlying Sierra Nevada deposits in the northern part of the site, selenium can exist as elemental selenium (zero valence) and selenide (Se^{2}). The solubility of selenate minerals generally is high (Elrashadi et al. 1987), and there are no apparent solubility constraints on selenate in shallow groundwater in the western San Joaquin Valley, even in groundwater saturated with respect to sulfate minerals (Deverel and Gallanthine 1989). Consequently, selenate tends to behave conservatively in oxidizing groundwater. The mobility of selenite in groundwater is severely constrained by adsorption onto a variety of mineral surfaces (Balistrieri and Chao 1987, Neal et al.1987, Goldberg and Glanbig 1988). The solubilities of the reduced forms of selenium (elemental selenium and selenide) are extremely low (Elrashadi et al. 1987). Field and laboratory studies of selenium contamination at Kesterson Reservoir demonstrated selenium removal by reduction of selenate to less mobile forms (Lawrence Berkeley Laboratory 1987, White et al. 1988, Weres et al. 1989). Similar geochemical processes may be responsible for the extremely low selenium concentrations observed in Wells 15C3 and 10G3 at the Tranquillity site.

Dubrovsky et al. (1993) noted that selenium concentrations in groundwater decreased rapidly at the same depth at which manganese concentrations increase at a research site located in the vicinity of the Tranquillity site in the western San Joaquin Valley. The authors concluded that the decrease in selenium is due to a process that occurs under reducing conditions. High concentrations of dissolved iron and manganese in groundwater can indicate geochemically reducing conditions. A similar trend is observed at the land retirement study site when ratios of selenium to manganese concentrations are plotted verses well depth. The selenium/manganese ratios are generally high in the shallow wells and extremely low in the deep wells, especially those perforated in the Sierran deposits (Figure 2-12). This supports the conceptual model that oxidizing conditions are prevalent in the shallow groundwater, and that reducing conditions are prevalent in the deep groundwater found in the Sierran deposits. The presence of reducing geochemical conditions in the Sierran deposits probably play a significant role in the extremely low selenium concentrations observed in wells 15C3 and 10G3.

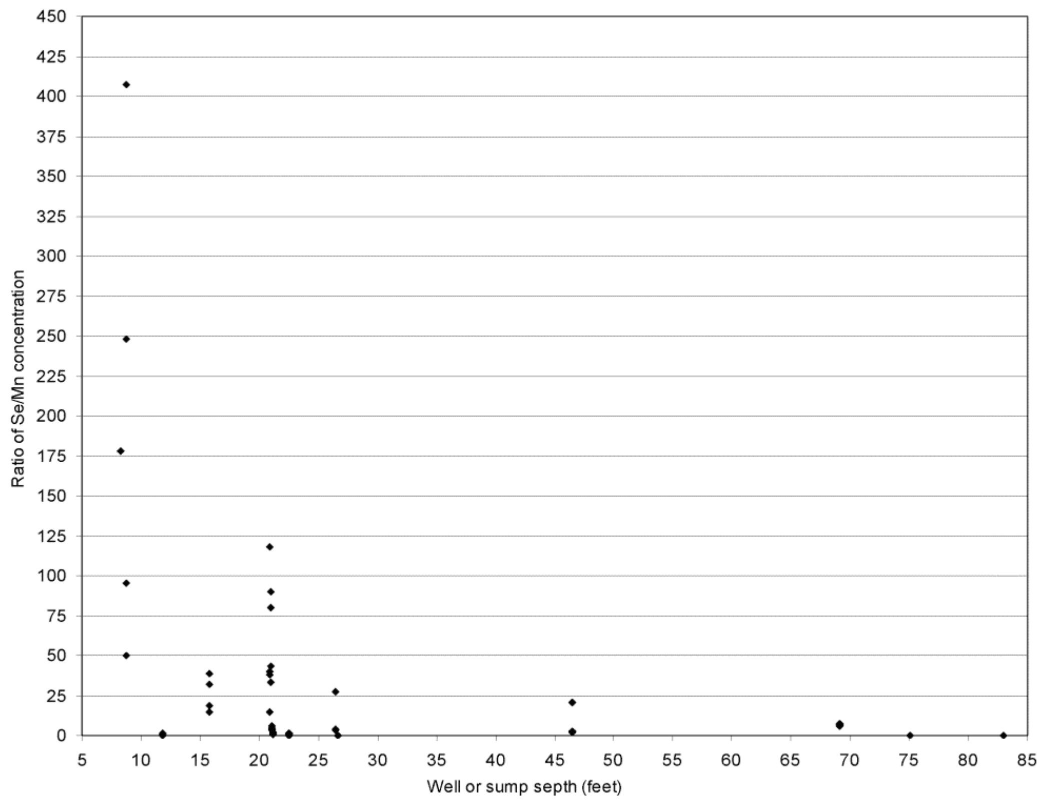

Figure 2-12. Ratio of Selenium to Manganese (Se/Mn) concentration in groundwater samples plotted verses well depth. The Se/Mn ratio shows a decreasing trend with depth indicating oxidizing geochemical conditions in the shallow wells and reducing conditions in the deep wells.

2.1.8.5. Selenium trends in shallow groundwater

The U.S. Fish and Wildlife Service (FWS) established performance standards for retired lands in the Recovery Plan for Upland Species of the San Joaquin Valley (FWS 1998). The performance standard for selenium in groundwater specifies that the selenium concentrations should not show an increasing trend over 5 years of monitoring. The high spatial variability and small sample size of the selenium data observed for the groundwater at the Tranquillity site precludes the comparison of mean or median values for the entire set of monitor wells. Given the variability of the baseline selenium data, over 200 wells would be required to accurately estimate the population mean concentration of selenium in the shallow groundwater at a given time. A time series analysis at each monitor well will be used to establish trends for selenium concentrations in the groundwater at the site. To establish reliable time series trends, autocorrelation or autoregression analyses will be performed on the time series data from each well. Both of these techniques require relatively long-term data records based on evenly spaced data. There currently are not enough data to draw any statistically meaningful conclusions regarding the trend of selenium concentrations in the groundwater. The current data consist of four quarterly samples obtained during year 1 and one sample obtained during year 2 of monitoring. Preliminary analysis of time series data from 11 wells at the site show a decreasing trend for 4 wells and an increasing trend for 7 wells. Only the increasing trends observed at wells 16J1 and 16Q1 are significant at the 95% confidence level (Table 2-11). The additional annual data collection over the life of the 5-year demonstration project should be adequate to establish definitive time series trends for selenium in the groundwater at the site.

Table 2-11. Preliminary analysis of Selenium trends in groundwater at the Tranquillity site.

Well	Preliminary trend	Correlation coefficient (r2)	Significance at 95% confidence
15M1	Downward	.57	Not significant
15P1	Upward	.08	Not significant
15M3	Downward	.02	Not significant
15B3	Upward	.39	Not significant
16J1	Upward	.86	Significant
15F1	Upward	.01	Not significant
16Q1	Upward	.71	Significant
16G1	Upward	.47	Not significant
16A1	Downward	.29	Not significant
16B1	Upward	.21	Not significant
10M1	Downward	.40	Not significant

2.1.8.6. Boron in groundwater

The presence of high concentrations of boron in the shallow groundwater is of concern due to potential toxicity to plants and wildlife. Boron concentrations in the shallow groundwater at the site are extremely high. The boron concentrations measured in the shallow wells range from 10 to 81 mg/l, with a median value of 45.5 mg/l (Table 2-9). No water-quality criteria for boron exist for aquatic life or human health. No more than 750 micrograms/liter (µg/l) of boron should be applied to sensitive crops (EPA 1986). Perry et al. (1994) proposed a toxicity threshold in water for crops and aquatic plants of 10 mg/l. Deverel and Millard (1988) noted that boron is geochemically mobile and present as oxyanions in oxidized, alkaline environments such as the western San Joaquin Valley shallow groundwater. The authors also reported high correlation between log transformed boron and specific conductance data for shallow groundwater in the western San Joaquin Valley. Boron concentrations observed in the deep wells at the site are an order of magnitude lower than those in the shallow wells. Boron concentrations measured in the deep wells during year-1 of monitoring range from 2.5 to 8.3 mg/l, with a median concentration of 3.2 mg/l (Table 2-10). The large difference in boron concentration between the shallow and deep groundwater at the site may be due to adsorption onto soil surfaces or differing geochemical conditions between the shallow and deep groundwater systems. Adsorption of boron on soil particles can affect and limit its solubility (Keren and Bingham 1985). Fujii and Swain (1995) concluded that the relatively conservative behavior of boron observed in shallow groundwater in the San

Joaquin Valley probably reflects the presence of high concentrations of competing constituents for adsorption sites.

2.1.8.7. Origin and isotopic composition of groundwater

Groundwater samples were analyzed for tritium and stable isotope ratios of oxygen and hydrogen during the first 3 years of monitoring. Tritium and stable isotope data are currently available for the first 2 years of monitoring. A summary of the tritium data is presented in Table 2-9 and Table 2-10. The oxygen and hydrogen isotope data shown in Figure 2-13 can provide insight into the evaporation history of the water, while the tritium data can be used to develop an understanding of the age and origin of the groundwater at the site.

2.1.8.8. Groundwater age

The levels of tritium, a radioactive isotope of hydrogen with a half-life of 12.43 years, rose in the environment during the 1950's and 1960's because of atmospheric detonation of nuclear weapons. Tritium concentrations can be used to develop an understanding of the origin and history of water samples. Tritium concentrations in water samples are reported in tritium units (TU). Prior to 1952, precipitation contained < 5 TU. Due to radioactive decay, groundwater derived from precipitation before 1952 now has < 0.5 TU. Groundwater derived from precipitation recharged since 1952, including canal water used as irrigation since 1968, commonly has a tritium concentration exceeding 10 TU. Groundwater with a tritium concentration of < 1.6 TU either has recharged prior to 1952 or may have originated as post-1952 irrigation water from deep wells. This large contrast in tritium concentration allows comparison of older groundwater, much of which was recharged prior to agricultural development, to young water recharged since 1952 and derived from irrigation (Dubrovsky et al. 1993).

The tritium data from the shallow wells indicate that the shallow, perched groundwater consist of a mixture of water recharged before and after 1952. Tritium concentrations of the shallow groundwater samples range from 0 to 6 Tritium Units (TU), with a median concentration of 2.4 TU. Low tritium concentrations (< 1 TU) observed in wells 16Q1 and 16F1 may indicate recharge from irrigation water that was pumped from deep production wells completed in the sub-Corcoran aquifer. The tritium data from the deep wells (Well 15M3 and 16B3) completed in coastal range deposits indicate that the groundwater was recharged before 1952. Tritium concentrations observed in these two wells ranged from 0 to 0.5 TU, with a median concentration of 0.1 TU. The tritium data from the deep wells completed in Sierra Nevada sediments indicate that the groundwater has been recharged since 1952. Tritium concentrations found in wells 15C3 and 10G3 range from 9.6 to 14.0 TU, with a median concentration of 10.5 TU.

2.1.8.9. Evaporative concentration of shallow groundwater

In areas where the water table is shallow in the western San Joaquin Valley, particularly at depths less than 1.5 meters below land surface, evaporative concentration of dissolved solids in groundwater can increase salinity and selenium concentrations far above the levels resulting from leaching of soil salts by irrigation (Deverell and Fujii 1988). Under irrigated conditions, loss of water by evapotranspiration tends to concentrate salts in groundwater rather than soil because the salts are regularly flushed downward by percolating irrigation water and net groundwater movement is generally downward (Dubrovsky et al. 1993).

Hydrogen and oxygen isotope concentrations from shallow groundwater samples at the Tranquillity site show that groundwater salinity is primarily a result of evaporation and evapotranspiration of the shallow groundwater. The evaporation process adds kinetic separation to the hydrogen^{2} (deuterium) and oxygen^{18} species causing increased enrichment in the O^{18} species (Gat and Gonfiantini 1981). This results in a plot of the delta deuterium (D) verses delta O^{18} that has a smaller slope than the meteoric water line. The comparison of delta D and delta O^{18} shown in Figure 2-13 illustrates the evaporation that has taken place in the shallow groundwater at the site. Similar evaporative trend lines have been reported by Deverell and Fujii (1988) and Presser and Barnes (1984) for shallow groundwater in the western San Joaquin Valley.

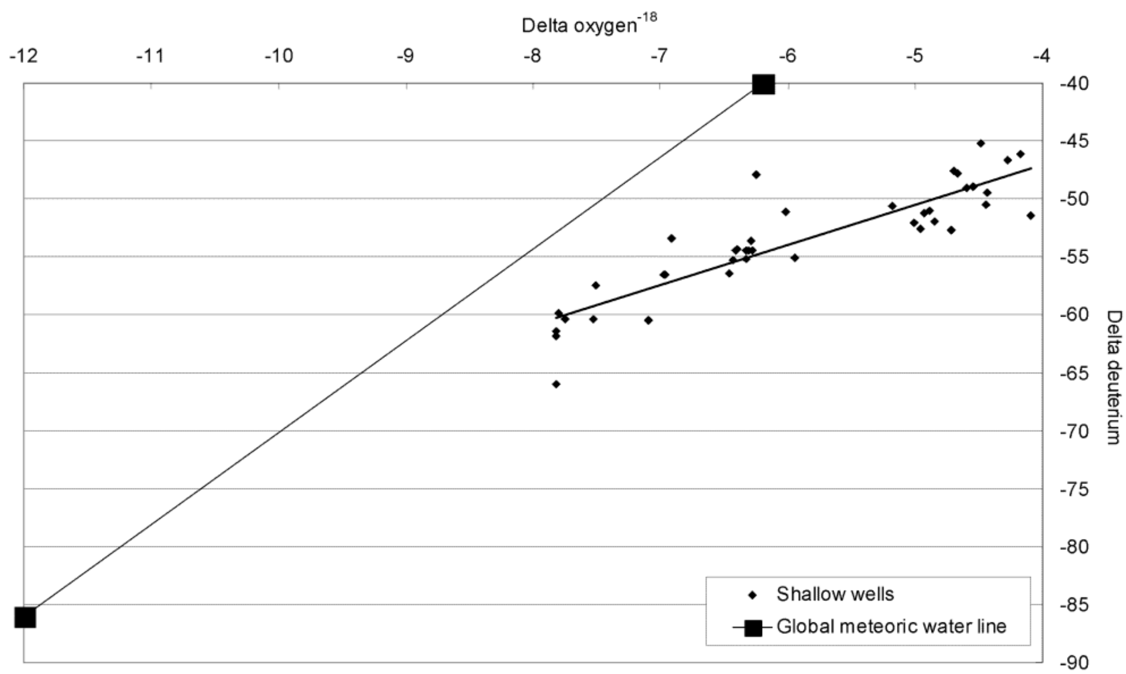

Figure 2-13. Plot of stable isotope data for groundwater samples from the Tranquillity site indicating the shallow groundwater has undergone significant evaporation.

2.2. *ATWELL ISLAND SITE*

2.2.1. Geology

The Atwell Island demonstration site lies on the southwestern margin of the Tulare Lake Bed, which is the dominant geologic feature in the study area. The site is underlain by lake-bed and marsh deposits consisting primarily of clay and silt with some sand with a thickness in excess of 3,600 ft (Page 1986). The Corcoran Clay member of the Tulare

Formation is a regionally extensive, fine-grained lake-bed deposit that underlies the Atwell Island site at a depth of approximately 900 ft below the land surface. A relict sand dune deposit consisting of fine-grained wind-blown sand from the former shoreline of the Tulare Lake Bed traverses the western boundary of the site from southwest to northeast.

2.2.2. Soils

Soils in the Atwell Island study area consist of silt loam and fine sandy loams that are formed in alluvium derived from igneous and sedimentary rocks. Silty clay loam soils are also present in the southeast portion of the site. Individual soil mapping units found in the study area, in the order of abundance, include the Posochanet silt loam, Nahrub silt loam, the Westcamp silt loam, Excelsior find sandy loam, and Lethent fine sandy loam (Figure 2-14). The Posochanet soils occur primarily in the central portion of the site and cover about 30% of the total study area. These soils are saline, alkaline, very deep, moderately well-drained with slow permeability. Subsoil and substrata textures are commonly silty clay loam and silty clay. Salinity ranges from 4 to 8 dS/m in the upper portion and 4 to 30 dS/m in the lower portion. Surface runoff is generally slow, with a low hazard of water erosion. Nahrub silt loam occurs on basin rims and consists of mixed alluvium from granitic rocks. Nahrub soils cover about 30% of the total surface area in the southeast part of the site. These soils are very deep, somewhat poorly drained, with very slow permeability. Salinity ranges from 1-16 dS/m in the upper part to 8-30 dS/m in the lower part. Surface runoff is very slow with low surface erosion hazard. Westcamp silt loam soils cover the northwest corner of the study area. The Westcamp soils are saline, alkaline soils that have a perched water table. These soils are very deep, somewhat poorly drained, with very slow permeability. A transient perched water table occurs at a depth of 4-6 ft. Salinity ranges from about 2-16 dS/m. Excelsior fine sandy loam soils are found on the sand ridge that traverses the site from northeast to southwest. The sand ridge covers about 15% of the total study area. The Excelsior soils are very deep, somewhat excessively drained, alkaline soils. Permeability of the sand ridge soil is moderately rapid, runoff is very slow and hazard of water erosion is slight, however the potential for wind erosion is high under sparsely vegetated conditions. Salinity ranges from 0-8 dS/m in the upper part and 2-16 dS/m in the lower part. The Lethent fine sandy loam occurs in a small area in the southwest part of the study area. This soil is saline, alkaline, very deep, and moderately well drained. Permeability is very slow and the hazard of water erosion is slight.

2.2.2.1. Soil monitoring

2.2.2.1.1. Soil sampling

Baseline soil sampling was conducted at the Atwell Island site during spring of 2002. Sixteen sites were sampled within each experimental study area. Each site was located at the approximate center of the 2-acre research plots (Figure 2-14). Three soil samples were collected from each site. A 0-12 inch, 4-increment composite soil sample was collected within 10 feet of the central boring. A single soil sample was collected from the 12-30-inch depth interval. This sample represents the active root zone of irrigated soils. A single soil sample was also collected from the 30-60-inch substrata zone. This zone represents the lower root zone just above the vadose zone. All soil material was sampled in the 12-30 and 30-60-inch samples. Sampling in this manner resulted in 48 soil samples collected on each 160-acre study area (Figure 2-14). Two field replicate (QC) samples were collected from each quarter section. Field replicate samples were obtained using the fractional shoveling method (Gerlach 2002). All sample sites were located and mapped using a global positioning system receiver.

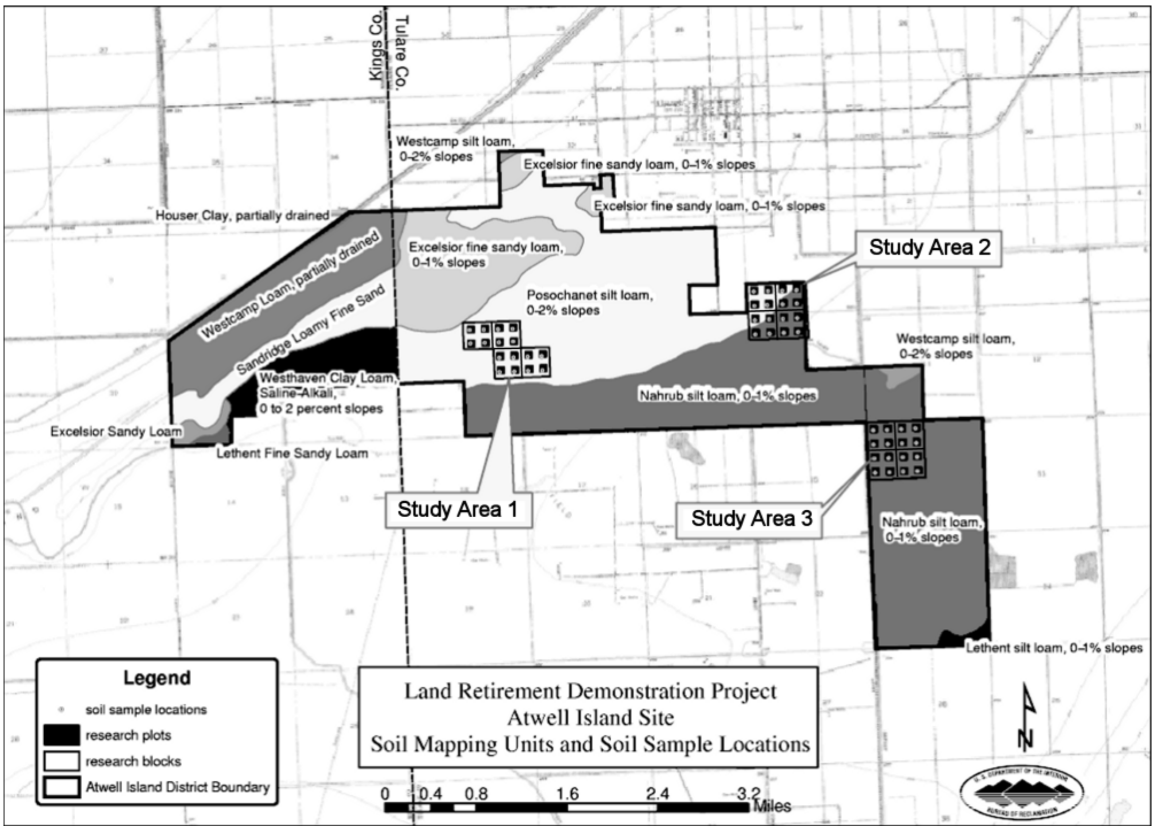

Figure 2-14. U.S. Department of Agriculture soil mapping units and soil sample locations at the Atwell Island site.

Soil samples were analyzed for total and water-soluble selenium, sulfate, chloride, electrical conductivity, and moisture. All surface soil samples were analyzed for boron, magnesium, potassium, sodium, carbonate, and nitrate. The Quality Assurance Project Plan (APP.) for the Land Retirement Demonstration Project described in detail the analytical procedures and quality assurance measures taken to ensure soil data quality (CH2M Hill 1999). The soils analyses were performed by the U.S. Geological Survey and the U.S. Bureau of Reclamation analytical laboratories in Denver, Colorado.

The baseline soil-sampling event was completed during March of 2002. Surface (0-12 inch) 4-icrement soil samples where collected within 10 feet of central deep boring sites. Deeper (12-30 inch and 30-60 inch) samples where collected from a single hand auger boring. All soil layers where included in the sampling. The soil samples have been analyzed and the data collected has been validated. A statistical summary of the baseline data is presented in section 2.2.2.1.2

2.2.2.1.2. Statistical summary of the baseline data

Statistical summaries of data collected during the 2002 baseline soil sampling event are presented in Table 2-12, Table 2-13, Table 2-15, and Table 2-16. All data are on a dry soil weight basis except for the soil salinity data, which are the concentration of the extract.

2.2.2.1.2.1. Total selenium

A statistical summary of total selenium concentrations is presented in Table 2-13. In Study Area 1 there appears to be a slightly inverted selenium distribution, possibly from upflux and evaporative processes, however this trend is not significant at the 95% confidence level. In Study Area 2: No trends with depth are apparent. In Study Area 3, the 30-60 substrata zone is significantly higher in total selenium than the 12-30 inch zone.

Table 2-12. Total selenium (mg/kg dry soil).

	Depth (inches)	Average	95% confidence interval
Study Area 1	0-12	0.097	0.076 - 0.118
	12-30	0.087	0.062 - 0.112
	30-60	0.076	0.061 - 0.091
	0-60 Weighted average	0.084	0.069 - 0.099
Study Area 2	0-12	0.144	0.092 - 0.196
	12-30	0.118	0.090 - 0.146
	30-60	0.139	0.100 - 0.178
	0-60 Weighted average	0.132	0.110 - 0.154
Study Area 3	0-12	0.104	0.083 - 0.125
	12-30	0.086	0.071 - 0.101
	30-60	0.141	0.110 - 0.172
	0-60 Weighted average	0.120	0.104 - 0.136

2.2.2.1.2.2. Soluble selenium 1-5 extract

A statistical summary of soluble selenium concentrations is presented in Table 2-13. The data are for 1 part soil to 5 parts DI water extracts. The concentrations found in the extracts were multiplied by a factor of 5 to determine the micrograms per kilogram (μg/kg) dry weight concentration in the soil.

Table 2-13. Soluble selenium 1-5 extract (μg/kg dry soil).

	Depth (inches)	Average	95% CI
Study Area 1	0-12	5.63	3.23 - 8.03
	12-30	4.5	2.23 - 6.73
	30-60	4.06	2.27 - 5.85
	0-60 Weighted average	4.53	3.22 - 5.84
Study Area 2	0-12	15.22	7.43 - 23.01
	12-30	24.22	11.89 – 36.54
	30-60	44.59	22.76 – 66.42
	0-60 Weighted average	32.63	18.44 – 46.82
Study Area 3	0-12	4.69	3.35 - 6.03
	12-30	18.03	13.97 – 22.09
	30-60	34.59	27.84 – 41.34
	0-60 Weighted average	23.67	19.45 – 27.89

In Study Area 1, no significant differences in soluble selenium occurred with depth. Study Area 2 showed no significant differences in soluble selenium concentrations due to the high selenium concentration variability. There appeared to be an increasing selenium concentration with depth in Study Area 2. However, the trend is not significant at the 95% confidence level. In Study Area 3, there was a significant increase in soluble selenium concentration with depth at this site (Table 2-13).

Soluble selenium commonly exhibits high, random spatial variability. The soils of the Atwell Island site were no exception, as coefficients of variation values were quite high (Table 2-13). The three study areas all had low total selenium values yet it appears that a significant portion of the selenium at many of the sampled sites is in soluble form (Table 2-14). The alkaline soil reaction at the sites and the oxidized nature of the soils tend to favor the selenate selenium species, which is very soluble.

Table 2-14. A comparison of total selenium concentrations with soluble selenium concentrations.

Study area	Weighted average of total selenium (mg/kg)	Weighted average of soluble selenium (mg/kg)	Percent soluble
1	0.084	0.0045	5.4
2	0.132	0.0326	24.7
3	0.120	0.0237	19.8

Study Area 1 was much lower in soluble selenium than the other two study areas. The distribution in the profile also was more uniform, probably indicative of upflux from shallow groundwater and the medium textured soils in Study Area 1 that are more conducive to capillary rise of water from the water table. Concentrations in surface soils were not elevated enough to warrant concern about terrestrial wildlife poisoning or accumulation in plants. The low total selenium concentrations at the site might cause selenium deficiencies for some organisms. However, a relatively large portion of the selenium probably is present in soluble and biologically available forms due to the oxidized, alkaline conditions prevailing in Atwell Island site soils.

The data summarized in Table 2-13 contains many values below the reporting limit. In all cases, the value used for statistical purposes was one-half of the lower reporting limit value.

2.2.2.1.2.3. Soil salinity

A statistical summary of soluble selenium concentrations is presented in Table 2-15. Although the variation in soil salinity with depth is not significant at the 95% confidence level in Study Area 1, the data indicate an inverted salinity profile. Study Area 1 contains medium textured soils that can conduct large amount of groundwater and salt into the root zone. Because of this soil texture, it will be important to lower the water table to at least 12 feet on this study area in order to avoid salt accumulation in the active root zone. Winter rains should gradually leach out excess salts in the 0-30-inch active root zone if the water table is lowered to 12 feet or greater.

Table 2-15. Soil salinity (EC5 dS/m).

	Depth (inches)	Average	95% CI
Study Area 1	0-12	9.25	7.75 - 10.75
	12-30	7.59	6.42 - 8.75
	30-60	5.66	4.75 - 6.55
	0-60 Weighted average	6.92	5.95 - 7.89
Study Area 2	0-12	3.85	1.54 -6.16
	12-30	7.34	4.71 - 9.97
	30-60	12.61	9.98 - 15.24
	0-60 Weighted average	9.28	7.18 - 11.38
Study Area 3	0-12	4.29	3.46 - 5.12
	12-30	9.21	8.19 - 10.24
	30-60	13.52	11.62 - 15.44
	0-60 Weighted average	10.39	9.16 - 11.61

The 30-60 inch substrata zone in Study Area 2 was significantly higher in salinity than the 0-12 and 12-30 inch zone. The soil profile exhibited what is termed a regular soil salinity pattern with salinity increasing with depth. Variability was very high in this study area; it appears we should evaluate dividing the study area into two areas for statistical analysis.

The profile for Study Area 3 shows a favorable regular salinity distribution. The salinity increase with depth is significant at the 95% level. The clay soils at this site tend to discourage upflux from the groundwater table. As long as the water table remains below 9 feet, this site should be slowly leached of salts in the 0-30-inch active root zone. Variation of soil salinity was low on this study area.

The weighted average soil salinity is higher in Study Area 3 than in Study Area 1 but this is somewhat misleading. Surface soil salinity is significantly higher on Study Area 1 than on the other two study areas. The elevated surface soil salinity could inhibit germination and emergence of seeds of salt sensitive plants, however most weedy plants can germinate and emerge from moderately saline surface soils.

2.2.2.1.2.4. Soluble Boron

A statistical summary of the data is presented Table 2-16. The data are from 1 part soil to 5 parts DI water extracts prepared on a weight basis. The data were converted to mg/kg dry soil by multiplying the 1/5 extract concentration by a factor of 5.

Table 2-16. Soluble boron 1-5 extract (mg/kg dry soil).

	Depth (inches)	Average	95% CI
Study Area 1	0-12	4.10	3.72 - 4.48
	12-30	2.99	2.67 - 3.30
	30-60	8.45	7.1 - 9.8
	Weighted average	5.93	5.23 - 6.64
Study Area 2	0-12	2.32	1.81 - 2.83
	12-30	14.13	10.80 - 17.4
	30-60	22.5	21.05 - 23.95
	Weighted average	15.94	14.47 - 17.41
Study Area 3	0-12	2.99	2.47 - 3.51
	12-30	14.91	12.56 - 17.24
	30-60	20.56	18.32 - 22.80
	Weighted average	15.34	13.68 - 17.00

The concentrations at all depths in Study Area 1 were significantly different from one another. In Study Area 2 and Study Area 3, boron concentrations increased sharply with depth with each depth increment significantly higher than the shallower sample zone. The surface (0-12 inch) concentration is suited for all plants but deeper concentrations could be phytotoxic to most plants (Table 2-16).

2.2.2.1.3. Spatial trends between study areas

Study Area 2 had the highest weighted-average total selenium values, while Study Area 3 is intermediate, and Study Area 1 has the lowest values (Table 2-12). At the 95% confidence level Study Area 2 and Study Area 3 are significantly higher than Study Area1 but are not significantly different from one another.

The 30-60 inch substrata zone in Study Area 2 and Study Area 3 are significantly higher than the substrata zone in Study Area 1 (95 % confidence level).

Soil selenium values are low at the Atwell Island site. USGS reports that the average total selenium value of a large random sample of western states soils is about .34 mg/kg. The geometric mean (median) value from the western states suite of soils was .23 mg/kg.

The selenium values at all three Atwell Island study areas are below toxic levels and may be deficient for some organisms. Soluble selenium data from the site will be examined to gain a better understanding of the selenium readily available for plant uptake and animal nutrition.

Boron concentration in Study Area 1 where much lower than in the other two study areas. Study Area 2 and Study Area 3 had similar elevated concentrations of soluble boron in substrata. Only boron tolerant plants are recommended for Study Area 2 and Study Area 3. Shallow rooted annual grasses may also tolerate the high boron concentrations at these sites. Plants moderately tolerant to boron should be successful at Study Area 1.

2.2.2.1.4. Soil interpretive summary

The Atwell Island site was relatively low in both soluble and total selenium. Boron concentrations were moderate in surface soils and are elevated in subsoils. Both boron and soil salinity are plant growth limiting factors at the Atwell Island sites. Study Area 1 appeared to be using moisture from the water table. While this has benefited plant growth in the short term, it may indicate soil salinity problems in the future. The medium textured soils at the Study Area 1 site exhibited capillary fringe zones approaching 5 feet thick. A declining shallow water table in response to land retirement will lessen the likelihood of salinization of surface soils.

2.2.3. Weather

Hourly precipitation, temperature, wind and relative humidity data are collected at the California Irrigation Management Information System (CIMIS) weather station #21, which is located approximately 18 miles west of the demonstration project site. The CIMIS station is operated and maintained by the California Department of Water Resources (CDWR), and can be used to guide crop irrigation scheduling and estimate consumptive water use for various crops. In 2002, a total of 4.94 inches of rainfall was recorded at CIMIS Station 21, with most of the rainfall occurring between January to June, and November to December (Figure 2-15).

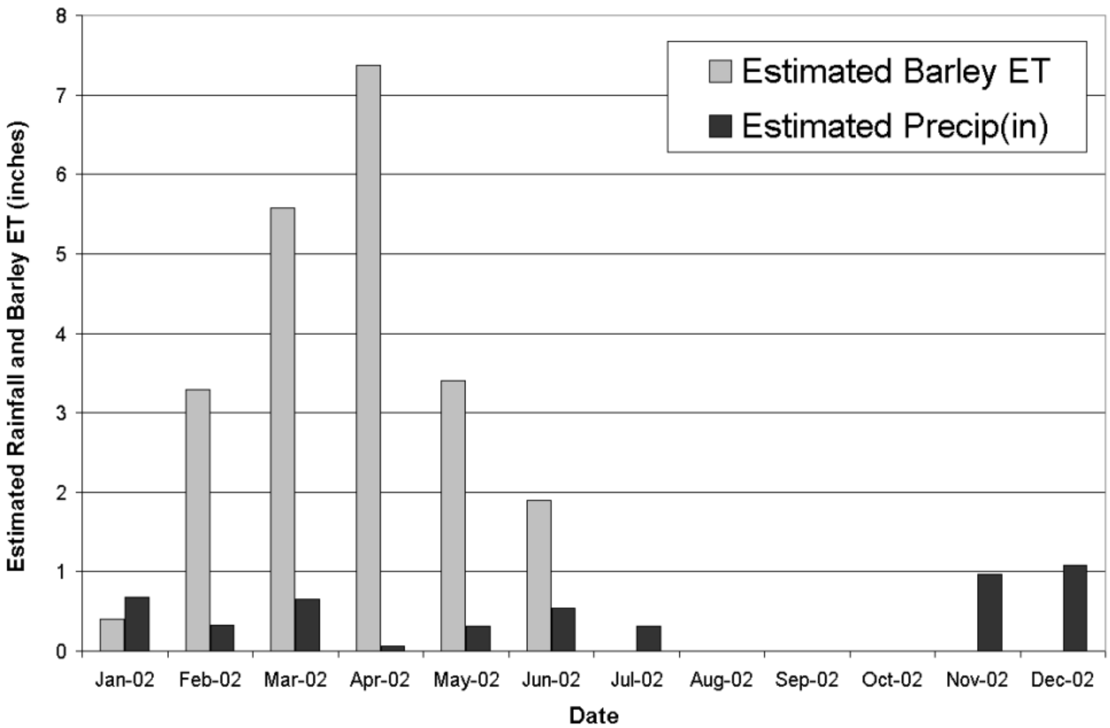

Figure 2-15. Monthly precipitation and estimated barley crop consumptive water use in 2002 at CIMIS Station 21.

2.2.4. Irrigation

The largest volume of irrigation water applied at the site during calendar year 2002 was from ongoing farming operations. Farming operations continued on approximately 2,350 acres of the Atwell Island site. Irrigation applications on these lands are currently scheduled based on a calendar or rotational approach. Metered pumping volumes for applied irrigation water are not available. Typical irrigation applications consist of gravity flow (flood irrigation) of about 6 acre-inches per acre. An estimate of applied water and deep percolation (groundwater recharge) for irrigated lands within the demonstration project boundary at the Atwell Island site during 2002 is shown in Table 2-17. Estimated deep percolation losses in 2002 are about 15 % less than those in 2001. Irrigation of high water use crops such as alfalfa will be phased out as restoration of the site to native upland progresses. 140 acres of barley were planted on the habitat restoration study blocks to provide weed and dust control, and to isolate the individual study plots. The barley crop was not irrigated in 2002.

Table 2-17. Estimated 2002 net crop water requirement and deep percolation losses at the Atwell Island site.

Crop	Acreage	Total crop water requirement[1] CWR (acre-feet)	Irrigation water application requirement[2] IWAR (acre-feet)	Estimated deep percolation[3] DP (acre-feet)
Alfalfa	1,179	4,710	7,246	2,536
Oats	1,137	932	1,433	502
Safflower	37	96	148	52
Total	**2,353**	**5,738**	**8,827**	**3,090**

[1] CWR = Crop ET - Effective Precip. + Leaching Requirement (after Smith, 2001)
[2] Assumes an Irrigation Efficiency of 65%
[3] IWAR - CWR = DP

2.2.5. Hydrology and Surface Water Monitoring

The natural drainage in the study area is to the north-northwest with ground surface elevations ranging from about 205 ft AMSL, in the southeast portion of the site to about 215 ft AMSL in the northeastern portion of the site. A pronounced sand ridge traverses the northern boundary of the site in a northeasterly direction. The sand ridge was formed from windblown sand deposited along the southern shore of the Tulare Lake bed. Surface water courses within the study area consist primarily of irrigation supply canals and irrigation return flow ditches. The site has an artificially constructed 20-acre wetland that is filled from surface irrigation water supplies. Shallow ephemeral surface water ponds may form on low lying portions of the site due to localized sheet flow run-off during prolonged winter storm events. The surrounding areas near the Atwell Island site receive periodic unregulated winter storm flows from Deer Creek, Poso Creek, and the White River. The study area parcels under consideration are generally not subject to long term flooding, due to their higher topographic position with respect to the adjacent lower lying lands.

The biological opinion for the demonstration project requires water quality monitoring for ephemeral surface water pools that form as a result of rainfall. No surface-water ponding that lasted more than 30 days was observed at the site during the calendar year 2002. However, ponded water from the artificial wetland at the site was sampled and analyzed for selenium in January, July, and October 2002. Selenium concentrations were below detection limits (<0.4 µg/L) in the January and July samples. A selenium concentration of 0.6 µg/l was observed in the October sample, which is below the 5 µg/L EPA water-quality criteria for long term exposure in aquatic environments (USEPA 1988).

2.2.6. Groundwater Level Monitoring

There are approximately twenty monitor wells in the project vicinity that are used to measure groundwater levels beneath the site on a quarterly basis. The well locations are shown on Figure 2-16 . Existing wells constructed prior to the purchase of the demonstration project lands were installed by the U.S.Geological Survey, the California

Department of Water Resources and the USBR to assess groundwater conditions in the Tulare basin. These existing wells are constructed of PVC casing ranging in diameter from 0.75 to 3 in and vary in depth from 20 to 190 ft below the ground surface. These wells were installed using various construction techniques that range from jetting a short length of pipe into the ground, to standard rotary drilling with hydraulic drill rigs. During the fall of 1999, the USBR installed 17 new monitoring wells for the purpose of measuring groundwater levels and obtaining representative groundwater samples for water quality analyses for the Land Retirement Demonstration Project. The new wells range in depth from 15 to 60 ft below land surface and were installed using a hollow stem auger drill rig and are constructed of 2 inch PVC casing. Well construction diagrams for the new wells are on file in the USBR offices in Fresno and Sacramento. Well construction information for the USGS wells are published by Beard et al. (1994), Fujii and Swain (1995) and Swain and Duell (1993).

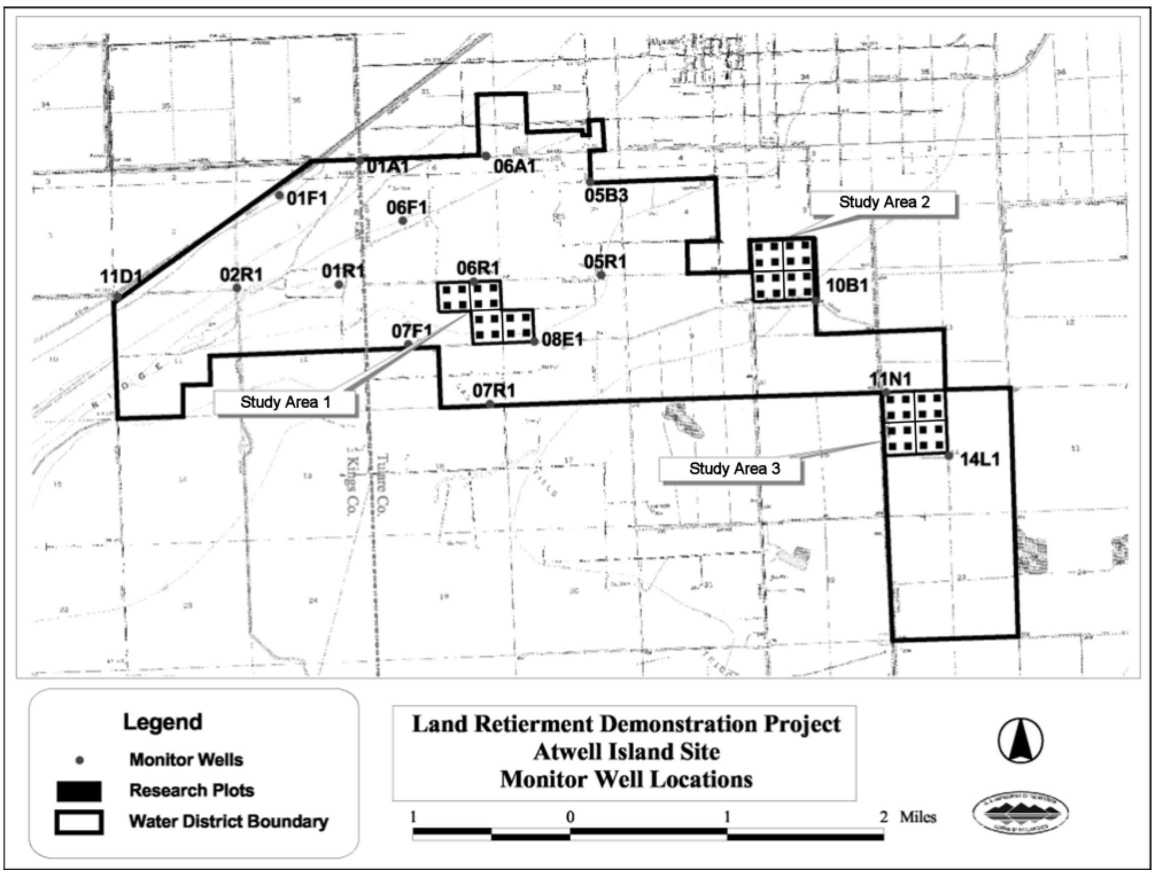

Figure 2-16. Monitor well locations at the Atwell Island site.

2.2.6.1. Groundwater levels

Calendar year 2002 served as the baseline year for establishing groundwater levels and groundwater quality at the Atwell Island site. Groundwater levels measured in twenty wells during 2002 confirm the presence of shallow, perched water table conditions at the Atwell Island site. Groundwater levels observed during January 2002 in the shallow groundwater system range from 4.3 to 14.8 ft below land surface. In general, the water table is highest (nearest the land surface) in the northeast corner of the site and becomes deeper in the southeast portion of the site. These observations are consistent with those of Beard et al. (1994) and the USBR (1982).

A declining shallow water table in response to land retirement has been observed on portions of the site where irrigation has been ceased or greatly reduced (Figure 2-17). Pre-project water level data reported by the USGS (Beard et al. 1994) show seasonal high groundwater levels around 5 feet below land surface. Post-project, seasonal high water levels measured in well 5B3 during 2002 have dropped to a depth ranging from approximately 7 to 8 feet below land surface (a decline of 2-3 feet). Groundwater level monitoring will continue at the site to evaluate shallow water table response to land retirement.

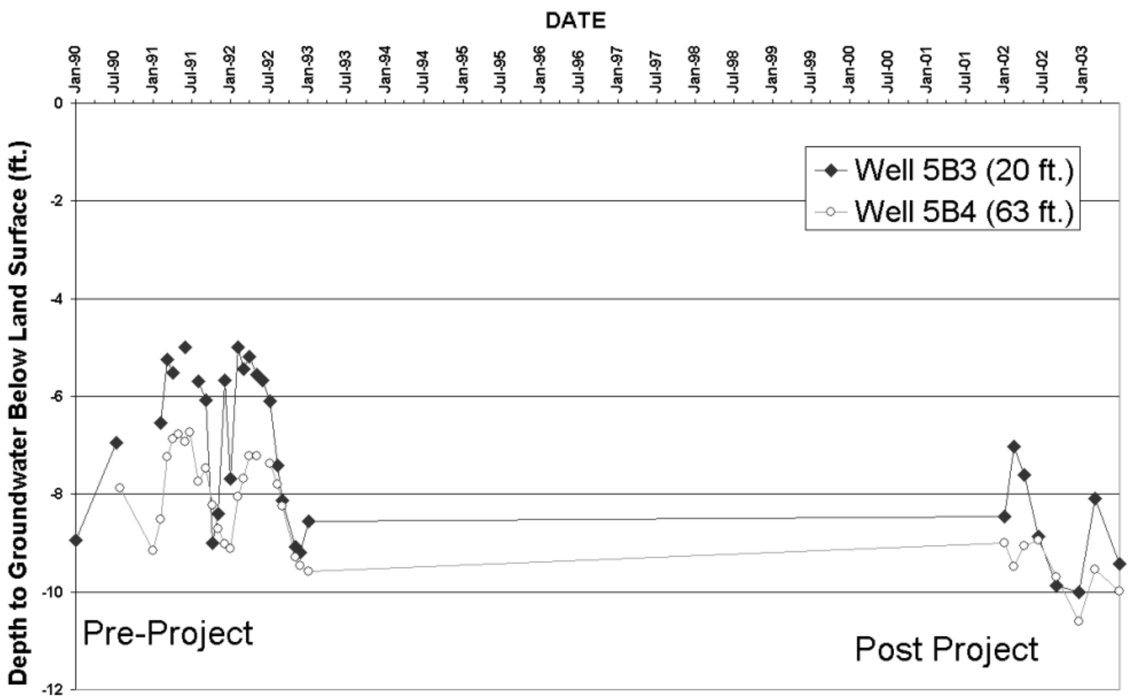

Figure 2-17. Hydrographs for wells 5B3 and 5B4 showing pre-project and post-project groundwater levels.

2.2.7. Groundwater Quality Monitoring

The purposes groundwater-quality monitoring at the site are to establish baseline conditions that can be used as a basis for comparison for change-detection analyses, and to collect data that can be used to evaluate selenium exposure risk to wildlife via the groundwater pathway. Baseline groundwater samples were taken on a quarterly basis during 2002 at the Atwell Island site. The baseline groundwater-quality samples were taken in January, May, July, and October 2002. Annual groundwater sampling began at Atwell Island in May 2003, and will continue for five years. Samping was conducted in spring to coincide with the seasonal high water table in the region. Annual and baseline groundwater-quality data will be compared to evaluate changes in groundwater quality. Unfiltered groundwater samples were taken from 16 wells to assess baseline groundwater quality at the site. Standard operating procedures for groundwater sampling used by the Mid-Pacific Region of the USBR and those outlined in the Quality Assurance Project Plan for the Land Retirement Demonstration Project (CH2M Hill 1999) were employed to obtain groundwater samples.

Unfiltered groundwater samples were analyzed for major ions (calcium, magnesium, potassium, sodium, chloride, sulfate, total alkalinity), trace elements (selenium, boron, iron, manganese) and isotopes (H^{-2}, O^{-18} and H^{-3}). Specific conductance (electrical conductivity), pH, and temperature of groundwater samples were measured in the field at the time of sampling. Flourometric analyses of groundwater samples for selenium were performed by Olsen Biochemistry Laboratories, South Dakota State University. Analyses for isotopes (H^{-2}, O^{-18}) were performed by the USGS Water Resources Division laboratory in Reston, Virginia. Analyses for tritium (H^{-3}) were performed by the USGS Water Resources Division laboratory in Menlo Park, California. All other analyses were performed by commercial laboratories under contract to the Bureau of Reclamation. The Quality Assurance Project Plan (QAPP) for the Land Retirement Demonstration Project describes in detail the analytical procedures and quality assurance measures taken to ensure groundwater data quality (CH2M Hill 1999).

2.2.7.1. Groundwater salinity

Baseline electrical conductivity (EC) data for the groundwater samples collected during the first year of monitoring are presented in Table 2-18. The shallow groundwater is moderately saline in nature. Salinity in the shallow groundwater samples, expressed as EC, ranged from 575 to 52,925 µS/cm, with a median value of 13,740 µS/cm. By comparison, drinking water typically is less than 750 µS/cm, irrigation water is less than 1,250 µS/cm, and seawater is about 50,000 µS/cm

The elevated salinity of the shallow groundwater at the site is a result of the irrigation of saline soils. Naturally occurring salts have been leached from the soil profile under irrigated conditions. Salts also have been transported to the site in the applied irrigation water. Direct evaporation from the shallow water table and transpiration of applied water by crops has concentrated salts in the shallow groundwater, resulting in the high EC values observed in the shallow groundwater samples.

2.2.7.2. Groundwater major ion chemistry

Baseline major ion chemistry data for the groundwater samples collected during 2002 at the Atwell Island site are presented in Table 2-18. The shallow groundwater at the site is best described as a sodium sulfate type of water. Sodium is the dominant major cation found in the shallow groundwater samples, with sodium concentrations ranging from 469 to 15,100 mg/l, and a median concentration of 4,500 mg/l. Sulfate is the dominant major anion found in the shallow groundwater with sulfate concentrations ranging from 261 to 22,200 mg/l, and a median concentration of 5,700 mg/l. By comparison, Fujji and Swain (1995) reported median shallow groundwater concentrations of 8,400 and 13,000 mg/l for sodium and sulfate, respectively in nine samples taken from the southwestern margin of the Tulare Lake Bed.

Table 2-18. Baseline groundwater quality data for shallow wells at the Atwell Island site - major ions, field parameters, and selenium. Note: selenium concentrations are expressed in micrograms/litre (μg/L). 72 samples were used to calculate the selenium statistics.

Statistic	Minimum	25th percentile	Median	75th percentile	Maximum	Mean
Number of Samples	64	64	64	64	64	64
EC(field) (μS/cm)	575	4615	13740	26095	52925	18059
pH (field)	6.24	7.21	7.49	7.93	9.12	7.60
Calcium (mg/l)	3	40	320	438	850	282
Magnesium (mg/l)	1	21	148	590	1800	390
Sodium (mg/l)	469	1290	4500	11350	15100	6180
Potassium (mg/l)	1	4	9	30	152	23
Total Alkalinity (mg/l)	366	429	580	881	2050	736
Chloride (mg/l)	216	549	3400	7385	12800	4312
Sulfate (mg/l)	261	1225	5700	17325	22200	8382
Selenium (μg/L)	<0.4	0.54	8.56	68.25	208	34.2

2.2.7.3. Selenium in groundwater

Selenium concentrations measured in the shallow groundwater wells at the site during the baseline year of monitoring range from less than the detection limit of 0.4 to 208 micrograms per liter (μg/L), with a median concentration of 8.56 μg/L (Table 2-18). The EPA water-quality criteria for long-term exposure to selenium in aquatic environments are 5 μg/l (USEPA 1988). Approximately 50% of the groundwater samples (35 of 72 samples) collected during the baseline year of sampling were less than the EPA aquatic life criteria. Selenium concentrations in the shallow groundwater show considerable spatial variation throughout the site. In general, the highest selenium concentrations in groundwater range from approximately 60 to over 200 μg/L, and are found in the central portion of the site under sections 5,6,7 and 8 (Figure 2-16). These high selenium areas are associated with the Excelsior and Posochanet soil series (Figure 2-14). The Posochanet soils found within Study Area 1 also contained the highest selenium concentrations observed in the baseline soil investigation. The groundwater underlying the eastern and western portions of the site contain much lower levels of selenium (<0.4 to 17μg/L). Fujii and Swain (1995) noted that the distribution of selenium in shallow groundwater in the Tulare Basin is strongly influenced by sources of selenium, selenium concentrations in soil, evaporation of shallow groundwater, and redox conditions.

The conceptual model of a declining shallow water table is an essential element of land retirement in light of the high concentrations of selenium observed in the shallow groundwater in the center of the Atwell Island site. If these waters were exposed at the land surface, wildlife could be exposed to potentially toxic conditions. Continued monitoring of groundwater levels and selenium concentrations in the shallow groundwater over the five-year project life is warranted and will provide useful data to quantify risk to wildlife exposure to selenium via the groundwater pathway.

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3. SELENIUM ACCUMULATION IN BIOTA

- Curt Uptain

3.1. INTRODUCTION

The soils and groundwater within drainage impaired lands (see Figure 1-1) contain high concentrations of salts, selenium, and other trace elements which are naturally occurring deposits in the marine sediments of the Coast Range and collect on the valley floor by alluvial deposition and runoff. The application of irrigation water to these lands results in additional loads of many of these elements and contributes to the accumulation of poor-quality, potentially toxic drain-water that is difficult to eliminate or treat. A variety of options to eliminate or reduce drain water have been explored including:

- A system of tile drains and canals to transport drain water to centralized locations within and outside of the Central Valley;
- Large scale evaporation ponds to concentrate and re-use drain water;
- Agroforestry plantations to use and reduce the quantity of drain water; and,
- Treatment facilities to reduce selenium in drain water through bioaccumulation.

Each of these potential solutions has associated difficulties, which makes implementation on a large scale problematic. One appealing way to help alleviate the accumulation of drain water is to reduce the amount of drain water produced, through selective retirement of irrigated agricultural lands. The land retirement program could reduce the quantity of drain water, improve the quality of drain water, lower groundwater levels, and reduce the accumulation of selenium, other toxic trace elements, and agricultural contaminants in groundwater and surface waters.

A variety of options are available for land use once land is retired including dryland farming and grazing, urban development, construction of transportation infrastructure, and restoration of wildlife habitat. The recovery plan for upland species of the San Joaquin Valley (FWS 1998) prominently features land retirement as a partial solution for recovery of listed and sensitive species in the San Joaquin Valley. To effectively contribute to wildlife habitat, retired lands must provide connectivity between existing populations of wildlife and they must not be allowed to become weedy fields that harbor undesirable plant and wildlife communities. Furthermore, wise land use and appropriate management of retired lands is necessary to reduce impacts of pests on neighboring farming operations. Accordingly, habitat restoration and management is an important component of land retirement.

The high concentrations of selenium in the groundwater and soils in combination with habitat restoration have the potential to be an "attractive nuisance" that could be detrimental to wildlife. High concentrations of selenium are known to cause a variety of adverse affects including embryonic malformation and death, reduced longevity, reduced reproductive success, reduced growth and survival rates, winter stress syndrome, food aversion and mass wasting, alopecia (loss of feathers) and loss of hair and nails, depressed immune system function, altered enzyme function, skin lesions, respiratory failure, and paralysis. Although the groundwater and soils contain high amounts of selenium, the degree that selenium is available to, and accumulates in biotic resources in agricultural lands and in upland habitats is not well understood. The affects of habitat restoration of retired agricultural lands on the bioavailability of selenium are not known.

We examine the risk to wildlife from exposure to the high selenium conditions that occur on retired agricultural lands by monitoring selenium concentrations in groundwater, soil, and biota at two project sites (see Figure 1-2, Figure 1-3). The results of monitoring selenium levels in groundwater and soils are presented in Chapter 2. In this Chapter, we present trends of selenium concentrations in various biota over the 4-year study period (1999 to 2002) and compare results between the two project sites. Results also are compared to performance standards established by the U.S. Fish and Wildlife Service for the project (FWS 1999) and to selenium levels in biota from selenium-normal situations in the western United States (USDI 1998). We also compare the concentrations of selenium in biota from the Tranquillity site to selenium concentrations found at Kesterson National Wildlife Refuge (Kesterson NWR, Figure 1-1), a site where high levels of selenium in biota resulted in a variety of toxic effects to wildlife (USDI 1992). When comparative data are not available from Kesterson NWR, we attempt to relate our findings to other local and regional information.

3.2. METHODS

A tiered monitoring program (Appendix 3-1) developed in consultation with the U.S. Fish and Wildlife Service (FWS) was used to determine the level of sampling that would be conducted at the two project sites for each biotic group. The sampling levels employed depend upon the selenium concentration in the groundwater, depth to groundwater, and the presence of surface water. Initially, conditions at the Tranquillity site mandated that the most rigorous level of sampling (Class IV level) be conducted. Because the depth to groundwater has declined since project inception (Uptain et al. 2002) and because surface water has not persisted (for 30 days or more), a Class III level of sampling could have been used in most subsequent years. However, the extremely high concentration of selenium in the groundwater and soils coupled with the high concern for the potential effects of selenium bioaccumulation prompted us to maintain sampling at the Class IV intensity. For similar reasons, sampling at the Class IV level was conducted at the Atwell Island project site during the 3 years of monitoring that was conducted at that site.

As dictated in the tiered monitoring program protocols, we monitored the depth to groundwater in the fall and winter of each year and we monitored selenium and other trace element concentrations in groundwater in the winter of each year (see Uptain et al. 2002 and Chapter 2 of this report). Vegetative and reproductive parts of plants were collected in the spring or early summer each year, except in 1999 when plants were collected later in the year because of the timing of project initiation (Table 3-1). Terrestrial invertebrates were collected in late spring or summer of each year. No standing water occurred on either site, consequently, no aquatic invertebrates were present. However, permanent water does occur in a number of canals at the Atwell Island site and these may be sampled for aquatic invertebrates during subsequent monitoring efforts. Very few reptiles and amphibians were observed on the Tranquillity site (see section 5.2), so samples of herptile blood and tissue were not obtained. Although reptiles and amphibians are more common in some areas of the Atwell Island site than at the Tranquillity site, their distribution and abundance is none-the-less limited. Samples from reptiles or amphibians were not collected from the Atwell Island site. Because there was no standing water present on the either of the sites and because there were few breeding birds observed, bird eggs were not collected for selenium analysis. Tissues of small mammals were collected in the summer and/or fall.

Table 3-1. List of biotic groups sampled, sampling dates, and seasons.

Group	Sample year	Sampling dates	Season
Tranquillity plants	1999	07/22-07/23, 11/05	Summer/Fall
	2000	06/02, 06/13-06/14,	Summer
	2001	05/10-05/11	Spring
	2002	04/16, 05/08	Spring
Atwell Island plants	2000	04/20, 05/04	Spring
	2001	05/16	Spring
	2002	04/24, 05/15	Spring
Tranquillity	1999	07/23	Summer
invertebrates	2000	06/13-06/14	Summer
	2001	06/19-06/22	Summer
	2002	05/13-05/16	Spring
Atwell Island invertebrates	2000	07/12-07/13	Summer
	2001	06/12-06/13	Summer
	2002	05/20-05/23	Spring
Tranquillity small mammals	1999	06/08-06/09, 11/10	Summer/Fall
	2000	06/09, 06/27-06/28	Summer
	2001	06/22, 09/05-09/06	Summer/Fall
	2002	09/16-09/18	Fall
Atwell Island small mammals	2000	10/25-10/26	Fall
	2002	09/23-09/25	Fall

Samples were collected from areas that were widely scattered over the project sites (Figure 3-1, Figure 3-2, Figure 3-3) and from a variety of cultivated, uncultivated, and experimental areas when possible. Cultivated areas are those where barley or some other irrigated crop was present, uncultivated areas are those that were fallowed or idled and have not received irrigation water. Experimental areas are those where restoration treatments (contouring, planting of native seed, contouring and planting of native seed, or no treatment) were applied.

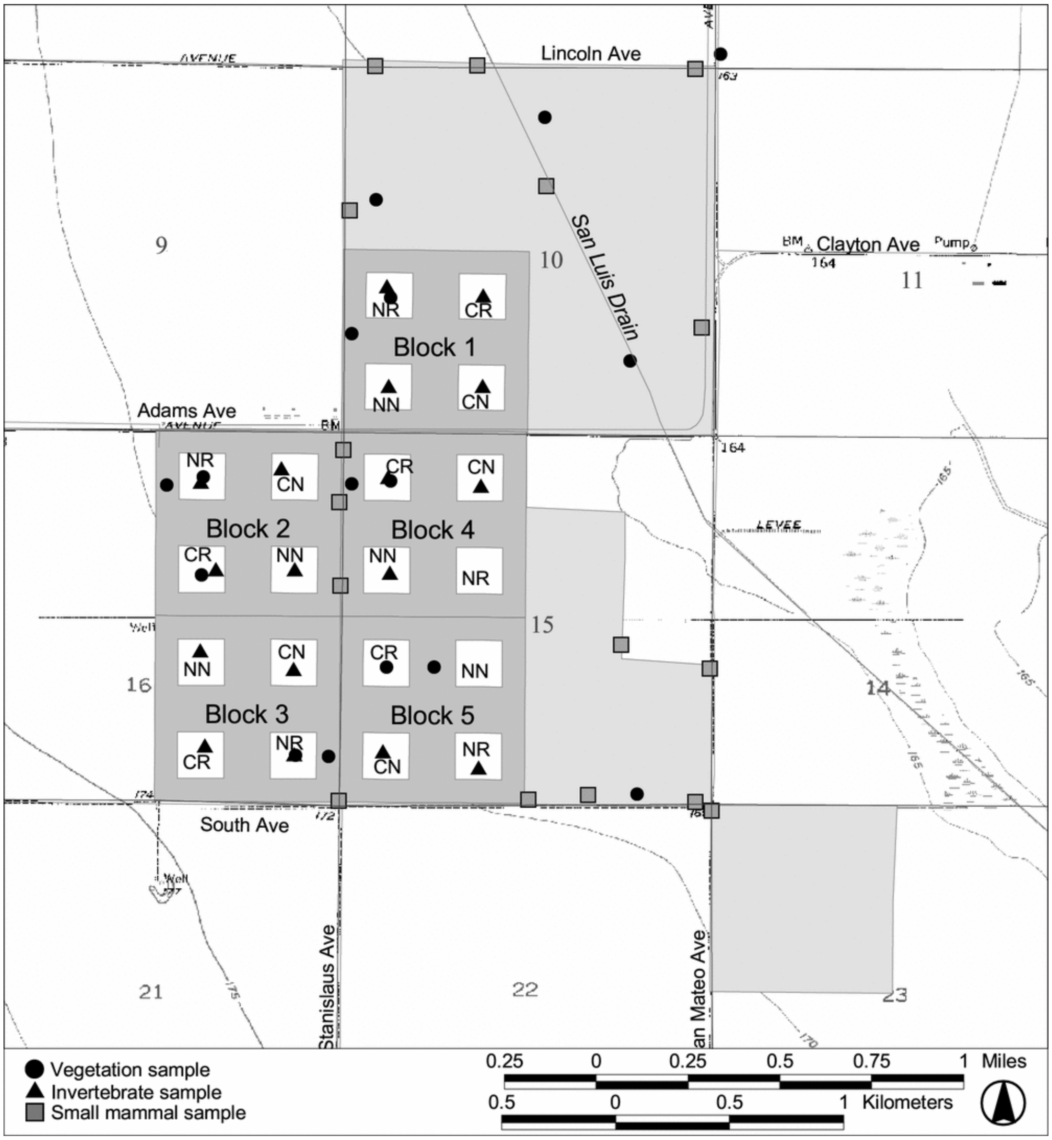

Figure 3-1. Sampling locations in 2002 for selenium analysis of biota at the Tranquillity project site.

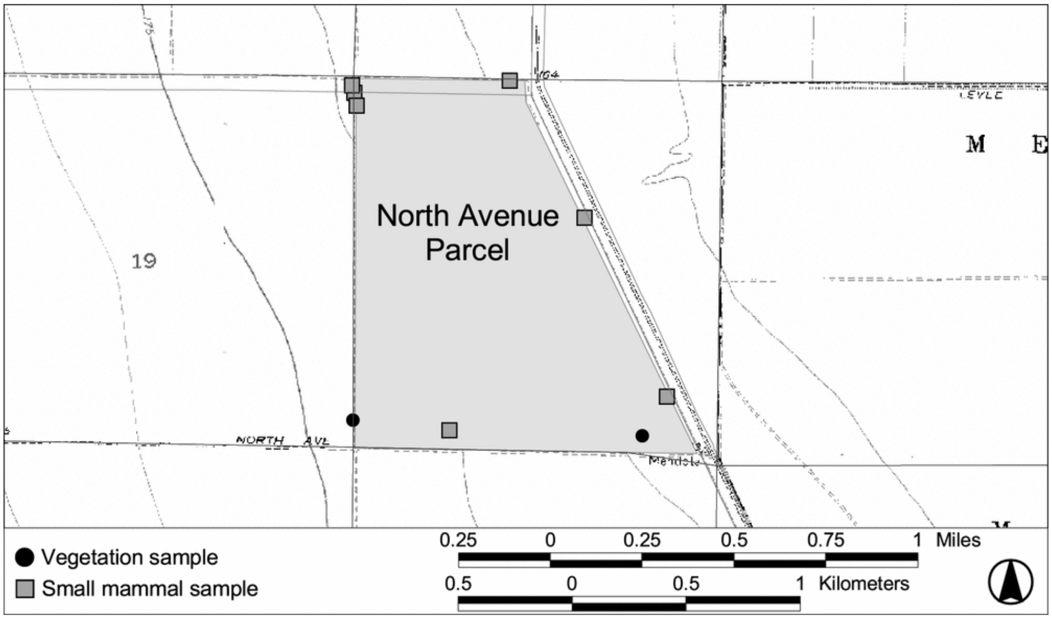

Figure 3-2. Sampling locations in 2002 for selenium analysis of biota at the North Avenue Parcel of the Tranquillity project site.

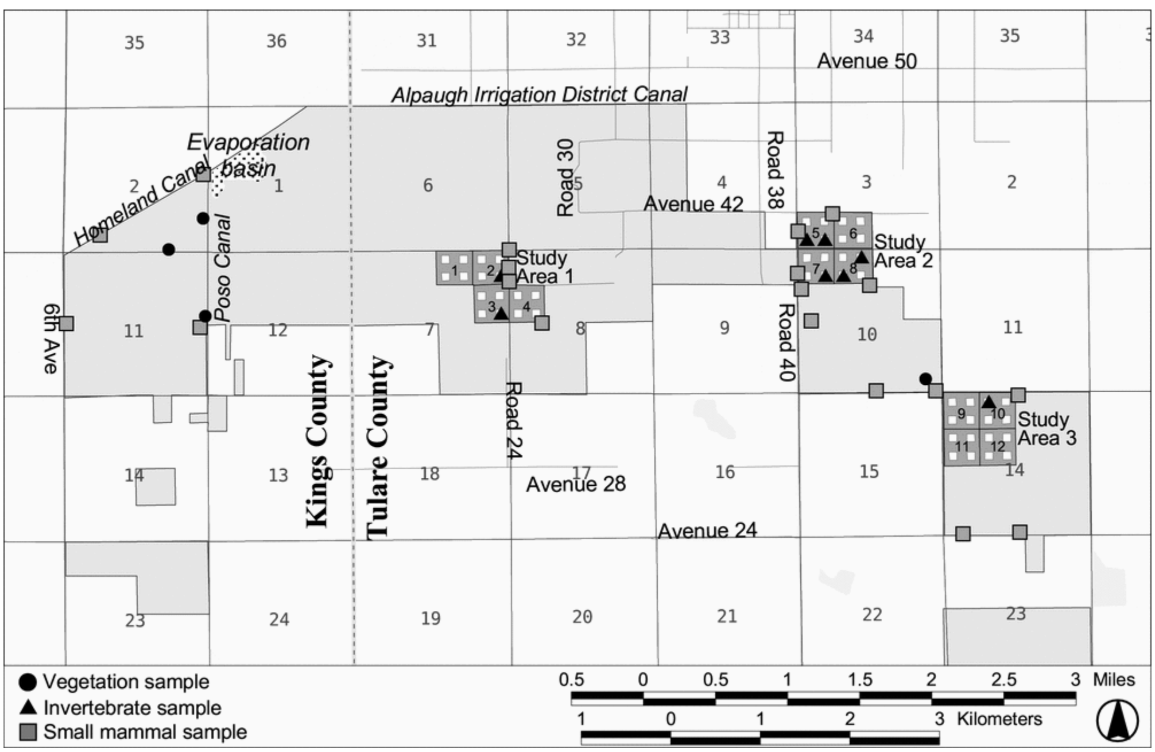

Figure 3-3. Sampling locations in 2002 for selenium analysis of biota at the Atwell Island project site.

Sampling protocols varied somewhat between biotic groups. Although vegetation samples were collected from the three landforms (cultivated areas, uncultivated areas, and experimental areas), we also collected some samples from "auxiliary" locations that include such areas as nearby Ecological Reserves, the San Luis Drain, or from study plots of our ancillary restoration trials. Plants collected from these auxiliary areas were not included in analyses unless they were obtained from LRDP lands. When included, they were assigned an appropriate landform type. We attempted to collect a standardized set of samples from each location each year that included a suite of species that were expected to occur in each of the collection areas and would be present throughout the study period. Some of these species were *Sisymbrium irio*, *Brassica nigra*, *Atriplex argentea*, *Atriplex polycarpa*, *Suaeda moquinii*, and *Hordeum vulgare*. We also collected samples of native vegetation that were planted or imprinted on the experimental areas and other dominant species in cultivated and uncultivated areas. The plants were collected when green and not showing signs of advanced water stress. Samples were placed in plastic bags, labeled, and stored on ice. After field collection, samples where taken to a lab facility where they were washed, dried, separated into "part" (e.g., seed, fruits, vegetative structures, etc.), transferred to a whirl-pack bag, and frozen.

Invertebrate samples were collected only from pitfall traps located within the experimental areas of the project sites. Invertebrates were collected during standard invertebrate abundance and richness monitoring efforts (see section 5.1). Invertebrate types collected for selenium analysis included beetles, spiders, crickets, and isopods. One composite sample of each invertebrate type was collected from each study block (a study block is a set of four 10-acre plots, one of each treatment configured in a randomized block design; see Chapter 5) at the Tranquillity site. At the Atwell Island site, one composite sample of each invertebrate type was collected from each study area (there are three study areas, each containing four blocks of four plots; see Chapter 5). We attempted to collect a composite sample of at least 2 grams of each invertebrate type from a pitfall bucket, pitfall array, multiple arrays on a plot, or sometimes multiple plots within a study block or study area. The spatial distribution of each sample depended upon abundance and availability of the invertebrate type being collected. All samples were individually bagged and labeled, immediately stored on ice, then transferred to a freezer upon returning to the lab.

Small mammal samples were collected from the two project sites by a combination of live trapping using Sherman traps and by collecting mammals from pitfall traps. At each project site, we attempted to collect five deer mice (*Peromyscus maniculatus*) from each landform (cultivated, uncultivated, and experimental) and five shrews (*Sorex ornatus*) from experimental areas only. Trapped animals were sacrificed by cervical dislocation, individually bagged and labeled, and placed on ice. Once the samples arrived at the lab, the livers were extracted from the animals and all samples were frozen. Small mammal liver tissues were analyzed for selenium concentration separately from the remaining body tissues.

All samples were shipped on dry ice to Laboratory and Environmental Testing (L.E.T.), Inc., Columbia, MO for analysis. Results obtained from the lab include selenium concentration by dry weight, selenium concentration by wet weight, sample dry weight, sample percent moisture, and sample detection limit. The laboratory also provided reports on duplicates, spikes, and reference samples for quality control. Selenium concentration by dry weight is used for analysis in this document.

All data were entered into a relational database. If the selenium concentration for a sample was less than the detection limit, then the value for that sample was set at the detection limit. Although this artificially inflates the values for group means, it does allow each sample to be included in the analyses. Subsets of data were queried and exported as dBASE tables and converted to Microsoft Excel spreadsheets. The tabular data was then reformatted for graph generation and statistical analysis. Graphs where generated in SigmaPlot (SPSS Inc) and Statistica (Statsoft Inc) was used for statistical analysis.. All data groups are presented graphically as geometric means (hereinafter referred to as simply "means") and standard deviations that are plotted on a logarithmic scale. Data were analyzed using analysis of variance tests (ANOVA), which were computed on log transformed data to normalize data distribution. If necessary, Student's *t*-tests were performed to determine differences between the means of particular subsets of data. Significance was assumed at the 95% confidence level ($p \leq 0.05$) for both ANOVA and Student's *t*-tests. Data points that exceeded the 90th percentiles (or less than the 10th percentiles) were plotted on the graphics as outliers. The data and map locations of records that exceeded the 90th percentiles were reviewed in an attempt to determine reasonable explanations for their unusually high level of selenium.

Mean selenium levels of the various taxonomic groups were compared to population-level performance standards established specifically for this project by the U.S. Fish and Wildlife Service (FWS 1999). Values also were compared to typical population-level background concentrations of selenium in the western United States (USDI 1998). Information from Kesterson NWR (USBR 1992) is used as a reference whenever possible to give indications of how the selenium levels on retired agricultural lands compare to an area where drainage water was deposited, adverse affects to wildlife occurred, and remedial actions implemented. Selenium values collected from 1988 to 1992 in the grassland habitat at Kesterson NWR were used for comparative purposes because the grassland habitat type most closely resembles the conditions present at our project sites. Selenium concentrations in the grassland habitat at Kesterson NWR tended to be intermediate between the "open habitat" and "filled habitat" designations at Kesterson NWR. Whenever comparative data from Kesterson NWR does not exist, our data are compared to other local and regional information when possible.

Our results were not statistically compared to performance standards, background levels, or results from other local and regional studies. We also did not statistically compare results between the two project sites. Instead, values are graphically presented and the comparisons are qualitative.

3.3. RESULTS

3.3.1. Tranquillity Site

3.3.1.1. Plants

To characterize the selenium concentration in vegetation on a generalized, site-wide basis, all plant data regardless of type or collection location were combined into a single data set. Accordingly, samples of vegetative parts, reproductive parts, selenium accumulators and selenium non-accumulators from cultivated, uncultivated, and experimental areas are all included in this analysis.

Mean selenium concentrations in vegetation on the Tranquillity project site were between 0.307 and 0.405 mg/kg during all 4 years of sampling (Figure 3-4, Appendix 3-2) and the variances among years were not significant ($p = 0.19$, $F = 1.58$). The mean concentrations of selenium in vegetation at the site are far below the performance standard of 2.0 mg/kg established for project lands (Figure 3-4, FWS 1999). Background selenium concentrations in vegetation occurring on non-seleniferous soils in the western United States is generally below 0.6 mg/kg, and is most typically about 0.25 mg/kg (USDI 1998). Mean selenium concentrations in vegetation at the Tranquillity site are above the reported typical background level, but are within acceptable background limits. It is expected that selenium concentrations in vegetation at Tranquillity would exceed typical background levels because of the high concentrations of selenium in the soils and groundwater. It is encouraging that the selenium levels in plants at the Tranquillity site are below the upper range of background levels (0.6 mg/kg). Overall geometric mean selenium concentrations in vegetation collected between 1988 and 1992 from grassland habitats at Kesterson NWR varied from 2.3 mg/kg to 6.7 mg/kg (Figure 3-4, USBR 1992). These values from Kesterson NWR are approximately an order of magnitude higher than those values found on the Tranquillity project site (Figure 3-4).

There were three data points that exceeded the 90^{th} percentile (0.81 mg/kg) in 1999 (Figure 3-4). These outliers contained selenium levels of 0.86, 1.00, and 1.40 mg/kg (Appendix 3-3). All outliers were samples of *Atriplex argentea*. These data points fall below the performance standard set by the FWS (FWS 1999) and they fall below the geometric means of selenium concentration in plants at Kesterson NWR. In 2000, there were eight data points that exceeded the 90^{th} percentile (0.88 mg/kg). Five of these were *Brassica nigra* that were collected from the buffer area of barley between study plots. They ranged in selenium content from 1.10 to 1.70 mg/kg. Two of these where samples of *Heliotropium curassavicum* that had selenium contents of 3.6 and 3.9 mg/kg. These were collected from an uncultivated field. Additionally, there was a single sample of *Sonchus* sp. collected from an experimental plot that contained a selenium concentration of 1.00 mg/kg. Only the two *H. curassavicum* exceeded the performance standard set by the FWS. They also exceeded the values of geometric means from plants collected from Kesterson NWR. We suspect that *H. curassavicum* is a selenium accumulator. *H. curassavicum* is uncommon on the Tranquillity project site, but it is one of the native plant species we are attempting to propagate and restore to retired lands. In 2001, there were four data points that exceeded the 90^{th} percentile (0.60 mg/kg). These were a sample of barley (*Hordeum vulgare*) collected from the buffer area with a selenium concentration of 1.30 mg/kg and two *Atriplexes* collected from experimental areas; an *A. argentea* and an *A. polycarpa* with selenium concentrations of 1.10 and 1.00 mg/kg, respectively. Finally, a sample of *Suaeda moquinii* collected from an experimental area ad a selenium concentration of 2.60 mg/kg. The *S. moquinii* sample exceeded the performance standard set by the FWS and was within the range of geometric means for selenium concentrations of plants collected from Kesterson NWR. In 2002, there were four data points that exceeded the 90^{th} percentile (1.50 mg/kg). These were two samples of *S. moquinii* (2.30 and 4.40 mg/kg) and two samples of *Sisymbrium irio* (1.70 and 2.40 mg/kg). All were collected from experimental areas, except the *S. irio* that contained a selenium concentration of 2.40 mg/kg, which was collected from an uncultivated field. All these plants except one exceeded the population-level performance standard set by the FWS, but were within or below the range of geometric means of selenium levels in plants collected from Kesterson NWR.

There appears to be no correlation between the plant samples that exceeded the 90^{th} percentiles (data outliers) and landform type; outliers were collected from all landform types in about equal numbers (cultivated = 6 samples, uncultivated = 3 samples, experimental = 7 samples, and unknown = 3 samples; Appendix 3-3). This does not necessarily mean, however, that bioaccumulation of selenium in each landform type is similar. An analysis of all data grouped by landform type would be needed to adequately address that question. We intend to perform that analysis when selenium results of the final (2003) data are obtained from the lab.

A grouping of plant outliers occurs in the northern portion of the project site and in Block 4 (Figure 3-5). However, because of the few data points available (19 outliers collected over an area of about 1,600 acres over a period of 4 years) and the unequal distribution of collected samples, these areas should not necessarily be interpreted as selenium "hot spots" or areas where selenium bioaccumulation is problematic. This is especially true when one considers that most of the outliers have selenium levels below the population-level performance standard set by the FWS. It is more reasonable to assume that high selenium concentration in these samples is a function of species; the highest selenium concentrations were found in *H. curassavicum*, *S. moquinii*, and *S. irio*. Furthermore, an analysis of the levels of total selenium in project site soils indicates that the variation between sample locations is low (see Table 30 in Uptain et al. 2001). The mean selenium concentrations in soils from the different fields on the project site varied from 0.88 to 1.14 mg/kg and the maximum variance was 0.113 at the 95% confidence level. This would indicate that soil selenium levels would not likely account for the presence of outliers. However, there may be a correlation between selenium content in soil and the bioaccumulation of selenium in plants, but we have not yet conducted that analysis.

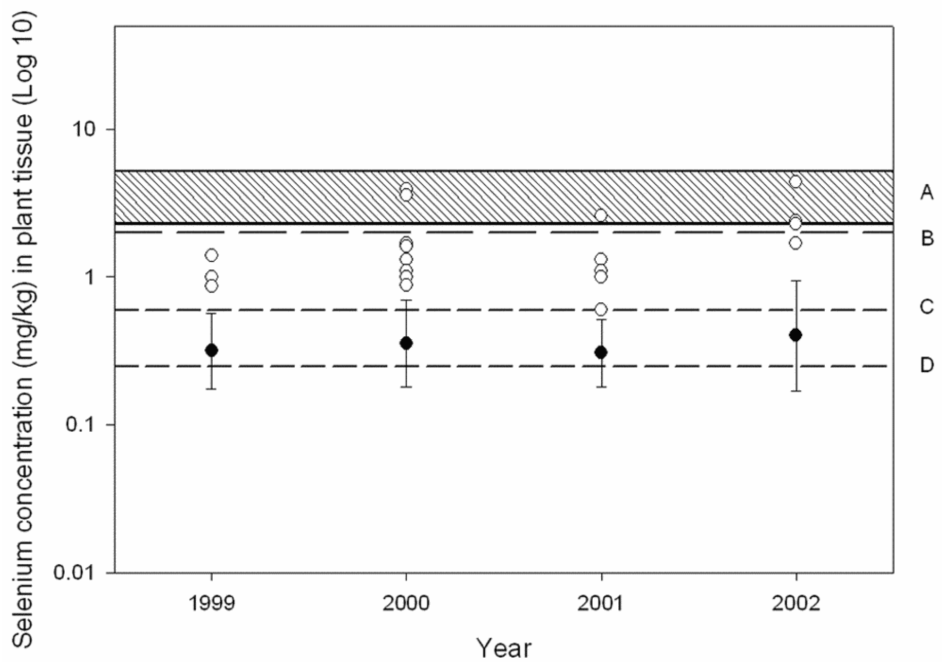

Figure 3-4. Geometric means and standard deviations of selenium concentration in plant tissue collected from the Tranquillity project site. Variances between years are not significantly different ($p = 0.19$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in vegetation (2.3 to 6.7 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR. B = the performance standard set by the U.S. Fish and Wildlife Service for selenium concentrations in vegetation (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999). C = upper threshold for background level of selenium in vegetation (0.6 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). D = typical background level threshold of selenium in vegetation (0.25 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998).

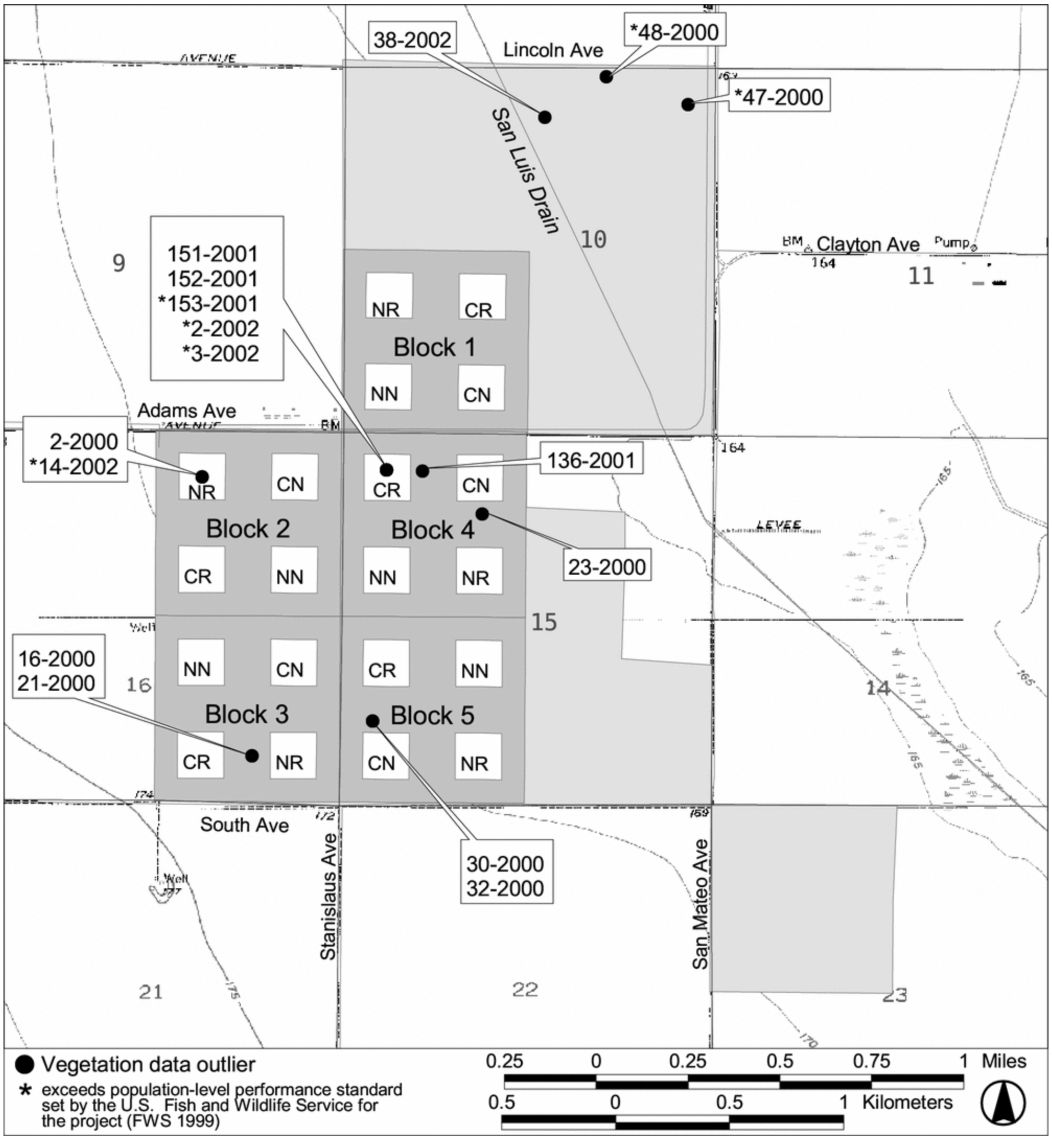

Figure 3-5. Distribution of vegetation data outliers at the Tranquillity project site, 1999 to 2002. The data points marked with an asterisk are those that exceed the population-level performance standard set by the U.S. Fish and Wildlife Service for the project (FWS 1999). Data point identification numbers correspond to record numbers shown in Appendix 3-3.

3.3.1.2. Invertebrates

To characterize the selenium concentration in invertebrates on a generalized basis, all invertebrate data regardless of invertebrate type (crickets, beetles, spiders, and isopods) were combined into a single data set and analyzed. Invertebrate types were also analyzed separately. All invertebrates were collected from pitfall traps on experimental areas. No standing water was present on the site; hence, no aquatic invertebrates were collected or analyzed.

3.3.1.2.1. All invertebrates

Mean selenium concentrations in terrestrial invertebrates varied from 0.81 to 1.65 mg/kg from 1999 to 2002 at the Tranquillity study site (Figure 3-6, Appendix 3-2). There were significant differences in variances among years ($p < 0.01$, F = 5.56). The mean selenium concentration in invertebrates from 2002 was significantly lower than in 2000 and 2001 ($p < 0.01$, $t = -3.35$ and $p < 0.01$, $t = -3.56$, respectively). Selenium in terrestrial invertebrates at the Tranquillity site remained below the performance standard of 2.0 mg/kg established for project lands (Figure 3-6, FWS 1999). Likewise, mean selenium concentrations remained below the threshold for background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). The geometric mean of selenium concentrations found in terrestrial invertebrates collected between 1988 and 1992 from grassland habitats at Kesterson NWR varied from 11.0 to 15.0 mg/kg (Figure 3-6, USBR 1992). These values from Kesterson NWR are approximately an order of magnitude higher than those values found on the Tranquillity study site.

All of the data points that exceeded the 90^{th} percentile levels from 1999 to 2002 (3.6, 3.4, 3.05, and 1.6 mg/kg, respectively) were isopods, except for one spider (Appendix 3-3). This is expected because isopods are detritivores and spiders are predators; both are expected to accumulate selenium at a greater level than invertebrates that feed solely on vegetation. All of these outliers had selenium levels between 1.8 and 5.6 mg/kg, except two that had selenium levels of 11.0 (the spider sample collected in 2002) and 13.0 (an isopod sample collected in 2001) mg/kg. These later two samples contained concentrations of selenium that are within the range of mean selenium levels found in terrestrial invertebrates at Kesterson NWR (Figure 3-6). However, when these data are analyzed by individual taxon (i.e., isopod, spider) the data points are not outliers and they do not approach the taxon-level selenium concentrations found at Kesterson (see sections 3.3.1.2.4 and 3.3.1.2.5 for spiders and isopods).

Of the invertebrate data points that exceed the 90^{th} percentiles (outliers); 6 out of 10 occurred in Study Block 4 (Figure 3-7). There were also outliers in blocks 1 and 5. The spider sample with the high selenium value (11.0 mg/kg) was collected from Block 5 whereas the isopod sample with the highest selenium value (13.0) was collected from Block 4. Block 4 contains a higher level of selenium in the soil (1.14 mg/kg; see Table 30 in Uptain et al 2000 and Chapter 2 of this report) than all other blocks. However, the difference in selenium levels of soils between Block 4 (1.14 mg/kg) and the other blocks (varying from 0.88 to 1.08 mg/kg) would not seem to be great enough to account for the higher occurrence of outliers Block 4.

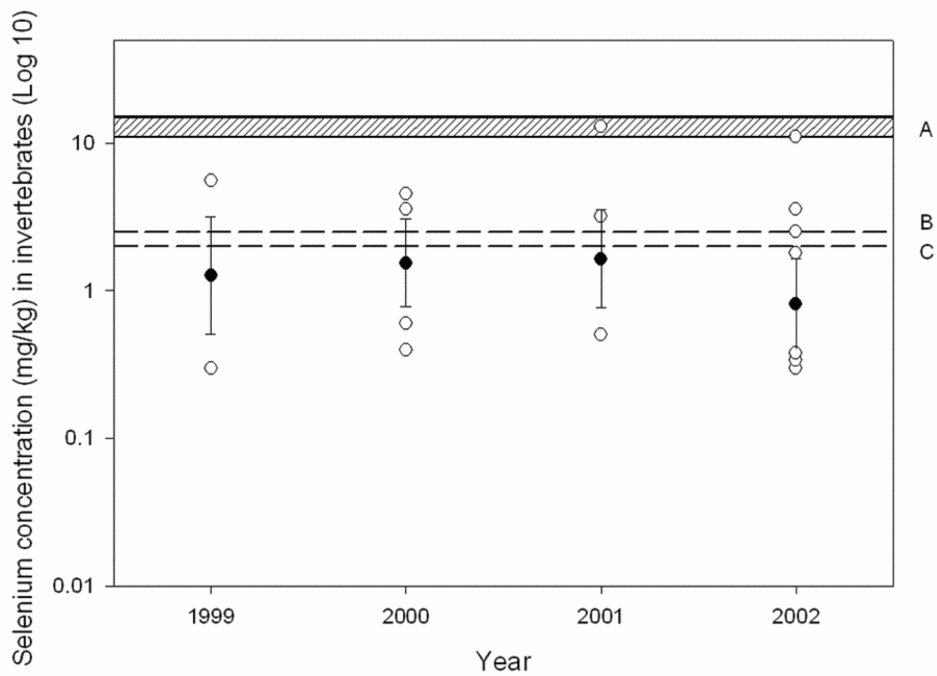

Figure 3-6. Geometric means and standard deviations of selenium concentrations in terrestrial invertebrates collected from the Tranquillity study site. The selenium concentration in invertebrates from 2002 significantly differs from 2000 and 2001 ($p < 0.01$ and $p < 0.01$, respectively). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in terrestrial invertebrates (11.0 to 15.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR. B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by the U.S. Fish and Wildlife Service for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999).

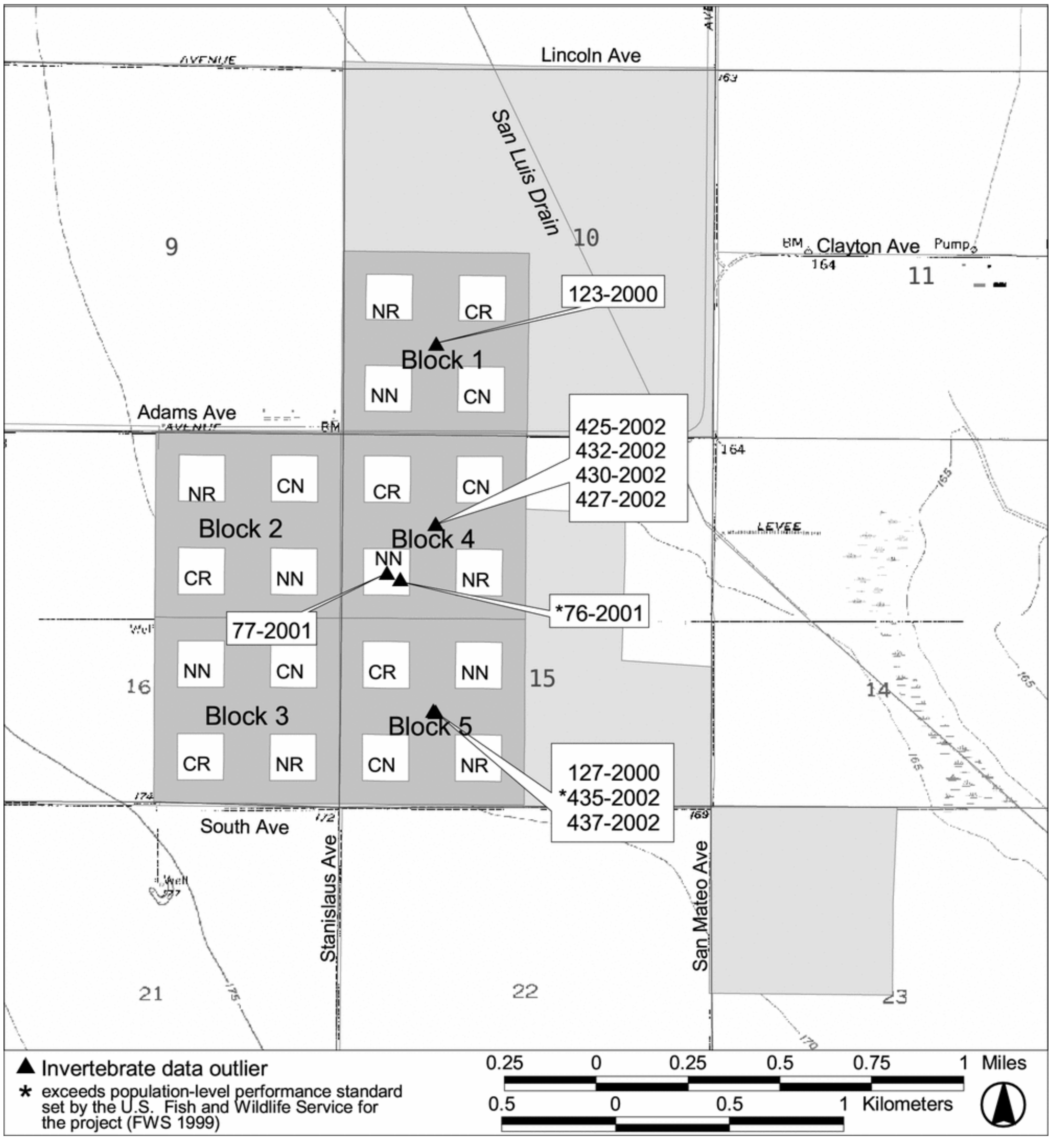

Figure 3-7. Distribution of invertebrate data outliers at the Tranquillity project site, 1999 to 2002. The data points marked with an asterisk are those that fall within the range of geometric means of invertebrate data collected from Kesterson NWR. Data point identification numbers correspond to record numbers shown in Appendix 3-3. Data points at the center of a research block contain samples from multiple plots.

3.3.1.2.2. Crickets

Mean selenium concentrations in crickets varied from 0.40 to 0.81 mg/kg from 1999 to 2002 at the Tranquillity site (Figure 3-8, Appendix 3-2). There were significant differences in variances between years (p = 0.03, F = 3.69). The mean selenium concentration in crickets from 1999 was significantly lower than in 2000 and 2001 (p = 0.04, t = -2.45 and p =0.04, t = -2.57, respectively), but not lower than in 2002 (p = 0.16, t = -1.48). However, selenium concentrations in crickets were lower in 2002 than in 2001 (p = 0.04, t = -2.23). The mean concentration of selenium in crickets at the Tranquillity site remained below the performance standard of 2.0 mg/kg established for project lands

(Figure 3-8; FWS 1999). Likewise, mean selenium concentrations remained below the background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). Geometric means of selenium concentrations in crickets collected between 1988 and 1992 in grassland habitat at Kesterson NWR varied from 5.9 to 7.6 mg/kg (Figure 3-8, USBR 1992). These values from Kesterson NWR are approximately an order of magnitude greater than those values found at the Tranquillity study site.

There was only one data point for crickets that exceeded the 90th percentiles (Figure 3-8). That sample was collected in 2002 from Block 4 (Figure 3-7, Appendix 3-3) and contained a selenium concentration of 1.20 mg/kg. That value is below the performance standard of 2.0 mg/kg established for project lands (FWS 1999) and it is below the background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). It also is below the mean selenium concentrations of crickets collected from Kesterson NWR.

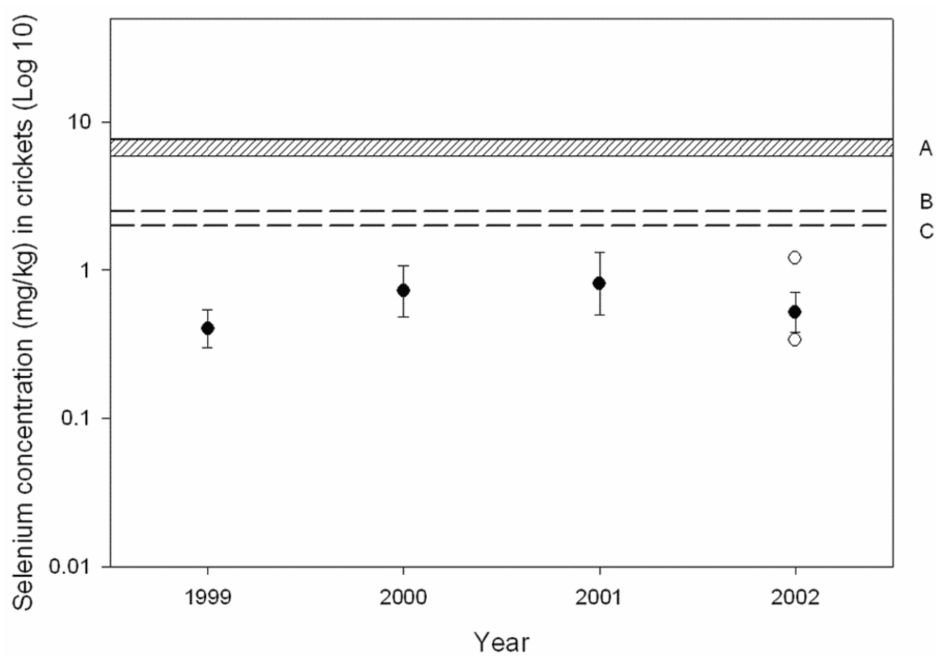

Figure 3-8. Geometric means and standard deviations of selenium concentrations in crickets collected from the Tranquillity study site. The selenium concentration in crickets from 1999 was significantly lower than in 2000 and 2001 (p = 0.04 and p = 0.04, respectively) and the concentration in 2002 was lower than in 2001 (p = 0.04). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in crickets (5.9 to 7.6 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR. B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by the U.S. Fish and Wildlife Service for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999).

3.3.1.2.3. Beetles

Mean selenium concentrations in beetles varied from 0.65 to 1.35 mg/kg from 1999 to 2002 at the Tranquillity project site (Figure 3-9, Appendix 3-2). There were significant differences in variances between years ($p = 0.05$, F = 3.08). The mean selenium concentration in beetles from 2002 is lower than in 2000 or 2001 ($p = 0.03$, $t = -2.35$ and $p = 0.02$, $t = -2.53$, respectively).

The mean concentration of selenium in beetles at the Tranquillity site remained below the performance standard of 2.0 mg/kg established for project lands (Figure 3-9, FWS 1999). Mean selenium concentrations in beetles also remained below background levels of terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). Although there were no outlying data points that exceeded the values for performance standards or background levels, in 2000 and 2001 the upper standard deviations of the geometric means exceeded 2.0 mg/kg (the FWS population-level performance standard). Geometric means of selenium concentrations in beetles collected between 1988 and 1992 in grassland habitats at Kesterson NWR varied from 8.7 to 21.0 mg/kg (Figure 3-9, USBR 1992). These values from Kesterson NWR are approximately an order of magnitude greater than those values found at the Tranquillity study site.

One value for beetles exceeded the 90th percentile (Figure 3-9, Appendix 3-3). In 2002 there was a beetle sample collected from Block 4 that contained a selenium concentration of 1.40 mg/kg. That value is below the performance standard of 2.0 mg/kg established for project lands (FWS 1999) and is below the background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). It also is well below the mean selenium concentrations found in beetles collected from Kesterson NWR.

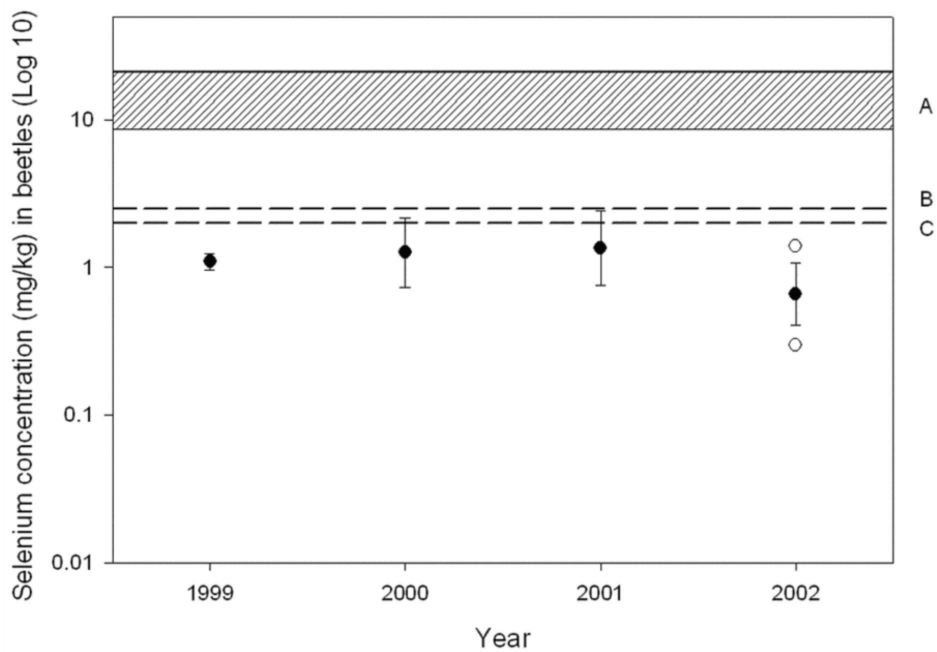

Figure 3-9. Geometric means and standard deviations of selenium concentrations in beetles collected from the Tranquillity study site. The selenium concentration in beetles collected in 2002 is significantly lower than previous years (p = 0.05). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in beetles (8.7 to 21.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR. B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the Western United States (USDI 1998). C = the performance standard set by the U.S. Fish and Wildlife Service for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999).

3.3.1.2.4. Spiders

Mean selenium concentrations in spiders varied from 1.27 to 2.24 mg/kg from 1999 to 2002 at the Tranquillity study site (Figure 3-10, Appendix 3-2). There were no significant differences in selenium concentration in spiders between years (p = 0.40, F = 1.03). The mean concentration of selenium in spiders was below the performance standard of 2.0 mg/kg established for project lands (FWS 1999) in 2000, 2001, and 2002 (1.90, 1.93, and 1.27 mg/kg, respectively), but exceeded the performance standard in 1999 (2.24 mg/kg, Figure 3-10). In no year did the mean concentration of selenium in spiders exceed typical background levels of selenium concentrations in terrestrial invertebrates in the western United States (2.5 mg/kg, USDI 1998). However, the standard deviations of the geometric means did exceed both the performance standard and background levels. Geometric means of selenium concentrations in spiders collected between 1988 and 1992 in grassland habitats at Kesterson NWR varied from 8.8 to 15.0 mg/kg (Figure 3-10, USBR 1992). These values from Kesterson exceeded the values from the Tranquillity study site by less than an order of magnitude.

In 2002, there was a spider sample with a selenium concentration of 11.0 mg/kg. This data point exceeded the 90^{th} percentile (Figure 3-10) and was collected from Block 5 (see Figure 3-7, Appendix 3-3). The selenium concentration in this sample is above the population-level performance standard of 2.0 mg/kg established for project lands (FWS 1999) and it is above the background selenium concentrations found in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). This sample falls within the range of mean selenium concentrations of spiders collected from Kesterson NWR.

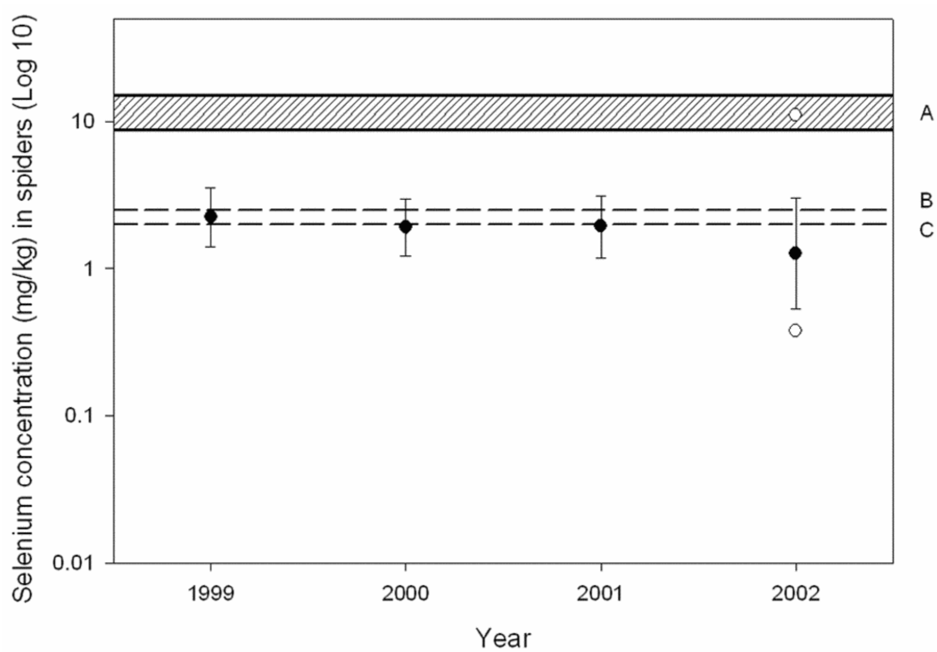

Figure 3-10. Geometric means and standard deviations of selenium concentrations in spiders collected from the Tranquillity study site. The selenium concentration in spiders did not significantly differ between years (p = 0.40). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in spiders (8.8 to 15.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR. B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the Western United States (USDI 1998). C = the performance standard set by the U.S. Fish and Wildlife Service for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999).

3.3.1.2.5. Isopods

Mean selenium concentrations in isopods varied from 1.04 to 3.46 mg/kg from 1999 to 2002 at the Tranquillity study site (Figure 3-11, Appendix 3-2). There are significant differences in variances between years (p = 0.00003, F = 29.25). The mean selenium concentration in 2002 was lower than in 2000 and 2001 ($p < 0.01$, $t = -3.27$ and $p = 0.01$, $t = -2.95$, respectively). The mean selenium concentration in isopods was only below the performance standard and typical background level in 2002 (Figure 3-11). However, data outliers that exceeded the 90^{th} percentiles (and standard deviations above the group means) generally exceeded the performance standard and typical background levels. It is not unexpected that the performance standard and background levels of selenium are exceeded by isopods because performance standard and background level values reflect representative samples of all invertebrates. Isopods are detritivores and are expected to accumulate selenium at levels higher than most other terrestrial invertebrates. Geometric means of selenium concentrations in isopod samples collected from 1988 to 1992 at Kesterson NWR varied from 53.0 to 60.0 mg/kg (Figure 3-11, USBR 1992). These values from Kesterson NWR exceeded the values from the Tranquillity study site by over an order of magnitude.

In 2002, an isopod sample contained a selenium concentration of 3.60 mg/kg. This data point exceeded the 90th percentile for the 2002 data set (Figure 3-11) and was collected on Block 5 (see Figure 3-7, Appendix 3-3). The selenium concentration of that sample is above the population-level performance standard of 2.0 mg/kg established for project lands (FWS 1999) and it is above the background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). However, the selenium concentration in that sample falls well below the mean selenium concentrations of isopods collected from Kesterson NWR (Figure 3-11).

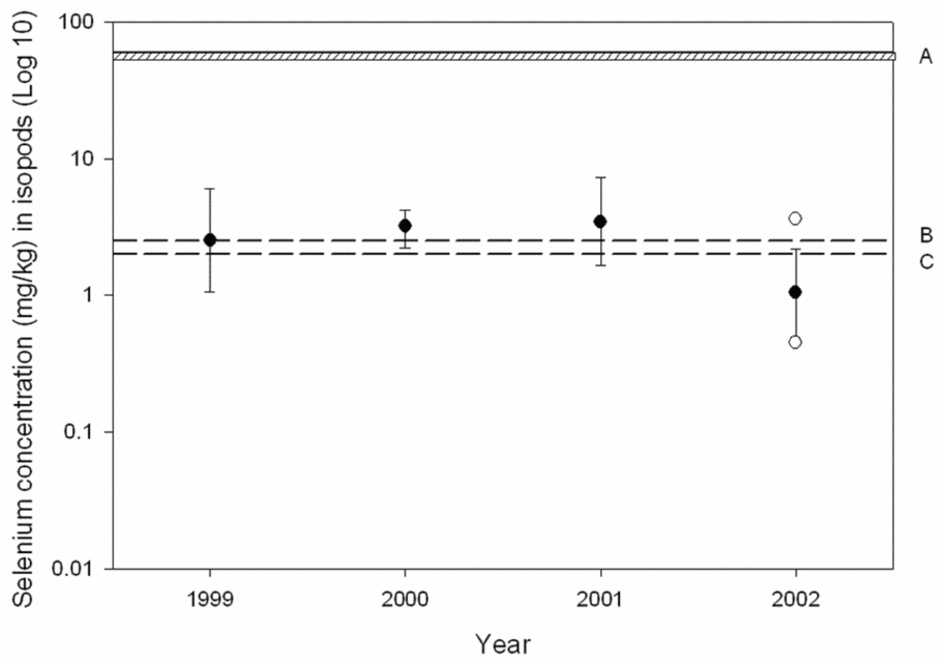

Figure 3-11. Geometric means and standard deviations of selenium concentrations in isopods collected from the Tranquillity study site. The selenium concentration in isopods was lower in 2002 than in 2000 and 2001 ($p < 0.01$ and $p = 0.01$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in isopods (53.0 to 60.0 mg/kg) collected from 1988 to 1992 in grassland habitat at Kesterson NWR. B = background level of selenium in terrestrial invertebrates (2.5 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998). C = the performance standard set by FWS for selenium concentrations in terrestrial invertebrates (2.0 mg/kg) for Land Retirement Demonstration Project lands (FWS 1999).

3.3.1.3. Small mammals

Small mammal tissues collected for selenium analysis at the Tranquillity study site were separated into four data groups; body tissues of deer mice (*Peromyscus maniculatus*; PEMA), liver tissue of deer mice, body tissues of shrews (*Sorex ornatus*; SOOR), and liver tissues of shrews. Although samples of deer mice were collected from a variety of landforms (cultivated, uncultivated, and experimental), data from all landforms were combined. Shrews were only collected from the experimental areas.

3.3.1.3.1. Deer mice

Mean selenium concentrations in deer mouse bodies varied from 0.89 to 1.09 mg/kg from 1999 to 2002 at the Tranquillity project site (Figure 3-12, Appendix 3-2). There were no differences in selenium concentrations between years ($p = 0.23$, $F = 1.48$). The mean selenium concentrations in deer mouse bodies, standard deviations of the data, and data outliers were all below the background selenium level found in small mammal body tissues from non-seleniferous soils in the western United States (generally less than 2.0 mg/kg, USDI 1998). No performance standards were set by the FWS for small mammal body tissues. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from deer mouse bodies exceeded those established for blood, but were lower than those established for hair. Geometric means of selenium concentrations in deer mouse whole bodies collected from 1988 to 1992 at Kesterson NWR varied from 4.8 to 11.0 mg/kg (Figure 3-12, USBR 1992). These values from Kesterson NWR exceeded the values from the Tranquillity project site by approximately an order of magnitude. However, the samples from Tranquillity were not whole body samples, they were body samples with the liver extracted. Liver tissues are known to concentrate selenium and liver tissues from deer mice captured at Tranquillity had higher selenium concentrations than the body tissues (see Figure 3-14). If the liver tissue had remained a part of the samples, the selenium values for whole body tissues would have been somewhat higher. However, liver tissue contributes a relatively small mass to the body and the selenium concentrations in the small mammal livers were not exceedingly high (see Figure 3-14). Accordingly, it is likely that any increase in selenium concentrations that would have been caused by the inclusion of livers would have been marginal and would probably not have resulted in selenium concentrations exceeding published background levels, let alone reaching the levels observed at Kesterson NWR.

Four samples of deer mouse body tissue exceeded the 90^{th} percentiles (Figure 3-12, Appendix 3-3). Of these, two where from 2002, one was from 1999, and one was from 2001. . These samples were scattered over the site and not clumped (Figure 3-13). Because of the few data points available (4 outliers collected over an area of about 1,600 acres over a period of 4 years) and the unequal distribution of collection locations, these areas should not necessarily be interpreted as selenium "hot spots" or areas where selenium bio-accumulation is problematic. Furthermore, all of these outliers have selenium levels that are below published population-level background concentrations for small mammal bodies occurring on non-seleniferous soils in the western United States (Figure 3-12).

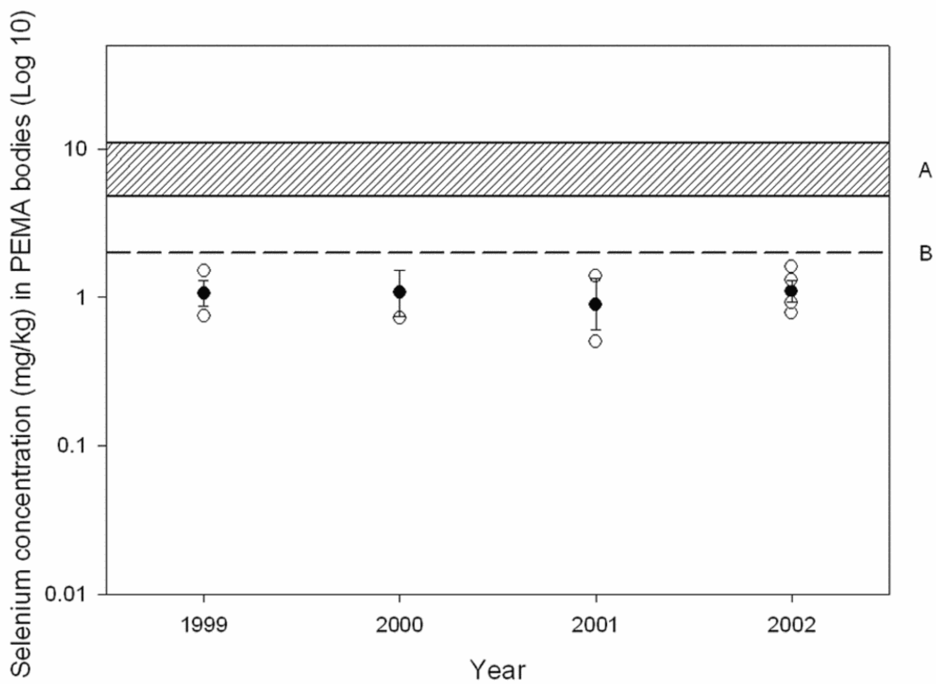

Figure 3-12. Geometric means and standard deviations of selenium concentrations in deer mouse (PEMA) bodies collected from the Tranquillity project site. The selenium concentration in deer mouse bodies did not significantly differ among years (*p* = 0.23). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in deer mouse bodies (4.8 to 11.0 mg/kg) collected from 1988 to 1992 at Kesterson NWR. B = background level of selenium in small mammal bodies (2.0 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998).

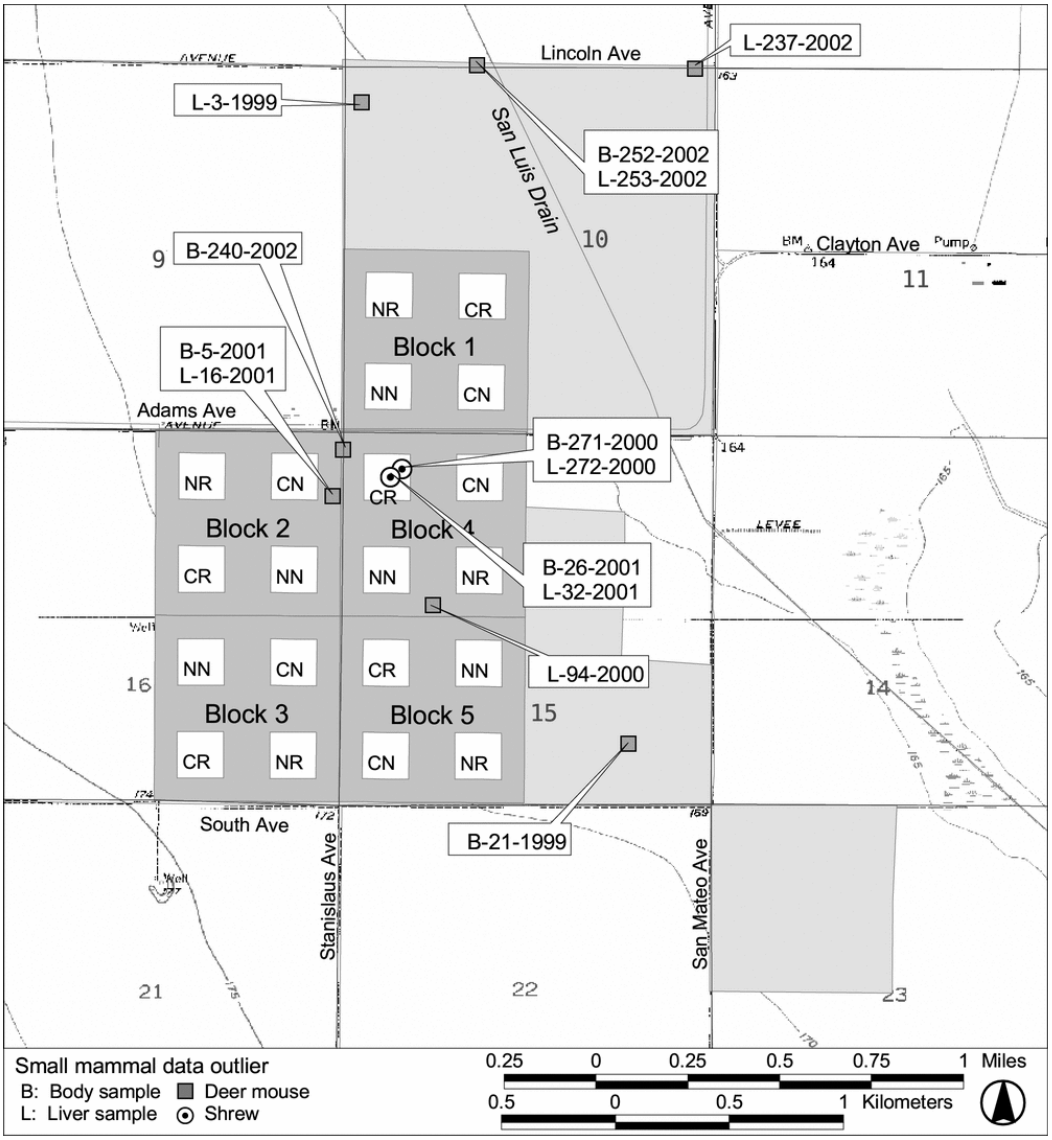

Figure 3-13. Distribution of small mammal data outliers at the Tranquillity project site, 1999 to 2002. The data points marked with (B) are body samples and those marked with (L) are liver samples. Data point identification numbers correspond to record numbers shown in Appendix 3-3.

Mean selenium concentrations in deer mouse liver tissues varied from 2.27 to 3.89 mg/kg from 1999 to 2002 at the Tranquillity project site (Figure 3-14, Appendix 3-2). There were significant differences in selenium concentrations between years ($p < 0.01$, F = 7.04). Selenium concentrations in 2001 were lower than in 1999 or 2002 ($p < 0.01$, $t = -2.86$, and $p < 0.01$, $t = -4.01$, respectively). There was no performance standard set by FWS for deer mouse livers for the Land Retirement Demonstration Project (FWS 1999). Likewise, there are no background levels available (USDI 1998) and there are no data on selenium concentrations in deer mouse livers from Kesterson NWR (USBR 1992). However, selenium levels in livers of small terrestrial mammals collected from near a selenium-normal wetland in the San Joaquin valley ranged from about 1 to 10 mg/kg (see Figure 3-14) and typically average about 5 mg/kg (Clark 1987). Small mammals collected from near an agroforestry plantation had selenium concentrations in livers that averaged less than 3 mg/kg (see Figure 3-14), except in areas where selenium-rich water was used for irrigation (CDFG 1993). Deer mouse livers from the Tranquillity project site contained selenium levels at or slightly above those found near the agroforestry plantation and are well within the range of selenium levels found in small mammal livers from the selenium-normal wetland.

There were four samples of deer mouse livers that exceeded the 90th percentiles; one each year that monitoring was conducted (Figure 3-14, Appendix 3-3). The selenium concentration of these outliers ranged from 4.4 to 5.5 mg/kg, which is near the typical average of selenium concentrations in small mammal livers collected from a selenium-normal wetland in the San Joaquin Valley (Clark 1987). The selenium levels in these samples however, do exceed the upper level of selenium concentrations found in small mammal livers from an agroforestry plantation in the San Joaquin Valley (CDFG 1993). The location of outlier samples were distributed throughout the project site and not clumped (see Figure 3-13). Because of the few data points available (4 outliers collected over an area of about 1,600 acres over 4 years) and the unequal distribution of collection locations, the locations where samples high in selenium concentrations should not necessarily be interpreted as selenium "hot spots" or areas where selenium bioaccumulation is problematic. It is puzzling that the liver samples that contained relatively high selenium concentrations were not always the same samples (thus different animals) as those that contained high selenium concentrations in the bodies.

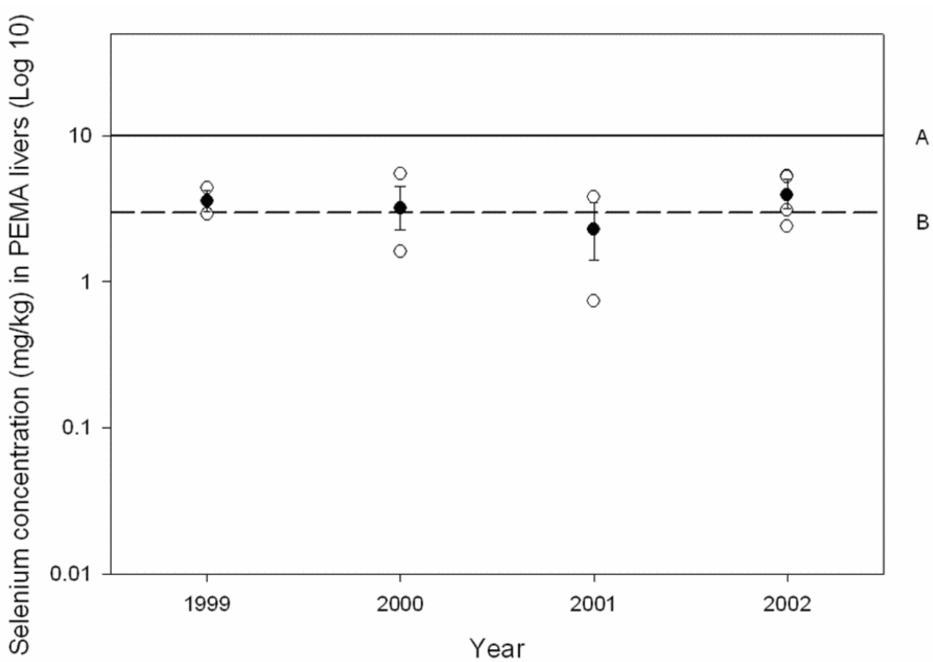

Figure 3-14. Geometric means and standard deviations of selenium concentrations in deer mouse (PEMA) livers collected from the Tranquillity project site. The selenium concentration in deer mouse livers were lower in 2001 than in 1999 or 2002 ($p < 0.01$ and $p < 0.01$, respectively). Outliers are represented by open circles lying outside of the standard deviation bars. A = the upper range of selenium in small mammal livers collected from near a selenium-normal wetland (range between 1 and 10 mg/kg). B =the upper range of selenium concentrations in small mammal livers collected from an agroforestry plantation (less than 3 mg/kg).

3.3.1.3.2. Shrews

Mean selenium concentrations in shrew bodies varied from 1.95 to 2.51 mg/kg from 1999 to 2002 at the Tranquillity study site (Figure 3-15, Appendix 3-2). There were no differences in selenium concentrations between years (p = 0.15, F = 1.93). The mean selenium concentrations in shrew bodies, the standard deviations of the data, and the outliers were all near the published upper level of background selenium concentrations for small mammal body tissues (generally less than 2.0 mg/kg; USDI 1998). This is not unexpected because shrews are insectivores and bioaccumulation of selenium in shrews is expected to be greater than in most other small mammals. No performance standards were set for small mammal body tissues by the FWS. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from shrew bodies exceeded those established for blood, but were lower than those established for hair. Geometric means of selenium concentrations in whole bodies of shrews collected from 1988 to 1992 at Kesterson NWR varied from 15.0 to 27.0 mg/kg (Figure 3-15, USBR 1992). These values from Kesterson NWR exceeded the values from the Tranquillity study site by approximately an order of magnitude. However, the samples from Tranquillity were not whole body samples, they were body samples with the liver extracted (except for the shrews captured in 1999, which did not have livers extracted). Liver tissues are known to concentrate selenium and, liver tissues from shrews captured at Tranquillity had higher selenium concentrations than the body tissues (see Figure 3-16). If the liver tissue had remained a part of the samples (as in 1999), the selenium values for whole body tissues would have been somewhat higher. However, liver tissue contributes a relatively small mass to the body and the selenium concentrations in the shrew livers were not exceedingly high (see below). Accordingly, it is unlikely that any increase in selenium concentrations caused by the inclusion of livers would have been substantial. In fact, the samples from 1999, which did not have livers extracted, were not appreciably higher in selenium levels than samples from other years. If bodies had remained intact, it is unlikely that selenium concentrations from shrew bodies collected at Tranquillity would have been as high as the levels observed at Kesterson NWR.

Two shrew bodies collected from the Tranquillity study site exceeded the 90th percentiles (Figure 3-15, Appendix 3-3). One was collected in 2000 and the other in 2001. Although both of these samples exceeded the mean background selenium concentration of small mammal bodies collected from non-seleniferous soils in the western United States, this is to be expected. These samples do not approach the level of selenium concentration observed at Kesterson NWR. Both samples were collected from Block 4 (see Figure 3-13). Because there were few data points available (2 outliers) and because there was an unequal distribution of collection locations, this area should not necessarily be interpreted as a selenium "hot spot" or an area where selenium bioaccumulation is problematic.

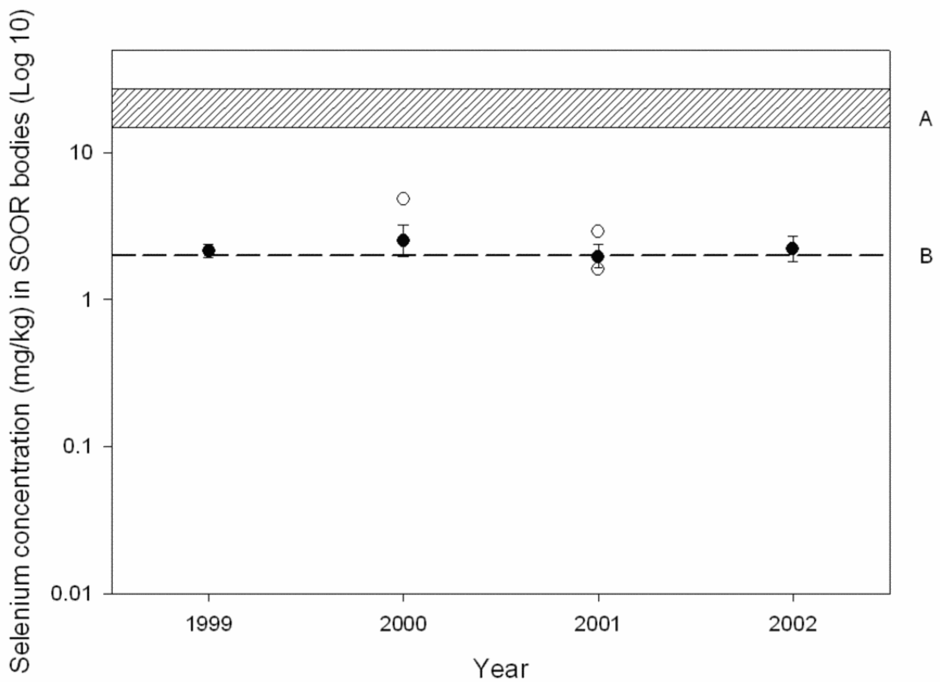

Figure 3-15. Geometric means and standard deviations of selenium concentrations in shrew (SOOR) bodies collected from the Tranquillity study site. The selenium concentration in shrew bodies did not significantly differ among years ($p = 0.15$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in shrew bodies (15.0 to 27.0 mg/kg) collected from 1988 to 1992 at Kesterson NWR. B = background level of selenium in small mammal bodies (2.0 mg/kg) collected from non-seleniferous soils in the western United States (USDI 1998).

Mean selenium concentrations in shrew livers varied from 2.00 to 4.18 mg/kg from 2000 to 2002 at the Tranquillity study site (Figure 3-16, Appendix 3-2). Livers were not extracted from the bodies of shrews in 1999, so no data are available for analysis. There were significant differences in selenium concentrations between years ($p = 0.02$, $F = 4.50$). The selenium concentration in shrew liver tissue in 2002 was lower than in 2000 ($p = 0.01$, $t = -3.03$), however, this may be misleading because of the small sample size ($n = 1$) of livers collected in 2002. There were no performance standards set by FWS for shrew livers for the Land Retirement Demonstration Project (FWS 1999). Likewise, there are no background levels available (USDI 1998) and there are no data for selenium concentrations in shrew livers from Kesterson NWR (USBR 1992). However, selenium levels in livers of small terrestrial mammals collected from near a selenium-normal wetland in the San Joaquin valley ranged from about 1 to 10 mg/kg (Figure 3-16) and typically average about 5 mg/kg (Clark 1987). Small mammals collected from near an agroforestry plantation had selenium concentrations in livers that averaged less than 3 mg/kg (Figure 3-16), except in areas where selenium-rich water was used for irrigation (CDFG 1993). The concentrations of selenium in livers collected from the Tranquillity study site are near the average selenium levels found in small mammal livers from the selenium-normal wetland. Shrew livers from Tranquillity had selenium concentrations near the average selenium concentration observed in small mammal livers collected from near the agroforestry plantation.

Two shrew livers collected from the Tranquillity study site exceeded the 90th percentiles. One was collected in 2000 and the other in 2001. Although both of these samples exceeded the upper level of selenium concentrations in small mammal livers collected from an agroforestry plantation, they are below the upper level of selenium in small mammal livers collected from near a selenium-normal wetland (Figure 3-16). Both samples were collected from Block 4 (see Figure 3-13), but because few data points available (2 outliers) and the unequal distribution of collection locations, this area should not necessarily be interpreted as a selenium "hot spot" or an area where selenium bioaccumulation is problematic.

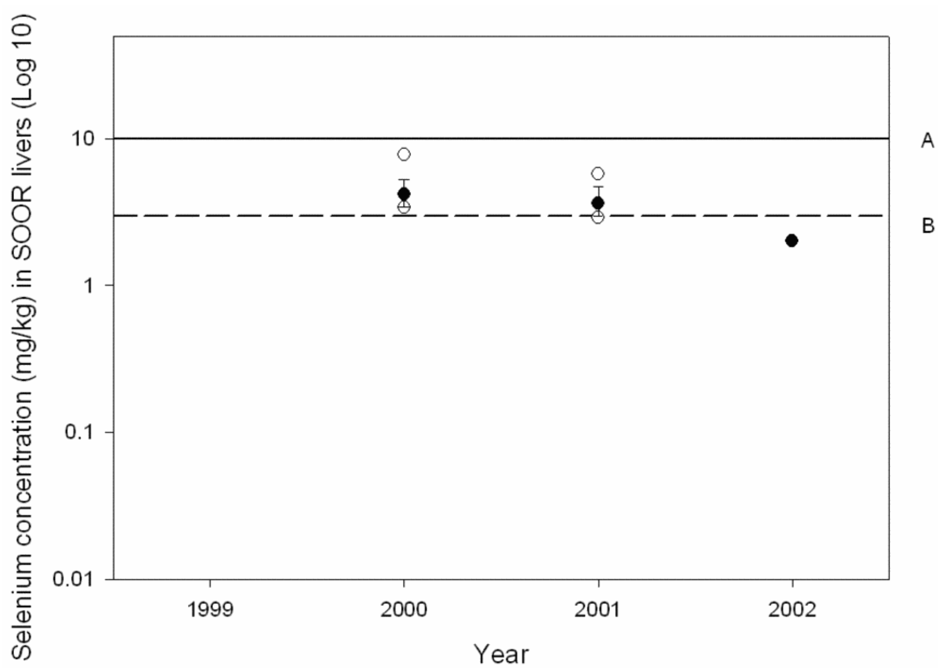

Figure 3-16. Geometric means and standard deviations of selenium concentrations in shrew (SOOR) livers collected from the Tranquillity study site. The selenium concentrations in shrew livers were significantly lower in 2002 than in 2000 ($p = 0.01$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the upper level of selenium in small mammal livers collected from near a selenium-normal wetland (range between 1 and 10 mg/kg). B =the upper level of selenium concentrations in small mammal livers collected from an agroforestry plantation (less than 3 mg/kg).

3.3.2. Atwell Island Site

3.3.2.1. Plants

The Atwell Island plant data were grouped and analyzed in a similar manner to data from the Tranquillity site. All plant data regardless of type or collection location were combined into a single data set. Accordingly, samples of vegetative parts, reproductive parts, selenium accumulators and selenium non-accumulators from cultivated, uncultivated, and experimental areas are all included in this analysis.

Mean selenium concentrations in vegetation on the Atwell Island project site remained between 0.199 and 0.213 mg/kg (Figure 3-17, Appendix 3-2) during the 3 years that samples were collected. Variances among years were not significant ($p = 0.49$; $F = 0.70$). The mean selenium concentrations in plants collected from the Atwell Island project site are slightly below the mean selenium concentrations of plants collected from the Tranquillity project site (Figure 3-17). However, some of the data points that exceed the 90th percentile (outliers) do exceed the mean selenium concentration of selenium in plants from the Tranquillity site (Figure 3-17). The mean concentrations of selenium in vegetation at the Atwell Island site are below the performance standard of 2.0 mg/kg established for project lands in the Biological Opinion (see Figure 3-4, FWS 1999). Background selenium concentrations in vegetation occurring on non-seleniferous soils in the western United States is below 0.6 mg/kg, and is most typically about 0.25 mg/kg (USDI 1998). Selenium concentrations in vegetation at the Atwell Island site are slightly below the typical background level. Plants collected from Atwell Island are substantially lower in selenium than plants collected from Kesterson NWR (see Figure 3-4).

There were 10 plant samples collected that exceed the 90th percentiles; 4 were collected in 2000, 2 in 2001 and 4 in 2002 (Figure 3-17, Appendix 3-3). The range of selenium concentration in these samples varied from 0.30 to 1.4 mg/kg, which is below the population-level performance standard of 2.0 mg/kg established for the project (FWS 1999). These values are also below the typical background selenium levels found in plants from non-seleniferous soils in the western United States (USDI 1998). Six of the outliers exceeded the range of mean selenium concentrations in plants collected from the Tranquillity project site between 1999 and 2002 (Figure 3-17). A variety of plant species were represented among these samples including *Brassica nigra*, *Distichlis spicata*, *Atriplex argentea*, *Hordeum murinum*, *Hordeum vulgare*, *Lactuca serriola*, *Sisymrium irio*, and *Bromus madritensis rubens*. Eight of the samples were collected from uncultivated lands and two were collected from cultivated lands, indicating that irrigation may not be providing a pathway for selenium accumulation at Atwell Island. To adequately determine this relationship however, an analysis of data grouped by landform would be required. Most of the outliers were collected from two areas: the extreme western portion of the project site and south of Study Area 2 (Figure 3-18). The western portion of the project site has been in the Conservation Reserve Program (hence, uncultivated) for approximately 2 decades. Much of it can be described as grazed old-field, but there is a fair amount of previously disturbed, partially natural plant community in the northern part of this area (see Uptain et al. 1998). The parcel south of Study Area 2 is a fallowed agricultural field that was dryland farmed with oats prior to being fallowed. Although the outliers were grouped in these two areas, they should not necessarily be interpreted as selenium "hot spots" or areas where selenium bioaccumulation is problematic; few data points are available (10 outliers collected over an area of about 4,000 acres over 3 years) and there was an unequal distribution of collection locations.

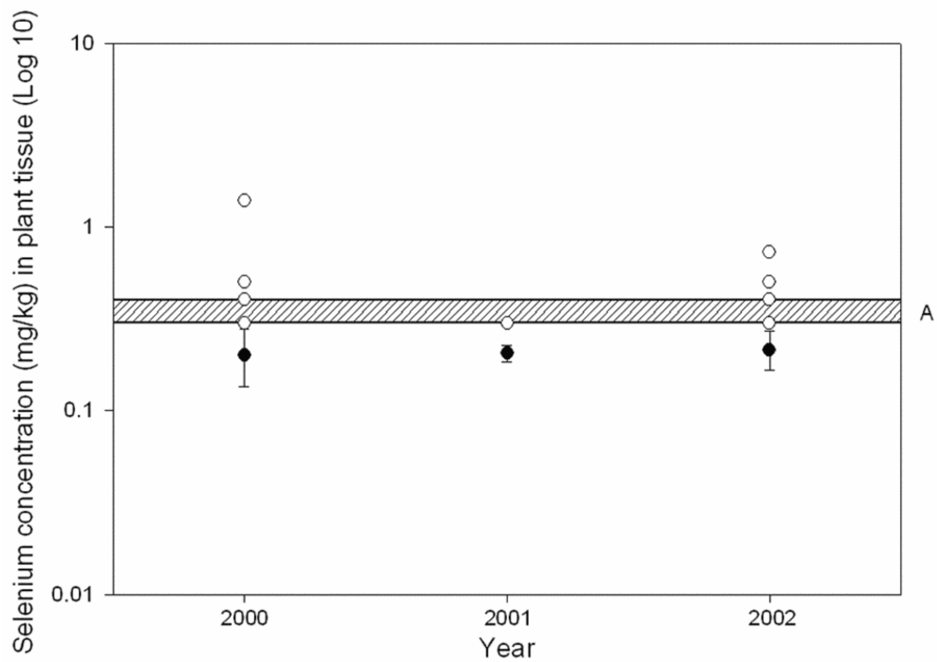

Figure 3-17. Geometric means and standard deviations of selenium concentration in plant tissue collected from the Atwell Island project site. Variances between years are not significantly different (p = 0.49). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in vegetation (0.307 to 0.405 mg/kg) collected from 1999 to 2002 at the Tranquillity study site.

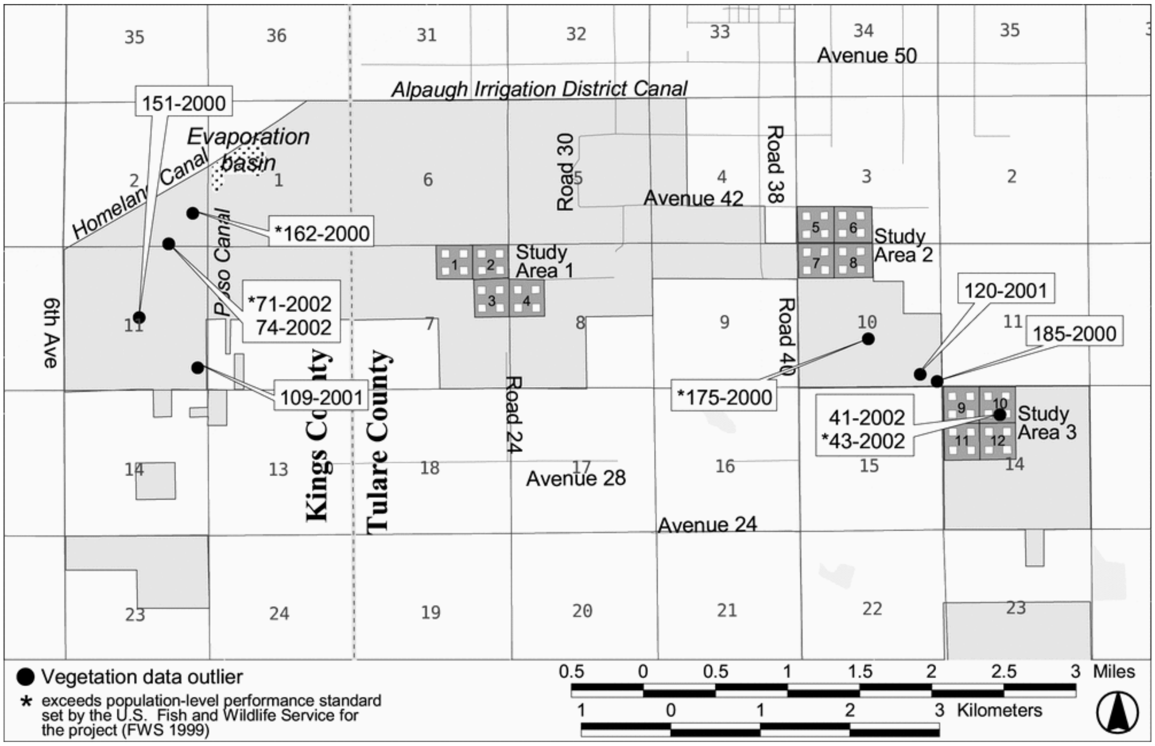

Figure 3-18. Distribution of vegetation data outliers at the Atwell Island project site, 2000 to 2002. The data points marked with an asterisk are those that exceed the population-level performance standard set by the U.S. Fish and Wildlife Service for the project (FWS 1999). Data point identification numbers correspond to record numbers shown in Appendix 3-3.

3.3.2.2. Invertebrates

To characterize the selenium concentration in invertebrates on a generalized basis, all invertebrate data regardless of invertebrate type (crickets, beetles, spiders, and isopods) were combined into a single data set and analyzed. Invertebrate types also were analyzed separately. All invertebrates were collected from pitfall traps on experimental areas, except in 2000 when some additional samples were collected from native lands on the western portion of the project site. No standing water was present on the site except in established canals; hence, no aquatic invertebrates were collected or analyzed. Accordingly, these results are for terrestrial invertebrates only.

3.3.2.2.1. All invertebrates

Mean selenium concentrations in terrestrial invertebrates varied from 0.167 to 0.715 mg/kg from 2000 to 2002 at the Atwell Island study site (Figure 3-19, Appendix 3-2). There were significant differences in variances among years ($p < 0.01$, F = 19.4). The mean selenium concentration in invertebrates collected in 2000 was significantly greater than in 2001 and 2002 ($p < 0.01$, t = 4.67 and $p < 0.01$, $t = 5.44$, respectively). Invertebrates did not differ in selenium levels between 2001 and 2002. The mean concentrations of selenium in terrestrial invertebrates collected from the Atwell Island study site in 2000 to 2002 were below the means observed at the Tranquillity study site from 1999 to 2002 (Figure 3-19). Selenium in terrestrial invertebrates collected from the

Atwell Island site were below the performance standard of 2.0 mg/kg established for project lands in the Biological Opinion (see Figure 3-6; FWS 1999). Likewise, mean selenium concentrations were below the background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998).

There were seven invertebrate samples collected that exceeded the 90th percentiles (outliers); three were collected in 2000, three in 2001, and one in 2002 (Figure 3-19, Appendix 3-3). All of the samples that exceeded the 90th percentile in 2000 were collected from native lands in the western portion of the project site (Figure 3-20). These samples consisted of one isopod and two spiders (Appendix 3-3) having selenium concentrations of 3.0, 2.4, and 5.0 mg/kg, respectively. The three samples that exceeded the 90th percentile in 2001 consisted of a beetle, a spider, and a cricket. These samples had selenium concentrations of 0.8, 1.0, and 0.9 mg/kg, respectively, and were collected from study areas 1 and 2. The one sample that exceeded the 90th percentile in 2002 was a spider with a selenium concentration of 0.41 mg/kg collected from Study Area 2. All of the data outliers collected from 2001 and 2002 have relatively low selenium concentrations. The values are below the performance standard set by the FWS for this project and they are below the mean selenium concentrations found in invertebrates collected from non-seleniferous soils in the western United States (USDI 1998). The values also are below or within the range of mean selenium levels found in invertebrates at the Tranquillity project site. Accordingly, the data outliers from 2001 and 2002 should not be considered problematic and the areas where they were collected from should not be considered selenium "hot spots". The data outliers collected in 2000 also are not exceedingly high, but warrant concern. The spiders (at 2.4 and 5.0 mg/kg) and the isopod (at 3.0 mg/kg) exceed the population-level performance standard of 2.0 mg/kg set by the FWS for the project (FWS 1998). Two of the samples (one spider and the isopod) also exceed the mean background level of selenium in invertebrates collected from non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998). The spider exceeds the range of mean selenium concentrations from spiders collected from the Tranquillity project site, but the isopod is within the range of mean selenium concentrations in isopods collected from the Tranquillity project site (see Figure 3-10, Figure 3-11).

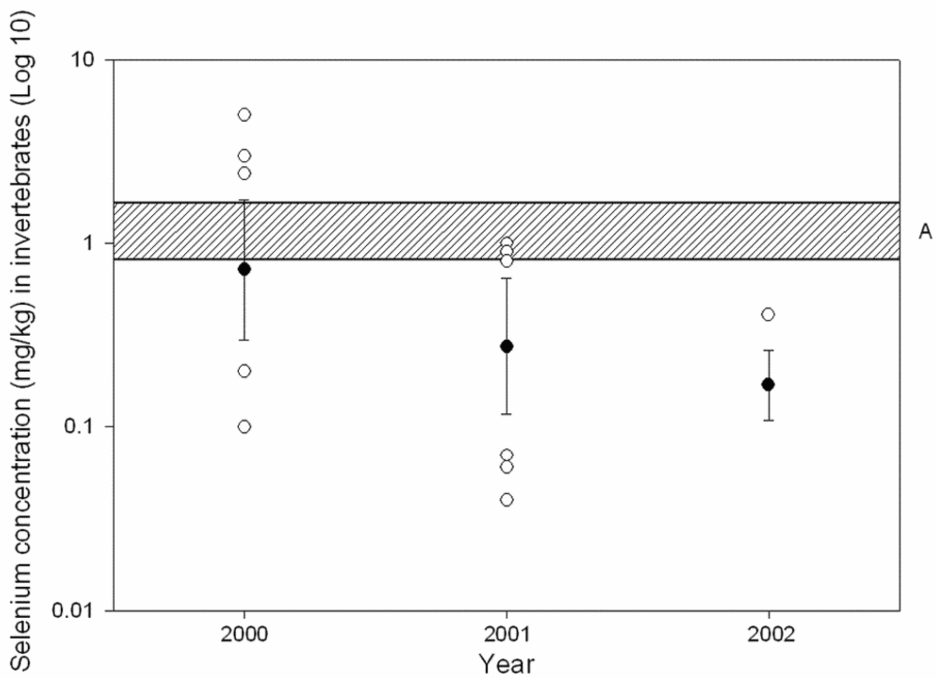

Figure 3-19. Geometric means and standard deviations of selenium concentration in invertebrates collected from the Atwell Island study site. The mean selenium concentration in invertebrates is greater in 2000 than in 2001 and 2002 ($p < 0.01$ and $p < 0.01$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in invertebrates (0.81 to 1.65 mg/kg) collected from 1999 to 2002 at the Tranquillity study site.

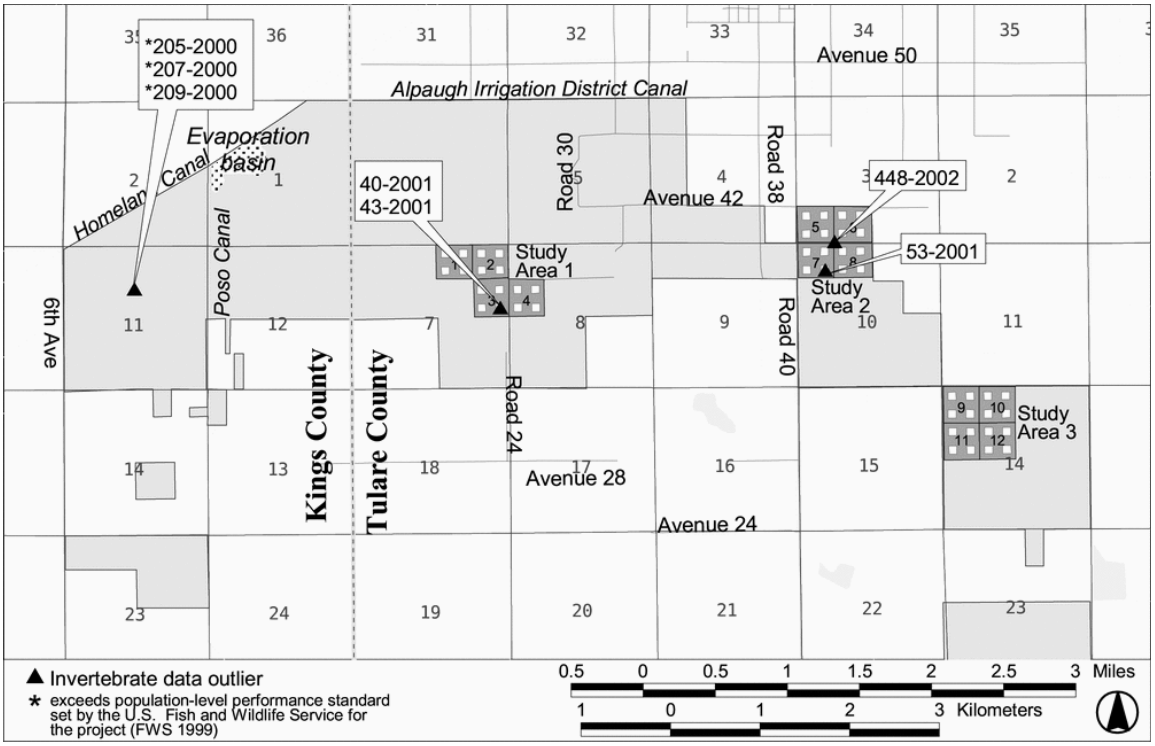

Figure 3-20. Distribution of invertebrate data outliers at the Atwell Island project site, 2000 to 2002. The data points marked with an asterisk are those that exceed the population-level performance standard of 2.0 mg/kg set by the FWS for the project (FWS 1998). Data point identification numbers correspond to record numbers shown in Appendix 3-3. Data points at the center of a research block contain samples from multiple plots.

3.3.2.2.2. Crickets

The mean selenium concentrations in crickets collected from the Atwell Island study site from 2000 to 2002 varied from 0.13 to 0.49 mg/kg (Figure 3-21, Appendix 3-2). Although there appears to be a decrease over time in selenium concentrations in crickets, there were no significant differences among years ($p = 0.11$, F = 2.66). The mean concentration of selenium in crickets collected from the Atwell Island study site in 2000 to 2002 were below the means observed at the Tranquillity study site from 1999 to 2002 (Figure 3-21). Selenium concentrations in terrestrial invertebrates collected from the Atwell Island site were below the performance standard of 2.0 mg/kg established for project lands in the Biological Opinion (see Figure 3-6, FWS 1999). Likewise, mean selenium concentrations were below the mean background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998).

In 2001 there was one cricket sample that exceeded the 90th percentile (Figure 3-21, Appendix 3-3). This was a cricket sample with a selenium concentration of 0.90 mg/kg and was collected from Study Area 2 (Figure 3-20). The selenium concentration of this is greater than the mean selenium concentrations in crickets collected from the Tranquillity study site (Figure 3-21), but it is below the population-level performance standard set for the project by the FWS (FWS 1999). The selenium concentration of this sample also is below the mean selenium concentrations in invertebrates collected from non-seleniferous soils in the western United States (USDI 1998).

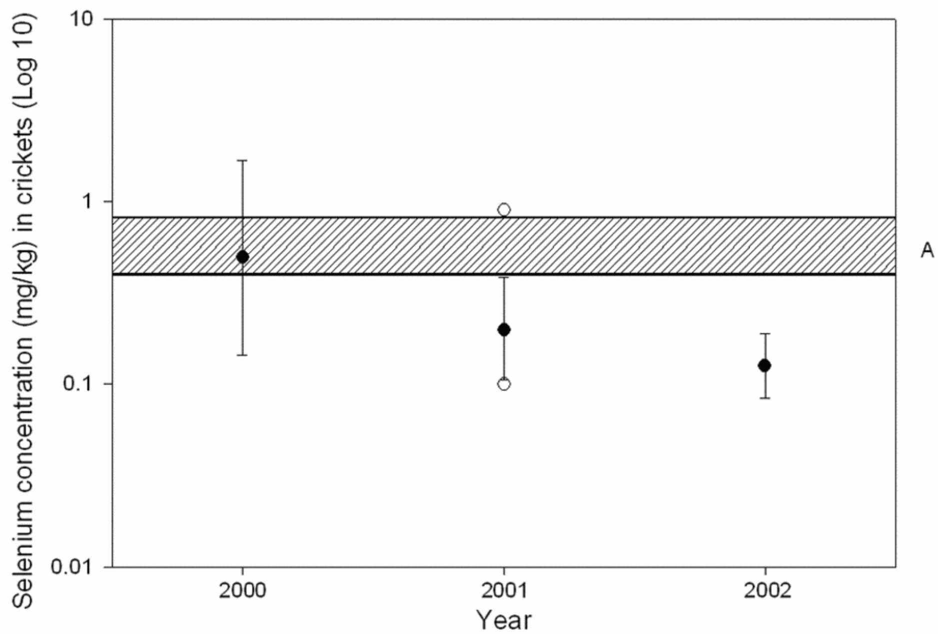

Figure 3-21. Geometric means and standard deviations of selenium concentration in crickets collected from the Atwell Island study site. No significant differences occur among years (p = 0.11). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in invertebrates (0.81 to 1.65 mg/kg) collected from 1999 to 2002 at the Tranquillity study site.

3.3.2.2.3. Beetles

The mean selenium concentrations in beetles collected from the Atwell Island study site from 2000 to 2002 varied from 0.14 to 0.85 mg/kg (Figure 3-22, Appendix 3-2). There were significant differences in among years ($p < 0.01$, F = 9.57). The mean selenium concentration in beetles was greater in 2000 than in 2001 or 2002 ($p < 0.01$, $t = 3.97$ and $p = 0.02$, $t = 2.67$, respectively). The mean concentrations of selenium in beetles collected from the Atwell Island study site were below the means observed at the Tranquillity study site except in 2000 (Figure 3-22). Selenium in beetles collected from the Atwell Island site were below the population-level performance standard of 2.0 mg/kg established for project lands in the Biological Opinion (see Figure 3-9, FWS 1999). Likewise, mean selenium concentrations were below the mean background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998).

In 2001 there was one beetle sample that exceeded the 90th percentile (Figure 3-22, Appendix 3-3). This was a beetle sample with a selenium concentration of 0.80 mg/kg and was collected from Study Area 1 (Figure 3-20). The selenium concentration of this sample is within the range of the mean selenium concentrations of beetles collected from the Tranquillity study site (Figure 3-22) between 1999 and 2002, but it is below the mean concentration of selenium in beetles collected from Tranquillity in 2001 (1.35 mg/kg).

This sample is below the population-level performance standard set for the project by the FWS (FWS 1999) and it is below the mean selenium concentrations in invertebrates collected from non-seleniferous soils in the western United States (USDI 1998).

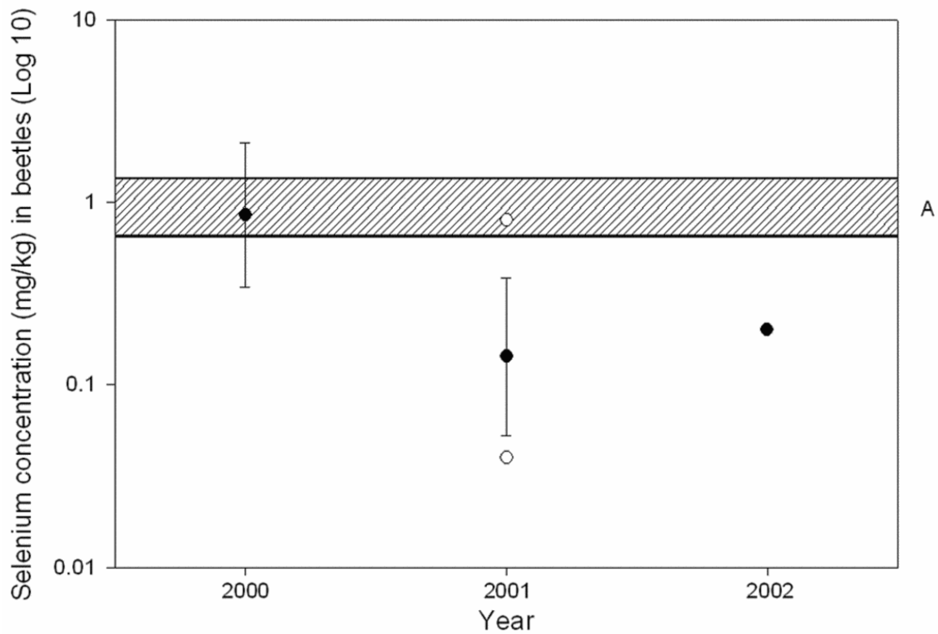

Figure 3-22. Geometric means and standard deviations of selenium concentration in beetles collected from the Atwell Island study site. The selenium concentration in beetles collected in 2000 was significantly higher than in 2001 and 2002 ($p < 0.01$ and $p = 0.02$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in beetles (0.81 to 1.65 mg/kg) collected from 1999 to 2002 at the Tranquillity study site.

3.3.2.2.4. Spiders

The mean selenium concentrations in spiders collected from the Atwell Island study site from 2000 to 2002 varied from 0.25 to 1.04 mg/kg (Figure 3-23, Appendix 3-2). There were significant differences in variances among years ($p < 0.01$, $F = 7.44$). The mean selenium concentrations in spiders significantly decreased each year (2000 to 2001 $p = 0.03$ and $t = 2.30$, 2001 to 2002 $p = 0.01$ and $t = 2.88$). The mean concentrations of selenium in spiders collected from the Atwell Island study site were below the means observed at the Tranquillity study site (Figure 3-23). Selenium in spiders collected from the Atwell Island study site were below the performance standard of 2.0 mg/kg established for project lands in the Biological Opinion (see Figure 3-10, FWS 1999). Likewise, mean selenium concentrations were below the mean background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998).

There were two spider samples that exceeded the 90^{th} percentile, one in 2000 (with 5.0 mg/kg selenium) and one in 2001 (with 0.41 mg/kg selenium). The sample collected in 2000 was collected from the western portion of the project site (see Figure 3-20, Appendix 3-3). The selenium concentration in this sample exceeded the mean selenium concentration of spiders collected from Tranquillity and it exceeded the population-level performance standards for invertebrates established for this project (FWS 1999). This sample also exceeded the mean selenium concentrations in invertebrates collected from non-seleniferous soils in the western United States (USDI 1998). The sample collected in 2001 was collected from Study Area 2 (see Figure 3-20). The selenium concentration in this spider sample is below the range of the mean selenium concentrations of spiders collected from the Tranquillity study site (Figure 3-23) between 1999 and 2002, and is below the population-level performance standard set for the project by the FWS (FWS 1999). The selenium concentration of this sample also is below the mean selenium concentrations in invertebrates collected from non-seleniferous soils in the western United States (USDI 1998).

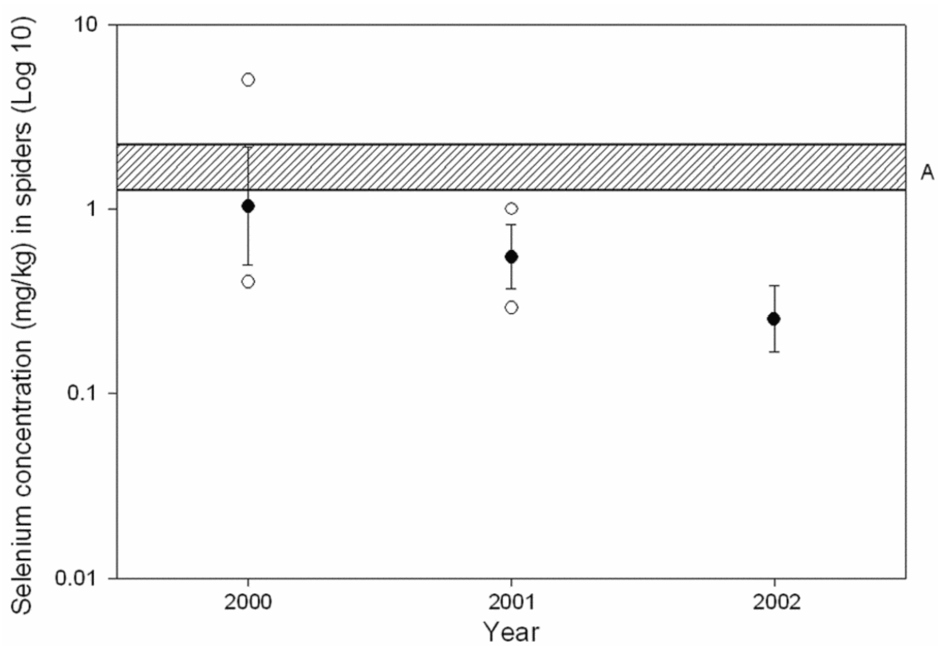

Figure 3-23. Geometric means and standard deviations of selenium concentration in spiders collected from the Atwell Island study site. There was a significant decrease in selenium concentrations in spiders each year from 2000 to 2002 (2000 to 2001 p =0.03 and 2001 to 2002 p = 0.01). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in spiders (1.27 to 2.24 mg/kg) collected from 1999 to 2002 at the Tranquillity study site.

3.3.2.2.5. Isopods

The mean selenium concentrations in isopods collected from the Atwell Island study site from 2000 to 2002 varied from 0.13 to 0.48 mg/kg (Figure 3-24, Appendix 3-2). There were significant differences in variances among years ($p < 0.01$, F = 4.10). The mean selenium concentrations in isopods collected in 2002 were significantly lower than those collected in 2000 and 2001 ($p = 0.01$, $t = -2.67$ and $p = 0.04$, t = -2.26, respectively). The mean concentrations of selenium in isopods collected from the Atwell Island study site were below the means observed at the Tranquillity study site (Figure 3-24). Selenium in isopods collected from the Atwell Island study site were below the performance standard of 2.0 mg/kg established for project lands in the Biological Opinion (see Figure 3-11, FWS 1999). Likewise, mean selenium concentrations were below the mean background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998).

There was one isopod sample collected from the Atwell Island project site in 2000 that exceeded the 90th percentile. This sample was collected from the western portion of the project site (see Figure 3-20) and had a selenium concentration of 3.0 mg/kg (Figure 3-24, Appendix 3-3). The selenium concentration in this sample was within the range of mean selenium in isopods collected from the Tranquillity project site from 1999 to 2002, but is above the population-level performance standard set by the FWS (FWS 1999). Likewise, this sample exceeds the mean background selenium concentrations in terrestrial invertebrates occurring on non-seleniferous soils in the western United States (2.5 mg/kg, USDI 1998).

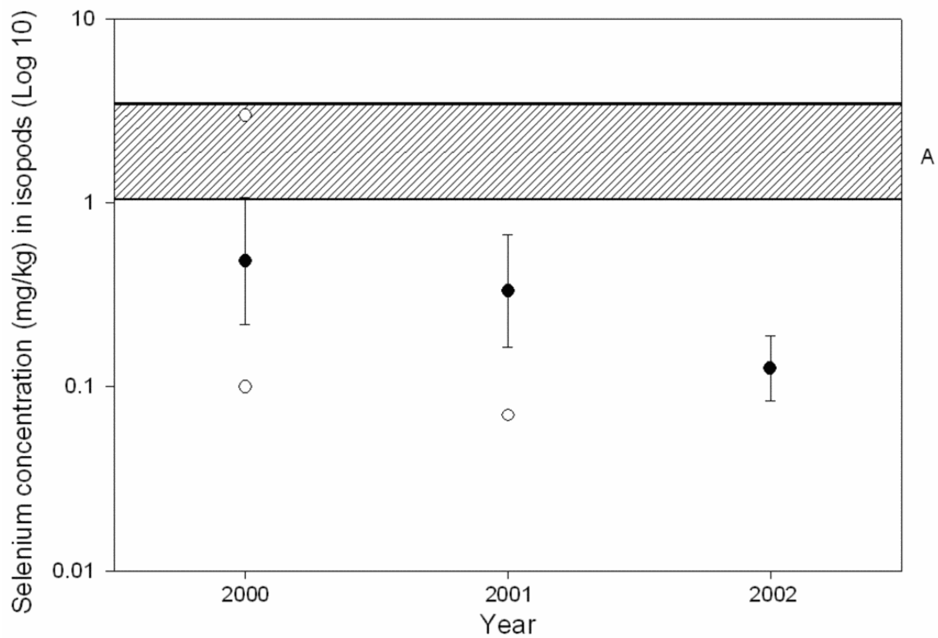

Figure 3-24. Geometric means and standard deviations of selenium concentration in isopods collected from the Atwell Island study site. There was a significant decrease in selenium concentrations in spiders each year from 2000 to 2002 (2000 to 2001 p = 0.03 and 2001 to 2002 p = 0.01). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in isopods (1.04 to 3.46 mg/kg) collected from 1999 to 2002 at the Tranquillity study site.

3.3.2.3. Small mammals

Selenium concentrations in small mammals collected at the Atwell Island project site are separated into 2 data groups; body tissues of deer mice and liver tissues of deer mice. Although samples of deer mice were collected from a variety of landforms (cultivated, uncultivated, and experimental), all data were combined into a single data set. Five shrews also were captured in pitfall traps at Atwell Island in 2002, but these were not sacrificed for selenium analysis because it is likely that they were Buena Vista Lake shrews a federally listed endangered species. Three of the five shrews were found dead in the pitfalls and were salvaged for genetic analysis and use as museum specimens.

Mean selenium concentrations in deer mouse bodies collected from the Atwell Island project site in 2000 and 2002 were 0.62 and 0.68 mg/kg (Figure 3-25, Appendix 3-2). There were no differences in selenium concentrations between years ($p = 0.38$, F = 0.80). The mean selenium concentrations in deer mouse bodies collected from the Atwell Island project site are below the selenium concentrations found to occur in deer mouse bodies collected from the Tranquillity project site from 1999 to 2002 (Figure 3-25). Likewise, the mean selenium concentrations are all below the mean background selenium levels in small mammal body tissues (generally less than 2.0 mg/kg, USDI 1998). No performance standards were set by the FWS for small mammal body tissues. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from deer mouse bodies slightly exceeded the values established for blood, but were much lower than the values established for hair.

Two deer mouse body samples exceeded the 90^{th} percentiles (Figure 3-25, Appendix 3-3). One was collected in 2000 and the other in 2002. Both samples were from the western portion of the project site (Figure 3-26). Although these outliers signify high selenium levels relative to the other samples obtained from the site, the selenium levels of these samples are low in comparison to other regional values. For example, the selenium concentrations in these samples (0.82 and 0.89 mg/kg) are well below typical background concentrations for small mammal tissues sampled from selenium-normal soils in the western United States (generally less than 2.0 mg/kg; USDI 1998). Furthermore, the selenium levels in these samples only slightly exceed the project performance values established for blood, but are much lower than the values established for hair (FWS 1999).

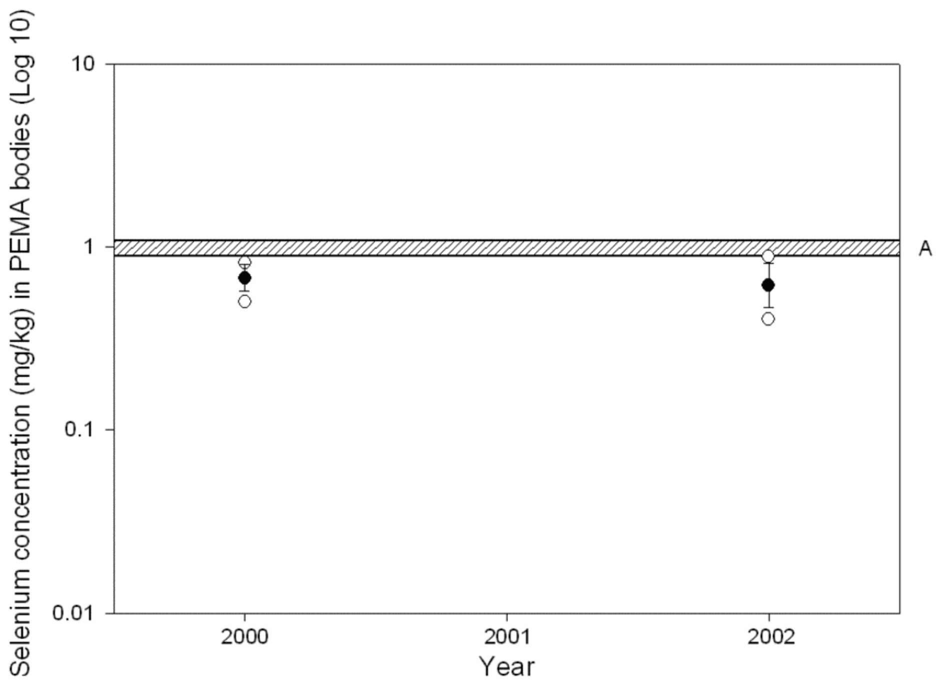

Figure 3-25. Geometric means and standard deviations of selenium concentration in deer mouse (PEMA) bodies collected from the Atwell Island project site. There was no significant difference in selenium concentrations between 2000 and 2002 (p = 0.38). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in deer mouse bodies (0.89 to 1.09 mg/kg) collected from 1999 to 2002 at the Tranquillity project site.

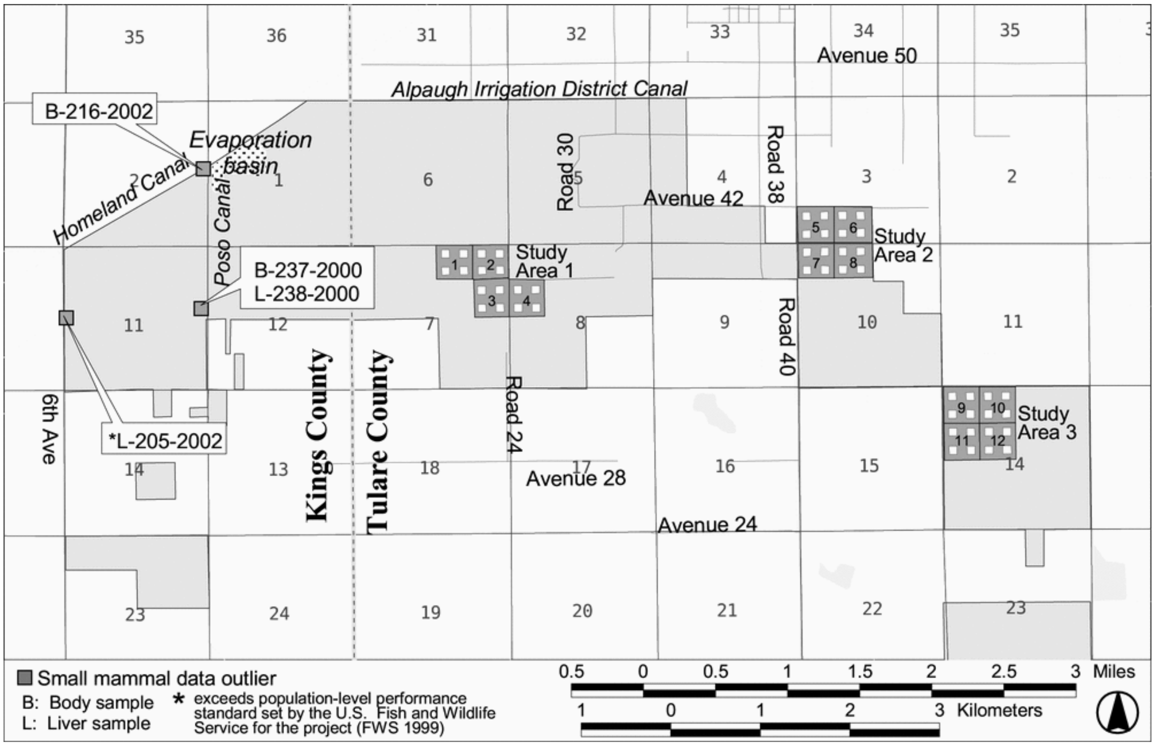

Figure 3-26. Distribution of small mammal data outliers at the Atwell Island project site, 2000 to 2002. The data points marked with (B) are body samples and those marked with (L) are liver samples. Data points marked with an asterisk exceed the range of means from the Tranquillity study site. Data point identification numbers correspond to record numbers shown in Appendix 3-3.

Mean selenium concentrations in deer mouse livers collected from the Atwell Island project site in 2000 and 2002 were 2.37 and 2.21 mg/kg (Figure 3-27, Appendix 3-2). There were no differences in selenium concentration between years ($p = 0.43$, F = 0.65). The mean selenium concentrations in deer mouse livers collected from the Atwell Island project site in 2000 are slightly above the lowest mean selenium concentration in livers from Tranquillity, but in 2002 selenium levels were lower than those at Tranquillity (Figure 3-27). Likewise, the mean selenium concentration, standard errors, and Outliers were all within the background selenium levels in small mammal liver tissues (generally less than 10.0 mg/kg, but typically less than 3 mg/kg, USDI 1998). No performance standards were set by the FWS for small mammal body tissues. Instead, performance standards were set for small mammal blood (0.5 mg/kg) and hair (5.0 mg/kg). The selenium values obtained from deer mouse livers exceed the values established for blood, but were lower than the values established for hair.

Two deer mouse liver samples exceeded the 90th percentiles (Figure 3-27, Appendix 3-3). These samples were both from the western portion of the project site (Figure 3-26). One of the samples exceeds the range of deer mouse livers collected from Tranquillity, and its value (4.90 mg/kg) is within the typical range of selenium levels in livers of small mammals collected from a selenium-normal wetland in the San Joaquin Valley (range from about 1 to 10 mg/kg and typically average about 5 mg/kg; Clark 1987). By contrast, small mammals collected from near an agroforestry plantation had selenium concentrations in livers that averaged less than 3 mg/kg, except in areas where selenium-rich water was used for irrigation (CDFG 1993).

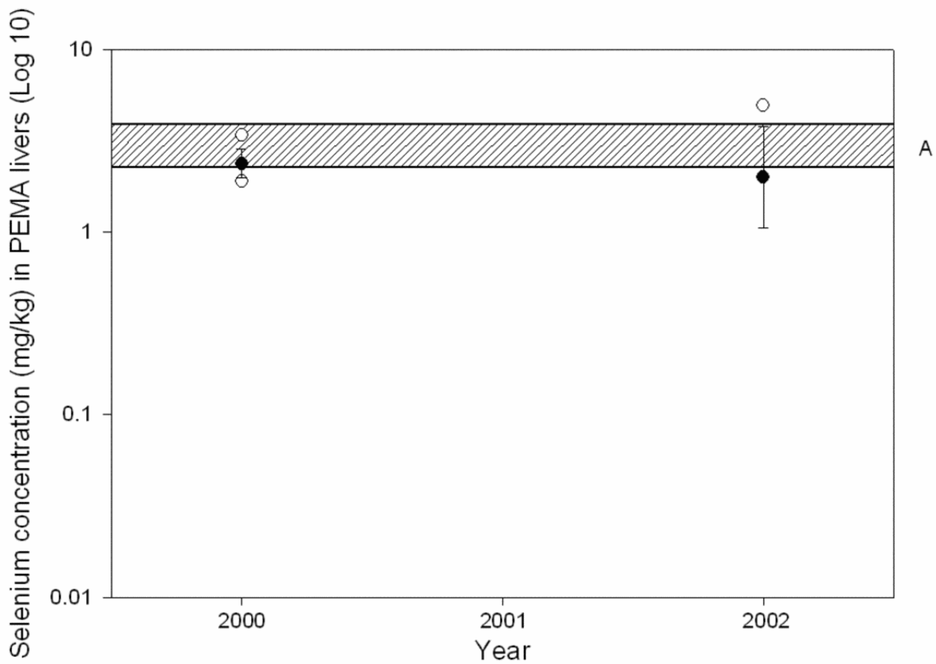

Figure 3-27. Geometric means and standard deviations of selenium concentration in deer mouse (PEMA) livers collected from the Atwell Island project site. There was no significant difference in selenium concentrations between 2000 and 2002 ($p = 0.43$). Outliers are represented by open circles lying outside of the standard deviation bars. A = the range of geometric means of selenium concentrations in deer mouse livers (2.27 to 3.89 mg/kg) collected from 1999 to 2002 at the Tranquillity project site.

3.4. DISCUSSION AND CONCLUSIONS

High selenium levels in the soil and groundwater at the Tranquillity project site result in an elevated risk to biota from exposure to selenium. There is a less risk of exposure of wildlife to selenium at the Atwell Island site because of lower levels of selenium in the soils. The magnitude of the risk at thew Tranquillity site is partially ameliorated by the decreasing groundwater levels resulting from cessation of irrigation on retired lands. Although there remains a potential for excessive bioaccumulation of selenium, there generally appears to be relatively low concentrations of selenium in plants and wildlife, especially at the Atwell Island project site. Selenium levels in biota on both project sites tends to be within the range typically found in biota occurring on non-seleniferous soils in the western United States and are generally below the population-level performance standards set for the project by the U.S. Fish and Wildlife Service (FWS 1999). Furthermore, selenium levels in biota from both project sites are generally an order of magnitude less than found at Kesterson National Wildlife refuge. Even though the levels of selenium in biota at the project sites are within acceptable limits, there have been a number of samples collected with high selenium levels. This indicates that there might be an elevated risk to plants and wildlife from exposure to selenium warranting continued monitoring.

A possible explanation for the generally low levels of selenium in biota may be that there has been very little water available during the study period. Precipitation has been below normal or near-normal, there are no wetlands present (although a wetland is being enhanced at the Atwell Island site), there have been no ephemeral pools (pools of water lasting 30 days or more) present, and we suspect that soil moisture has been too low to allow a high degree of selenium uptake. That this is a dry, upland environment rather than an aquatic or wetland environment also may reduce the potential for the bioavailability and bioaccumulation of selenium. We will be testing this hypothesis next year by installing artificial ephemeral pools that will be kept full of irrigation water for 30 days or more prior to sampling. Similarly, we will be collecting samples from our native plant nursery, which will be regularly irrigated (by both sprinkler and flood irrigation methods). Samples collected from the nursery should provide an indication of bioaccumulation of selenium in above-average rainfall conditions.

Based upon the low standard deviations observed in the data and the few data outliers obtained, we believe that the monitoring program is sufficient to determine the level of selenium in biota on the project sites. Accordingly, we are not recommending any changes to the selenium monitoring program, other than the tests making abundant water available in pools and in the nursery. However, further in-depth analysis of the data will be conducted for the final 5-year study report. Some additional analyses that will be completed will include an analysis of selenium accumulation based upon landform type (cultivated, uncultivated, experimental), a spatial analysis of selenium in biota in conjunction with selenium levels in soils, a spatial analysis of data outliers, and a species by species analysis of selenium levels in some prevalent plants species.

3.5. LITERATURE CITED

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APPENDIX 3-1. TIERED MONITORING PROGRAM GUIDELINES

Table 3-2. Tiered classification of contaminant monitoring needs for the CVPIA Land Retirement Program.

If		Then			
shallow groundwater is	**and selenium concentration is**	**considered for NWR**	**groundwater monitoring**	**biota monitoring**	**Tiered Classification**
0 - 7 ft	>50 ppb	N	Y	Y	IV
	2-50 ppb	P	Y	Y	III
	<2 ppb	Y	Y	Y	II
7 - 15 ft	>50 ppb	P	Y	Y	III
	2-50 ppb	P	Y	N	II
	<2 ppb	Y	N	N	I
>15 ft	>50 ppb	P	Y	Y	II
	2-50 ppb	Y	Y	N	II
	<2 ppb	Y	N	N	I
Y - Yes N - No P - Possible After Appropriate Monitoring					

Class I - No monitoring is required but baseline groundwater depth and selenium concentrations are appropriate. May be appropriate to use as a reference site for detailed monitoring.

Class II - Monitoring of groundwater depth and selenium is required on a periodic basis with baseline data collection on a few biotic components. May be appropriate to use as a reference site for detailed monitoring.

Class III - Annual monitoring is required of groundwater depth and selenium along with periodic and baseline data collection on biotic components. Results may trigger Class IV monitoring or additional periodic biota sampling.

Class IV - Detailed monitoring of biotic and abiotic components is required on an annual and/or seasonal basis for 5 years or until a representative hydrologic profile (wet year/dry year) is adequately monitored.

* Applies to Grasslands, Westlands, Tulare, and Kern sub areas as defined by the San Joaquin Valley Drainage Implementation Program (SJVDIP). Assumes no tile drains on site. If tile drains are present then ground water at 7-15 ft and <2 ppb becomes Class II.

Table 3-3. Minimum requirements for the CVPIA Land Retirement Contaminant Monitoring Program.

Type of Monitoring	Class I	Class II	Class III	Class IV	Comments
Surface Water		B	P	A	If present, include mercury
Groundwater					
Depth	B	P	A	S	
Selenium	B	P	A	A	
Other	B		B	A	
Plants					
Roots					
Vegetative		B	P	A	
Reproductive		B	P	A	
Invertebrates					
Terrestrial		B	P	A	5 composite samples
Aquatic		B	P	A	If present, 5 composite samples
Mammals					
Blood			B	P	III – small mammals IV - predators
Hair/Fur			B	A	
Tissue			B		Depends upon blood or fur results
Birds					
Blood			B		If surface water present
Feathers			B		If surface water present
Eggs			B		If surface water present
Reptiles					
Blood				P	
Feces					
Tissue			B	A	Whole body or reproductive organs

Actual sampling needs for a given site depends upon resources at risk and those available for sampling. Surface water sampled only if pooled for more than 30 days.

B - Baseline, A – Annual, P - Periodic, S - Seasonal.

Table 3-4. Site-specific worksheet for the CVPIA Land Retirement Contaminant Monitoring Program.

Site Name:____Date:_____________

Type of Monitoring	Winter	Spring	Summer	Fall	Comments
Surface Water	A				If present
Groundwater					
Depth	A			A	
Selenium	A				
Other	A				
Plants					
Roots					
Vegetative		A			
Reproductive		A			
Invertebrates					
Terrestrial		A			5 composite samples
Aquatic	A				If present, 5 composite samples
Mammals					
Blood			P		III – small mammals IV - predators
Hair/Fur			A		
Tissue					Depends upon blood or fur results
Birds					
Blood					If surface water present
Feathers					If surface water present
Eggs		A			If surface water present
Reptiles					
Blood				P	
Feces					
Tissue				A	Whole body or reproductive organs

Actual sampling needs for a given site depends upon resources at risk and those available for sampling. Surface water sampled only if pooled for more than 30 days.

APPENDIX 3-2. SUMMARY STATISTICS OF SELENIUM CONCENTRATIONS.

Table 3-5. Summary statistics of selenium concentrations. Boita = taxonomic class of the data group, Year = year in which samples were collected, N = sample size, CI – 95% = lower 95% confidence level, CI + 95% = upper 95% confidence level, GM = geometric mean, Min. = minimum sample value, Max. = maximum sample value, SD = standard deviation of the mean, Geo SD = standard deviation of the geometric mean, 10th perc. = 10th percentile of the data group, 90th perc. = 90th percentile of the data group, F = F statistic of the respective biota data group, P = *p* statistic of the respective biota data group.

Biota	Year	N	CI -95%	CI +95%	GM	Min.	Max.	SD	Geo SD	10th perc.	90th perc.	F	P
Tranquillity project site													
All plants	1999	33	0.282	0.487	0.317	0.200	1.400	0.289	0.255	0.200	0.810	1.58	0.195
	2000	88	0.357	0.609	0.353	0.200	3.900	0.594	0.295	0.200	0.880		
	2001	67	0.285	0.455	0.307	0.200	2.600	0.347	0.228	0.200	0.600		
	2002	41	0.375	0.893	0.401	0.200	4.400	0.821	0.375	0.200	1.500		
All invertebrates	1999	14	0.933	2.704	1.271	0.300	5.600	1.533	0.400	0.360	3.600	5.56	0.001
	2000	20	1.346	2.428	1.541	0.400	4.500	1.155	0.297	0.625	3.400		
	2001	20	1.039	3.536	1.646	0.500	13.000	2.667	0.331	0.700	3.050		
	2002	41	0.622	1.695	0.813	0.300	11.000	1.700	0.307	0.400	1.600		
Crickets	1999	4	0.208	0.622	0.401	0.300	0.600	0.130	0.127	0.300	0.600	3.69	0.028
	2000	5	0.406	1.130	0.722	0.400	1.200	0.291	0.174	0.400	1.200		
	2001	5	0.261	1.539	0.812	0.500	1.800	0.515	0.207	0.500	1.800		
	2002	11	0.400	0.702	0.523	0.340	1.200	0.225	0.135	0.440	0.580		
Beetles	1999	2	-0.171	2.371	1.095	1.000	1.200	0.141	0.056	1.000	1.200	3.08	0.054
	2000	5	0.453	2.387	1.265	0.600	2.700	0.779	0.234	0.600	2.700		
	2001	5	0.481	2.599	1.352	0.700	2.800	0.853	0.252	0.700	2.800		
	2002	10	0.484	0.980	0.660	0.300	1.400	0.347	0.212	0.350	1.250		
Spiders	1999	5	1.237	3.603	2.244	1.100	3.600	0.952	0.199	1.100	3.600	1.03	0.400
	2000	5	1.151	2.929	1.908	0.900	2.700	0.716	0.192	0.900	2.700		
	2001	5	0.962	3.258	1.933	0.950	3.200	0.925	0.211	0.950	3.200		
	2002	10	-0.187	4.333	1.272	0.380	11.000	3.160	0.377	0.575	6.400		
Isopods	1999	3	-2.576	8.909	2.532	1.000	5.600	2.312	0.378	1.000	5.600	29.26	0.000
	2000	5	2.283	4.357	3.234	2.200	4.500	0.835	0.113	2.200	4.500		
	2001	5	-1.238	10.438	3.462	2.100	13.000	4.702	0.324	2.100	13.000		
	2002	10	0.600	2.074	1.042	0.450	3.600	1.030	0.321	0.455	3.050		
All deer mouse bodies	1999	10	0.934	1.240	1.068	0.750	1.500	0.213	0.087	0.785	1.350	1.48	0.233
	2000	10	0.854	1.424	1.080	0.730	1.700	0.399	0.148	0.740	1.700		
	2001	11	0.720	1.172	0.889	0.500	1.400	0.337	0.164	0.540	1.300		
	2002	16	1.012	1.211	1.097	0.780	1.600	0.187	0.072	0.920	1.300		
All deer mouse livers	1999	10	3.285	3.915	3.576	2.900	4.400	0.440	0.053	3.000	4.200	7.04	0.001
	2000	10	2.603	4.117	3.200	1.600	5.500	1.059	0.148	1.900	4.700		
	2001	11	1.855	3.115	2.275	0.740	3.800	0.938	0.210	1.300	3.400		
	2002	16	3.568	4.357	3.894	2.400	5.300	0.741	0.086	3.100	5.200		

Biota	Year	N	CI -95%	CI +95%	GM	Min.	Max.	SD	Geo SD	10th perc.	90th perc.	F	P
All shrew bodies	1999	2	0.244	4.056	2.145	2.000	2.300	0.212	0.043	2.000	2.300	1.93	0.155
	2000	13	2.127	3.057	2.513	2.000	4.800	0.770	0.106	2.000	3.500		
	2001	6	1.498	2.468	1.946	1.600	2.900	0.462	0.089	1.600	2.900		
	2002	5	1.654	2.826	2.204	1.900	3.000	0.472	0.086	1.900	3.000		
All shrew livers	2000	13	3.562	5.038	4.178	3.400	7.800	1.221	0.102	3.500	5.700	4.50	0.027
	2001	6	2.614	4.919	3.652	2.900	5.800	1.098	0.114	2.900	5.800		
	2002	1			2.000	2.000	2.000			2.000	2.000		
Atwell Island project site													
All plants	2000	67	0.182	0.260	0.200	0.100	1.400	0.160	0.168	0.100	0.300	0.70	0.498
	2001	31	0.197	0.216	0.205	0.200	0.300	0.025	0.044	0.200	0.200		
	2002	51	0.197	0.247	0.213	0.200	0.730	0.089	0.105	0.200	0.200		
All invertebrates	2000	36	0.699	1.378	0.715	0.100	5.000	1.003	0.382	0.200	2.000	19.41	0.000
	2001	35	0.279	0.462	0.274	0.043	1.000	0.266	0.368	0.080	0.730		
	2002	12	0.130	0.239	0.169	0.100	0.410	0.086	0.189	0.100	0.200		
Crickets	2000	3	-1.680	3.346	0.493	0.200	2.000	1.012	0.534	0.200	2.000	2.61	0.115
	2001	9	0.064	0.447	0.199	0.100	0.900	0.250	0.288	0.100	0.900		
	2002	3	-0.010	0.277	0.126	0.100	0.200	0.058	0.174	0.100	0.200		
Beetles	2000	10	0.596	1.704	0.852	0.200	2.000	0.775	0.396	0.200	2.000	9.57	0.001
	2001	8	0.012	0.443	0.143	0.043	0.800	0.258	0.429	0.043	0.800		
	2002	3			0.200	0.200	0.200	0.000	0.000	0.200	0.200		
Spiders	2000	11	0.485	2.295	1.037	0.400	5.000	1.348	0.321	0.590	2.400	7.44	0.004
	2001	9	0.416	0.762	0.550	0.290	1.000	0.225	0.173	0.290	1.000		
	2002	3	-0.031	0.571	0.254	0.200	0.410	0.121	0.180	0.200	0.410		
Isopods	2000	12	0.190	1.160	0.482	0.100	3.000	0.764	0.346	0.300	1.000	4.10	0.031
	2001	9	0.241	0.549	0.334	0.073	0.600	0.200	0.302	0.073	0.600		
	2002	3	-0.010	0.277	0.126	0.100	0.200	0.058	0.174	0.100	0.200		
All deer mouse bodies	2000	10	0.607	0.761	0.676	0.500	0.820	0.108	0.071	0.545	0.815	0.80	0.384
	2002	7	0.467	0.816	0.617	0.400	0.890	0.188	0.131	0.400	0.890		
All deer mouse livers	2000	10	2.069	2.751	2.371	1.900	3.400	0.477	0.081	1.950	3.150	0.65	0.432
	2002	7	1.129	4.071	2.208	1.000	4.900	1.591	0.269	1.000	4.900		

APPENDIX 3-3. LIST OF DATA OUTLIERS

Table 3-6. List of data outliers. Record numbers correspond to those presented in Figure 3-5, Figure 3-7, Figure 3-13, Figure 3-18, Figure 3-20, and Figure 3-26. Those record numbers marked with an asterisk are special cases. Tranquillity (TRNQ) plant records marked with an asterisk are those that exceed the population-level performance standard established for the project (FWS 1999). Tranquillity invertebrate records that are marked with an asterisk are those that fall within the range of geometric means of selenium levels in invertebrates collected from Kesterson National Wildlife Refuge between 1988 and 1992 (USBR 1992). Atwell Island (ATWL) plant and invertebrate records that are marked with an asterisk are those that exceed the population-level performance standard established for the project (FWS 1999). Atwell Island small mammal records that are marked with an asterisk are those that exceed the range of geometric means of selenium levels found in small mammals at the Tranquillity project site between 1999 and 2002. SE = selenium concentration in mg/kg, Log SE = log (base 10) of selenium concentration in mg/kg.

Record	Year	Site	Taxon code	Biota	Part	Land type	SE	Log SE
70-1999	1999	TRNQ	ATAR	Plant	Veg	Unkn	0.86	-0.07
72-1999	1999	TRNQ	ATAR	Plant	Veg	Unkn	1.40	0.15
73-1999	1999	TRNQ	ATAR	Plant	Fruits	Unkn	1.00	0.00
30-2000	2000	TRNQ	BRNI	Plant	Veg	Cult	1.30	0.11
32-2000	2000	TRNQ	BRNI	Plant	Fruits	Cult	1.10	0.04
23-2000	2000	TRNQ	BRNI	Plant	Veg	Cult	1.60	0.20
16-2000	2000	TRNQ	BRNI	Plant	Veg	Cult	1.70	0.23
21-2000	2000	TRNQ	BRNI	Plant	Fruits	Cult	1.60	0.20
2-2000	2000	TRNQ	SO_SP	Plant	Whole	Exp	1.00	0.00
*48-2000	2000	TRNQ	HECU	Plant	Whole	Uncult	3.90	0.59
*47-2000	2000	TRNQ	HECU	Plant	Whole	Uncult	3.60	0.56
136-2001	2001	TRNQ	HOVU	Plant	Veg	Cult	1.30	0.11
151-2001	2001	TRNQ	ATAR	Plant	Veg	Exp	1.10	0.04
152-2001	2001	TRNQ	ATPO	Plant	Veg	Exp	1.00	0.00
*153-2001	2001	TRNQ	SUMO	Plant	Veg	Exp	2.60	0.41
*2-2002	2002	TRNQ	SUMO	Plant	Veg	Exp	4.40	0.64
*3-2002	2002	TRNQ	SIIR	Plant	Veg	Exp	2.40	0.38
*14-2002	2002	TRNQ	SUMO	Plant	Veg	Exp	2.30	0.36
38-2002	2002	TRNQ	SIIR	Plant	Veg	Uncult	1.70	0.23
127-2000	2000	TRNQ	ISOP	Invert	Body	Exp	4.50	0.65
123-2000	2000	TRNQ	ISOP	Invert	Body	Exp	3.60	0.56
*76-2001	2001	TRNQ	ISOP	Invert	Body	Exp	13.00	1.11
77-2001	2001	TRNQ	SPID	Invert	Body	Exp	3.20	0.51
425-2002	2002	TRNQ	SPID	Invert	Body	Exp	1.80	0.26
432-2002	2002	TRNQ	ISOP	Invert	Body	Exp	2.50	0.40
430-2002	2002	TRNQ	BEET	Invert	Body	Exp	1.40	0.15
427-2002	2002	TRNQ	CRIC	Invert	Body	Exp	1.20	0.08
*435-2002	2002	TRNQ	SPID	Invert	Body	Exp	11.00	1.04

Record	Year	Site	Taxon code	Biota	Part	Land type	SE	Log SE
437-2002	2002	TRNQ	ISOP	Invert	Body	Exp	3.60	0.56
21-1999	1999	TRNQ	PEMA	Mammal	Body	Cult	1.50	0.18
5-2001	2001	TRNQ	PEMA	Mammal	Body	Cult	1.40	0.15
252-2002	2002	TRNQ	PEMA	Mammal	Body	Uncult	1.60	0.20
240-2002	2002	TRNQ	PEMA	Mammal	Body	Cult	1.30	0.11
3-1999	1999	TRNQ	PEMA	Mammal	Liver	Uncult	4.40	0.64
94-2000	2000	TRNQ	PEMA	Mammal	Liver	Cult	5.50	0.74
16-2001	2001	TRNQ	PEMA	Mammal	Liver	Cult	3.80	0.58
237-2002	2002	TRNQ	PEMA	Mammal	Liver	Uncult	5.30	0.72
253-2002	2002	TRNQ	PEMA	Mammal	Liver	Uncult	5.20	0.72
271-2000	2000	TRNQ	SOOR	Mammal	Body	Exp	4.80	0.68
26-2001	2001	TRNQ	SOOR	Mammal	Body	Exp	2.90	0.46
272-2000	2000	TRNQ	SOOR	Mammal	Liver	Exp	7.80	0.89
32-2001	2001	TRNQ	SOOR	Mammal	Liver	Exp	5.80	0.76
185-2000	2000	ATWL	BRNI	Plant	Veg	Uncult	0.40	-0.40
*175-2000	2000	ATWL	BRNI	Plant	Veg	Uncult	0.50	-0.30
*162-2000	2000	ATWL	DISP	Plant	Whole	Uncult	1.40	0.15
151-2000	2000	ATWL	ATAR	Plant	Whole	Uncult	0.40	-0.40
109-2001	2001	ATWL	ATAR	Plant	Veg	Uncult	0.30	-0.52
120-2001	2001	ATWL	HOMU	Plant	Fruits	Uncult	0.30	-0.52
41-2002	2002	ATWL	HOVU	Plant	Veg	Cult	0.30	-0.52
*43-2002	2002	ATWL	LASE	Plant	Veg	Cult	0.50	-0.30
*71-2002	2002	ATWL	SIIR	Plant	Veg	Uncult	0.73	-0.14
74-2002	2002	ATWL	BRMA	Plant	Whole	Uncult	0.40	-0.40
*205-2000	2000	ATWL	ISOP	Invert	Body	Uncult	3.00	0.48
*207-2000	2000	ATWL	SPID	Invert	Body	Uncult	5.00	0.70
*209-2000	2000	ATWL	SPID	Invert	Body	Uncult	2.40	0.38
40-2001	2001	ATWL	BEET	Invert	Body	Exp	0.80	-0.10
43-2001	2001	ATWL	SPID	Invert	Body	Exp	1.00	0.00
53-2001	2001	ATWL	CRIC	Invert	Body	Exp	0.90	-0.05
448-2002	2002	ATWL	SPID	Invert	Body	Exp	0.41	-0.39
237-2000	2000	ATWL	PEMA	Mammal	Body	Uncult	0.82	-0.09
216-2002	2002	ATWL	PEMA	Mammal	Body	Uncult	0.89	-0.50
238-2000	2000	ATWL	PEMA	Mammal	Liver	Uncult	3.40	0.53
*205-2002	2002	ATWL	PEMA	Mammal	Liver	Uncult	4.90	0.69

4. HABITAT RESTORATION

4.1. THE HABITAT RESTORATION STUDY PLOTS – TRANQUILLITY SITE

- Nur Ritter

4.1.1. Materials and Methods

In 2002, two rounds of quantitative vegetation monitoring were conducted on the HRS plots. As in previous years, data were collected for all vegetation in the late spring (see Uptain et al., 2002 for an overview of experimental design). Additionally, a census of the shrubs (and shrub-like annuals) was conducted in the late summer. These two regimes are distinguished here as "spring monitoring" and "shrub monitoring." Quantitative monitoring was augmented by photographic monitoring as described below. Plant productivity samples were not collected in 2002 and are not scheduled to be collected again until the last year of sampling as per defined protocols (Selmon 2000).

4.1.1.1. Spring monitoring

Spring monitoring on the Tranquillity HRS plots was conducted during March 11, 12, 15, and 20. In previous years, vegetation monitoring had been conducted much later in the year (i.e., late April to late May). However, it is essential that monitoring be conducted when the vegetation is still in recognizable condition and the extremely dry conditions in 2002 resulted in an early senescence of much of the annual vegetation on the HRS plots. Data were collected from 24 quadrats (35 x 70 cm) on each plot. A stratified random sampling approach was employed, with plots divided into six sections (Figure 4-1) and four sampling points randomly selected within each section. All species were noted and the percent cover for each species estimated using a modified Daubenmire cover scale (0-1%; 1-5%; 5-25%; 25-50%; 50-75%; 75-95%; 95-100%; Bonham 1989). The total percent cover of all species within each quadrate was also estimated using the same scale. Whenever possible, species were identified completely; failing this, species were assigned morpho-species names (e.g., "Unknown Malvaceae").

Data sheets were structured to facilitative the inclusion of additional data. Qualitative data were entered for each plot, quadrat (e.g., whether or not the percent cover of vegetation in the quadrate was representative of the general area), and individual species (e.g., flowering condition). A running list was compiled of all species noted on each plot to document species that were present, but which did not fall within the quadrats,. These additional species were not included in the estimates of plot species richness; rather, they were used to help assess the effectiveness of the sampling methodology. All plant species noted during monitoring were included in the catalog of species encountered on the Tranquillity HRS site.

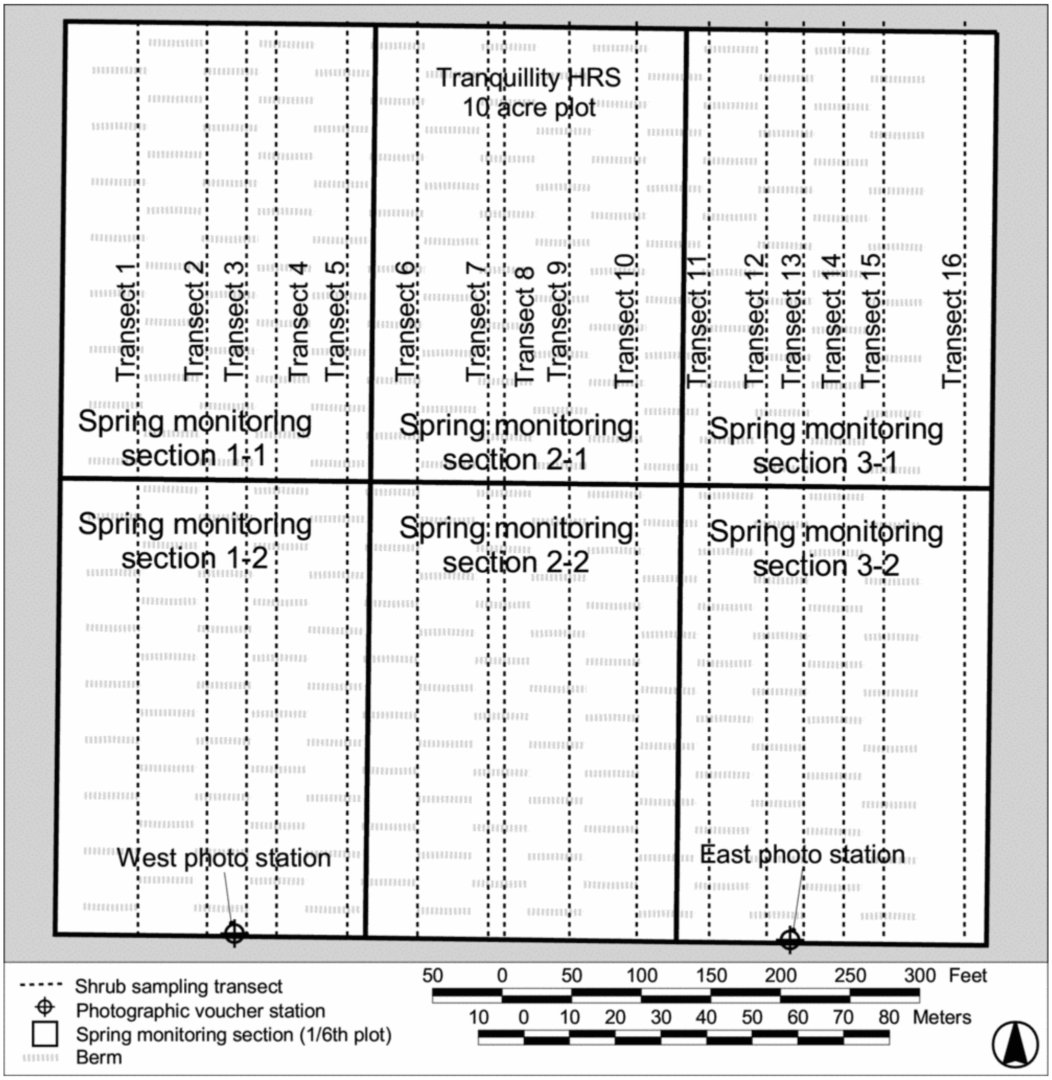

Figure 4-1. Spring monitoring sections, shrub sampling transects, and photo stations at the Tranquillity HRS, 2002.

4.1.1.2. Shrub monitoring

Shrub monitoring on the Tranquillity HRS plots was conducted during October and November 2002 (Oct. 22-24; Oct. 29-30; Nov. 4; Nov. 13). Both shrubs and "shrub-like annuals" (as defined later in this section) were included in the census; hereafter, the term "shrub" is used to refer to all members of both groups.

Shrub monitoring employed a point-intercept methodology (Table 4-1). The plot was divided into 16 40-ft- wide "segments", oriented north to south and a transect established within each segment at a randomly selected location. In theory, the length of the segments was intended to match that of the berms, such that the number of berms intersected by each transect would be constant. However, in practice, there was sufficient variability in berm length and location to preclude this relationship. In order to ensure that individual shrubs would intersect no more than a single transect, transect locations were modified such that they were a minimum of 10 ft apart. In future years, as shrub diameters increase, it probably will be necessary to increase the minimum distance between transects. Transect length was about. 660 ft; hence, approximately10,560 ft (2 miles) of transect were surveyed on each plot. Therefore, total transect length for the Tranquillity HRS plots was approximately 40 miles.

Monitoring methodology was as follows. Both ends of each transect were delineated with pin flags. In areas where the height of the vegetation was sufficient to obscure visibility of pin flags, t-posts were used to delineate the transects. Monitoring was accomplished by teams of two researchers. One researcher searched the transect for shrubs, while a second researcher stood at one end of the transect and determined whether or not any portion of a particular shrub intersected the transect (Figure 4-2). Determinations were facilitated by using a metal tape rule to establish a plumb line to the shrub, while the other researcher ascertained the relationship of the plumb line to the transect.

Figure 4-2. Shrub monitoring, Tranquillity HRS, 2002. Biologist Scott Deal is pictured recording shrub data after having sighted along the transect to the far edge of the plot. Not pictured is the second researcher whose function was to walk the transects and take measurements.

Included in shrub monitoring were all woody perennials and all non-woody species with a “shrub-like” form (e.g., the tumbleweeds *Atriplex argentea* and *Salsola tragus*). Originally, it was intended that only those individuals above a minimum height (9 inches) would be included in the monitoring. However, monitoring did not commence until after senescence in the shrub-like annuals was fairly well advanced (e.g., disarticulation had begun). Therefore, it was decided that a minimum height requirement should not be considered, as it would have excluded many individuals that would have been included if monitoring had been initiated sooner.

4.1.1.3. Photo points

Photographic vouchers were taken on the experimental plots (Figure 4-1) in order to document post-treatment conditions on the plots and to provide a permanent record of changes in vegetation structure and composition. Photographs (one 35-mm and one digital) were taken from each of two standard locations along the southern boundary of each plot (43 m from each of the corners), with the cameras oriented northwards. Copies of the photos are archived at ESRP and USBR offices in Fresno; the 35 mm photos are stored in binders and the digital photos are archived on compact disk.

4.1.1.4. Data storage and analysis

Data were entered into a relational database (FileMaker Pro, Figure 4-3) and were proofed from printed copies of the database records. As in previous years (Selmon et al. 2000; Uptain et al. 2001; Uptain et al. 2002), species were grouped by “origin” (e.g., introduced, native, etc.) for some analyses. Two additional categories were added for this year’s analyses: 1) “Native - Undesirable”; and, 2) “Imprinted and Introduced”.

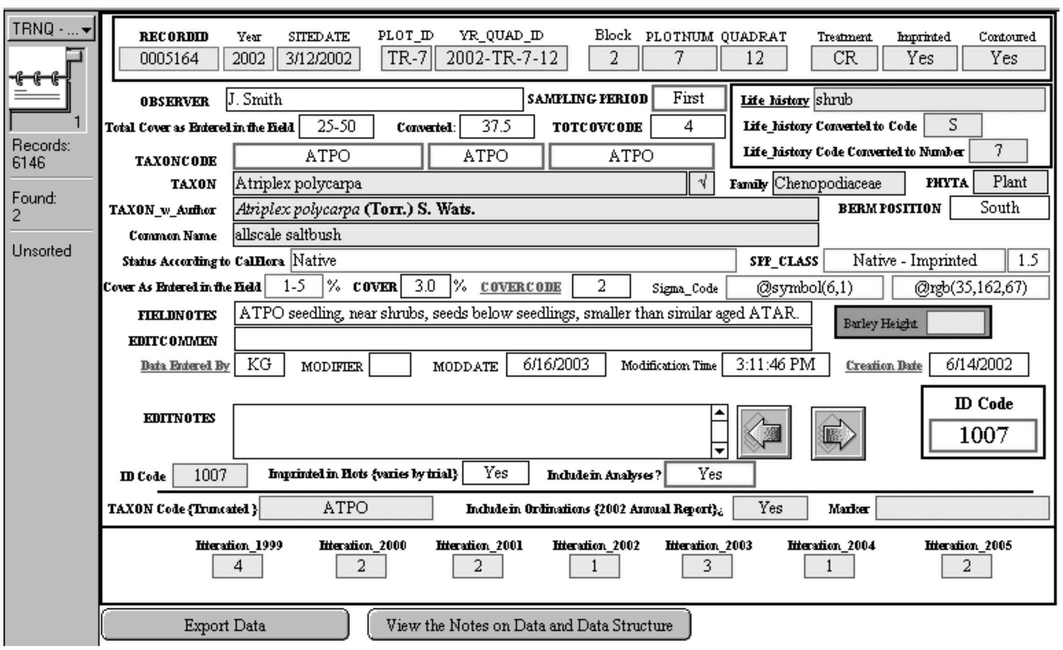

Figure 4-3. An interface to one of the LRDP database tables. Data entered from the field survey forms comprise only a portion of the fields pictured here. The remaining fields are used to display related data from other tables or are used for preliminary analyses and error checking.

The Native—Undesirable category contains a single species, the tumbleweed *Atriplex argentea* (silverscale saltbush). This species—which, although an annual, possesses a shrub-like form—has demonstrated the capacity to quickly become established and to dominate large areas of the study plots. These characteristics might normally be considered desirable in a restoration strategy. However, the stems of *A. argentea* decompose very slowly and seedlings of *A. argentea* and most other species on the site appear to be extremely limited in their ability to germinate beneath these old stems. Two species that are able to become established beneath the *A. argentea* stems are the non-native mustards, *Sisymbrium irio* and *Brassica nigra*. *Sisymbrium irio* is particularly adept at germinating under these conditions and has come to dominate large areas of the Tranquillity HRS plots. This same successional pathway also has been observed on many fallowed agricultural lands on the west side of the San Joaquin valley.

The “imprinted and introduced” category was created in order to integrate the contribution of species that could be ascribed to genera that were represented in both the “Native—imprinted” and “introduced” categories, but which were frequently not identifiable to the level of species. The “imprinted and introduced” category was represented at the Tranquillity HRS by a single pair of species: the grasses *V. microstachys* (imprinted) and *Vulpia myuros* (introduced). Although fertile individuals of both species were encountered in the study plots during vegetation monitoring in 2002, quadrats would often contain only infertile material, and it was not possible to confidently ascribe this material to a particular species. It was assumed that both species were present on any plot in which *Vulpia* was noted; hence, the Imprinted and Introduced category contributed two species to estimates of species richness.

Descriptive statistics, *t*-tests, and analysis of variance (ANOVA) were performed using the software package STATISTICA. In order to simultaneously express floristic relationships among the Tranquillity study plots and to examine the relationship between site vegetation and block effect, data were organized into a binary matrix of plots versus species (recorded as % cover values) and were ordinated using Detrended Correspondence Analysis (DCA, Hill and Gauch Jr. 1980). Ordinations were conducted using the software package PC-Ord (McCune and Mefford 1997).

4.1.2. Results and Discussion

Results are considered in the following order:

1. Site-wide patterns
2. Patterns among treatments and blocks
3. Species-specific patterns.

The most pertinent data are presented within the body of this report; additional relevant data and figures are presented in the appendix at the end of this chapter.

4.1.2.1. Spring monitoring

4.1.2.1.1. Site-level

At the site level, species richness initially increased after imprinting, i.e., from 1999 to 2000 (Table 4-1). Nevertheless, site-level richness decreased during the following 2 years; reaching levels that were equivalent to that of the baseline year (i.e., 1999). A list of all species observed on the HRS plots during all 4 years of vegetation monitoring is presented in Table 4-33 (Appendix 4-1).

Table 4-1. Overall vegetation species richness in the Tranquillity HRS plots. Numbers are based solely on those species which occurred within the quadrats.

Species Category	1999	2000	2001	2002
Native - Imprinted	0	5	5	4
Native	3	5	2	2
Native - Undesirable	1	1	1	1
Imprinted and Introduced	0	2	2	2
Barley	1	1	1	1
Introduced	15	16	15	12
Not Known	6	5	1	4
Total	**26**	**35**	**27**	**26**

Seed of 13 native species were imprinted into the plots in 2000 (Table 4-2, Appendix 4-1; see Selmon 2000 for an overview of the experimental design and plot installation). Of these imprinted species, only six (46.2%) were noted during vegetation monitoring in 2000 and 2001 (Table 4-1), and only five (38.5%) were noted in 2002. Note that in order to arrive at these totals, it is necessary to add one to the number of species listed as "native - imprinted" in Table 4-1, in order to account for the contribution of the "imprinted and introduced" category. Less than half of the imprinted species were observed during any particular year's monitoring. Nevertheless, during monitoring in the 3 years following imprinting a total 9 of the 13 imprinted species have been observed (Table 4-3).

Table 4-2. Species imprinted in the study plots at the Tranquillity HRS site, with families and common names.

Species	Family	Common name	Life-form
Allenrolfea occidentalis	Chenopodiaceae	iodine bush	shrub
Atriplex polycarpa	Chenopodiaceae	allscale saltbush	shrub
Atriplex spinifera	Chenopodiaceae	spiny saltbush	shrub
Bromus carinatus	Poaceae	California brome	annual herb
Frankenia salina	Frankeniaceae	alkali heath	subshrub
Heliotropium curassavicum	Boraginaceae	heliotrope	perennial herb
Hemizonia pungens	Asteraceae	spikeweed	annual herb
Isocoma acradenia	Asteraceae	goldenbush	shrub
Lasthenia californica	Asteraceae	goldfields	annual herb
Leymus triticoides	Poaceae	creeping wildrye	perennial herb
Sporobolus airoides	Poaceae	alkali sacaton	perennial herb
Suaeda moquinii	Chenopodiaceae	bush seepweed	subshrub-shrub
Vulpia microstachys	Poaceae	Nuttall's fescue	annual herb

Table 4-3. Imprinted species noted in the quadrats during vegetation monitoring in the Tranquillity HRS plots, 1999-2002.

Species	1999	2000	2001	2002
Atriplex polycarpa	-	-	-	+
Bromus carinatus	-	+	+	+
Frankenia salina	-	+	-	+[1]
Hemizonia pungens	-	-	+	-
Isocoma acradenia	-	+	-	-
Lasthenia californica	-	+	+	+
Leymus triticoides	-	-	+	-
Suaeda moquinii	-	+	+	-
Vulpia myuros [2]	-	+	+	+

[1] Only noted in a single, non-imprinted plot.

[2] In some other tables represented as "*Vulpia* spp." in the "Imprinted and Introduced" Category.

In addition to species that are actively introduced to restoration sites through imprinting and direct planting, we hoped that native species would become established on retired lands without human intervention. We expected that these species would become established either through existing seed banks or through colonization from other areas and, indeed, at the Tranquillity HRS a number of non-imprinted natives have been noted on the plots (Table 4-4). As discussed in the Methods section (4.1.1), the native *Atriplex argentea* can be considered to have an overall negative impact on restoration and, hence, is generally not desirable. Therefore, that species is not included in the tally of "naturally established" native species. Discounting *A. argentea*, eight non-imprinted native species have been noted on the HRS plots (Table 4-4).

Non-imprinted native species were best-represented during the first year of restoration (2000, Table 4-4), with five species noted during monitoring. However, only two such species were noted during each of the subsequent year's monitoring (Table 4-4). As will be discussed later, in no instance were any of these eight species well-represented on the HRS plots.

Table 4-4. Non-imprinted native species (excluding *Atriplex argentea*) noted in the quadrats during vegetation monitoring in the Tranquillity HRS plots, 1999-2002.

Species	1999	2000	2001	2002
Amsinckia menziesii	-	-	+	+
Eremalche parryi	+	-	-	-
Hordeum depressum	+	+	-	-
Malacothrix coulteri	-	-	-	+
Malvella leprosa	-	+	-	-
Monolepis nuttalliana	-	+	-	-
Phacelia ciliate	+	+	+	-
Solanum americanum	-	+	-	-
Total	**3**	**5**	**2**	**2**

An examination of the frequencies (i.e., the number of quadrats) of the various species categories (Table 4-5) suggests an even greater dominance of introduced species than was evidenced from the richness data. Nevertheless, it is important to recognize that imprinted species would not necessarily be expected on half of the plots (i.e., the non-imprinted plots). Hence, comparisons among treatments (see section 4.1.2.1.2) are much more instructive than are examinations made at a site-wide scale (section 4.1.2.1.1).

Although site-level patterns in richness may be too coarse a resolution to offer much insight, still a few patterns are worth noting. Foremost among these was the poor recruitment native species on the plots. The 13 species that were included in the seed mixture for the study plots were selected, in part, because they were representative of species found on the remaining remnants of native habitat in the west side of the valley. Nevertheless, none of the imprinted species were noted during baseline sampling in the study area, and since that time, a single “imprinted species” has been noted in the non-imprinted plots (*Frankenia salina*; Plot 10, % cover = 0-1%). Similarly, with the exception of the tumbleweed *Atriplex argentea*, few non-imprinted native species have been observed on the study plots. To date, only a single native species, *Malacothrix coulteri* (snake’s head), has shown any sign of become well-established on some of the plots and buffer areas, although *Amsinckia menziesii* also has been observed (Table 4-4).

Table 4-5. Overall frequency of vegetation species categories in the Tranquillity HRS plots, 1999-2002. Impr. = imprinted.

Species Category	1999		2000		2001		2002	
	All	Impr.	All	Impr.	All	Impr.	All	Impr.
Native - Imprinted	–	–	157	157	27	27	21	20
Native	14	12	24	17	6	5	6	4
Native - Undesirable	7	7	87	45	50	39	13	7
Imprinted and Introduced	–	–	77	77	18	18	37	36
Barley	479	239	403	203	159	81	136	50
Introduced	853	408	1307	668	949	488	1213	627
Not Known	24	17	41	41	–	–	–	4
No Vegetation	1	1	2	1	31	21	–	–
Total	**1378**	**684**	**2098**	**1209**	**1240**	**679**	**1430**	**748**

Also of note was the difference in appearance between the herbaceous vegetation on the plots and in the buffer areas. In general, species in the buffer were more robust and showed less stress with the onset of the dry season than did the same species on the plots. In part, this pattern may be attributable to the barley providing some level of amelioration of conditions (e.g., better conservation of soil moisture, lower temperatures at ground level, or both). These differences in the vegetation also may point to the negative impacts of imprinting on the clay soils at the Tranquillity site, as the depressions created by the imprinter appear to facilitate soil erosion. Furthermore, although quantitative data were not collected from the buffers, it appeared that non-imprinted native species were frequently better represented and more abundant in the buffers than in the study plots. This difference in native species representation may simply be an indication that the native species are better able to compete with barley than with the weedy species that dominate the plots or that barley acts as a nurse plant for these natives. We considered that this difference also might be due to the act of imprinting somehow limiting the establishment of natives from the seed bank. However, were this the case, it would be expected that an equivalent amount of "volunteer" natives would be present in the non-imprinted plots as in the buffers.

Figure 4-4. *Malacothrix coulteri* (snakes head), seemingly one of the few native species that has become established on the plots through the existing seedbank.

4.1.2.1.2. Treatments and blocks

Both of the imprinted treatments (CR and NR, Figure 4-5) were richer in species than the two non-imprinted treatments (CN, NN). Nevertheless, differences in richness among treatments were slight. This same general pattern has been observed throughout the experiment (Figure 4-5). Richness data for all plots and years is presented in Appendix 4-1.An examination of differences in mean species richness among blocks in 2002 (Figure 4-5), suggests that blocking effects were significant, with Block 1 clearly poorer in species than the other blocks. The relative impoverishment of Block 1 is even more striking when considered within a historical context, as Block 1 was initially the richest of the blocks (Figure 4-5). Percent cover of vegetation (Table 4-6) at the plot level ranged from 36.43 (Plot 11) to 86.17 (Plot 6). Despite this broad range cover, vegetation cover on the plots was much more equitable than in the preceding year, when cover ranged from 3.57 to 86.17% (Table 4-6). Furthermore, there was a general tendency for vegetation cover in 2002 to be greater than in the preceding year, when approximately two-thirds (13) of the plots in 2001 had less cover than about one-third of the plots in 2002 with the least cover. Nevertheless, as will be discussed presently, these gains in vegetation cover were not generally due to an increased abundance of desirable species (i.e., imprinted and adventive natives).

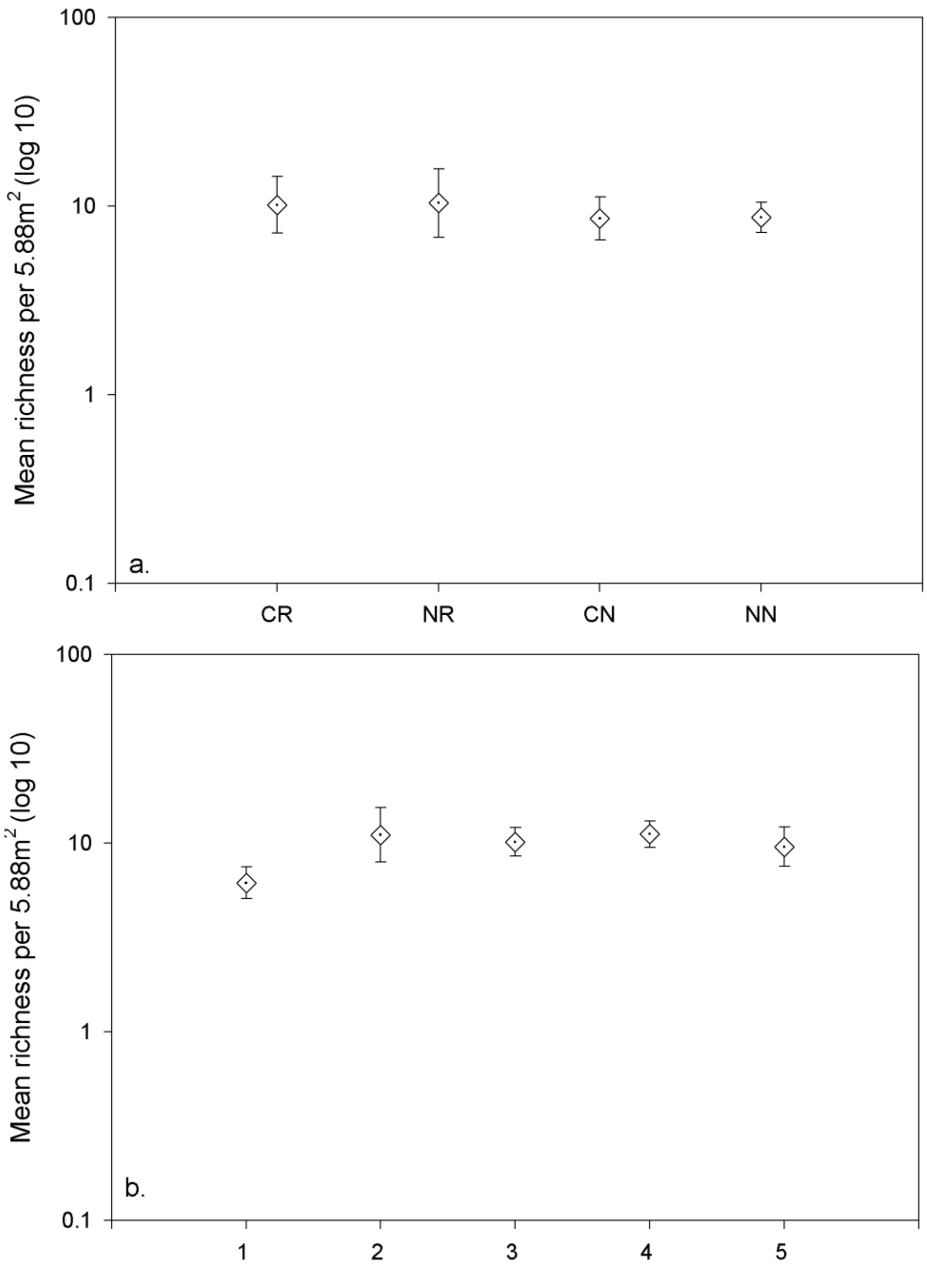

Figure 4-5. Plant species richness at the Tranquillity HRS plots, 2002. Richness values represent the geometric means of the number of species observed in the 24 0.245 m^2 quadrats that were sampled on each plot (5.88 m^2). a. Species richness among treatments. Codes: CR, contoured and imprinted; NR, imprinted, but not contoured; CR, contoured, but not imprinted; NN, not imprinted or contoured. b. Species richness among blocks.

Table 4-6. Plant cover on the Tranquillity HRS plots. Plots are ordered by treatment, and then numerically by plot number. Hence, the first plot listed for any treatment is situated in Block 1, the second in Block 2, etc.

Treatment	Plot	1999	2000	2001	2002
Contoured and imprinted	2	32.00	61.10	32.88	67.09
	7	42.81	68.38	33.30	49.01
	11	26.88	37.49	36.89	36.43
	13	47.05	28.27	3.57	55.99
	17	49.96	26.26	36.31	67.59
Imprinted, but not contoured	1	34.30	73.92	56.03	81.50
	5	34.59	41.24	36.99	73.82
	12	41.35	58.75	25.30	39.43
	16	54.76	26.82	25.06	66.64
	20	20.14	40.54	25.14	54.95
Contoured, but not imprinted	4	35.33	80.81	60.71	60.36
	6	51.84	49.99	27.27	86.17
	10	73.36	47.18	22.45	52.88
	14	68.90	49.72	23.25	56.26
	19	33.98	52.74	67.71	64.87
Not imprinted or contoured	3	36.16	93.83	79.33	62.24
	8	29.42	65.64	42.20	66.86
	9	29.51	52.78	43.85	45.42
	15	49.42	37.31	19.70	50.77
	18	28.46	54.53	54.38	81.40

Differences in mean percent cover among treatments were slight, and were of smaller magnitude than the standard deviations around the mean (Figure 4-6a). These large standard deviations give another indication of blocking effects at the site. Mean percent cover was greatest on Block 2 and lowest on Block 3 (Figure 4-6b). However, as with the comparison among treatments, differences among blocks were small scale, and were characterized by large standard deviations.

During 2002, vegetation was generally more abundant on the plots than in the baseline year (Figure 4-7a-d; Figure 4-8 a-d). However, year-to-year variability among both particular treatments and blocks was such that any distinct trends were precluded. As with the 2002 data (Figure 4-6), standard deviations among the plots that constituted each treatment exceeded the differences in mean abundance among treatments (Figure 4-7a-d). The same relationship was also evident at the block level (Figure 4-8 a-d).

Despite the small gains in richness over the course of the experiment, an examination of the abundances contributed by the various categories clearly emphasizes the dominance of introduced species.

In order to evaluate the contribution of “desirable” versus “undesirable” vegetation, species were identified by origin (e.g., native, introduced, etc.) and rank-abundance curves were generated for each plot, and were graphed with plots grouped by treatment (Figure 4-9; Figure 4-10). Plots were ordered sequentially by block number within each graph; hence, the leftmost curve represents the plot from Block 1, the second to the left, Block 2, etc. Rank-abundance curves were plotted along the x-axis in such a way as to minimize overlap. Thus, no ordinal scale is presented along the x-axis; rather, the curves are interpreted such that the leftmost data point represents the highest (first) ranked species, with subsequent data points representing the 2^{nd} highest ranked species, etc.

Regardless of treatment, the most abundant species on all plots were either introduced (18 plots) or barley (2 plots). In no instances, were imprinted native species highly ranked. Generally, the slopes of the curves were more gradual for the restored plots (Figure 4-9 a-b) than for the non-restored plots (Figure 4-10 a-b). This pattern suggests that vegetation on the restored plots had achieved a greater evenness. The vegetation on Block 1 constituted an exception to this pattern, as graphs from all plots on this block (i.e., the lefthand-most curves for each treatment) possessed steep slopes.

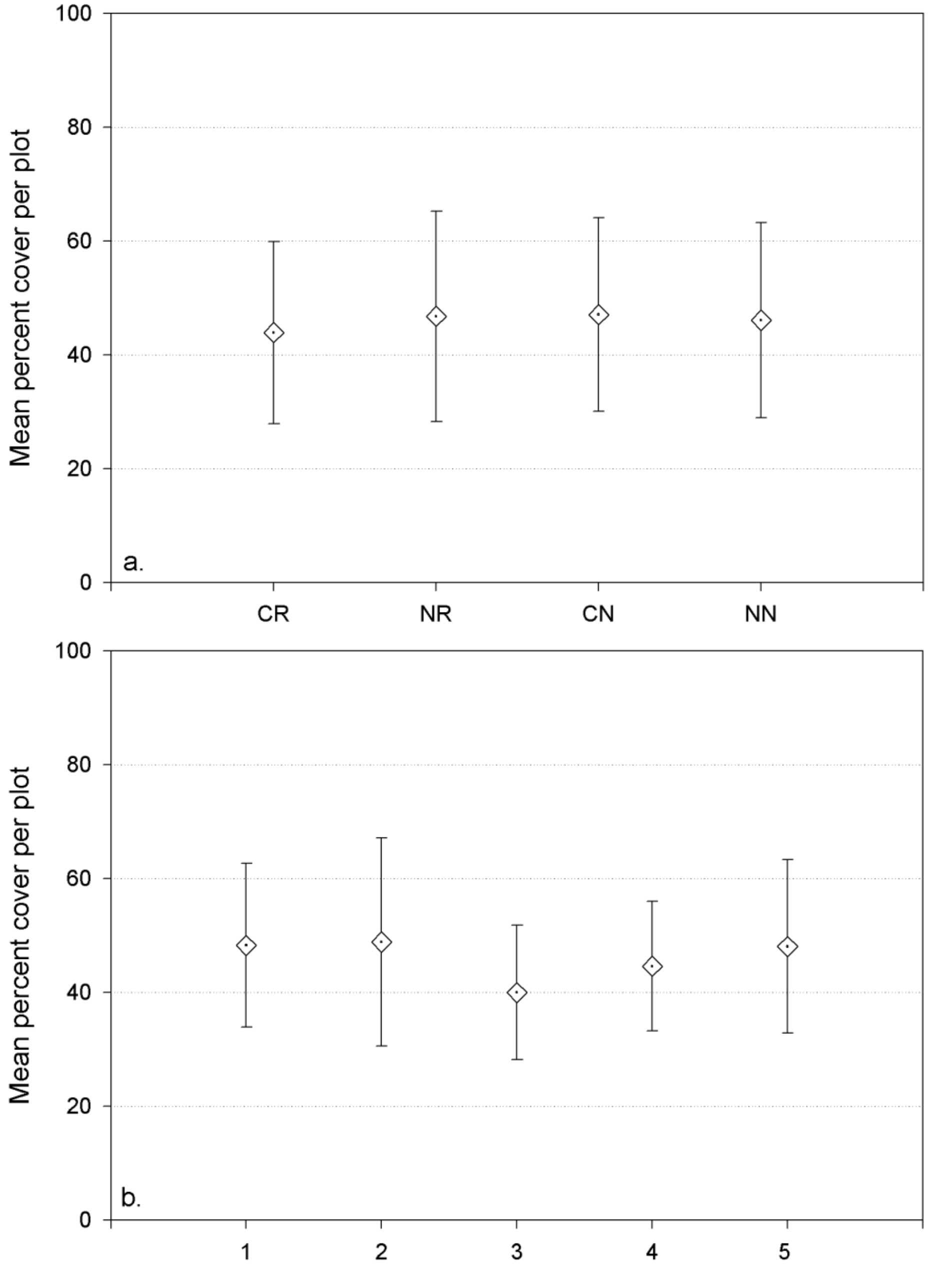

Figure 4-6. Plant cover on the Tranquillity HRS plots, 2002. a. Comparison of cover among treatments. Codes: CR, contoured and imprinted; NR, imprinted, but not contoured; CN, contoured, but not imprinted; NN, not imprinted or contoured. b. Comparison of cover among blocks.

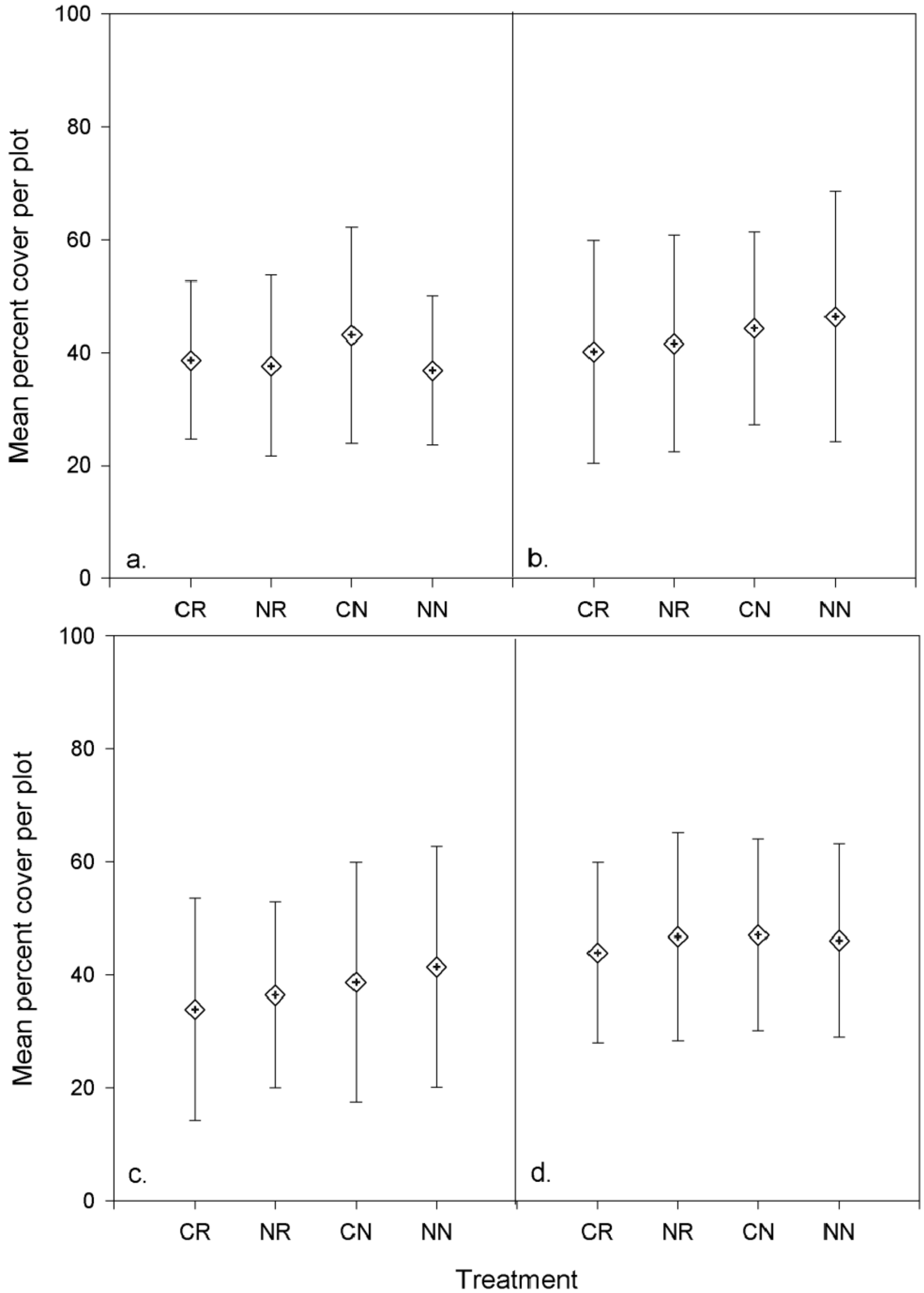

Figure 4-7. Plant cover among treatments on the Tranquillity HRS plots. Bars represent one standard error. Treatment codes: CR, contoured and imprinted; NR, imprinted, but not contoured; CR, contoured, but not imprinted; NN, not imprinted or contoured. Key: a. 1999; b. 2000; c. 2001; d. 2002.

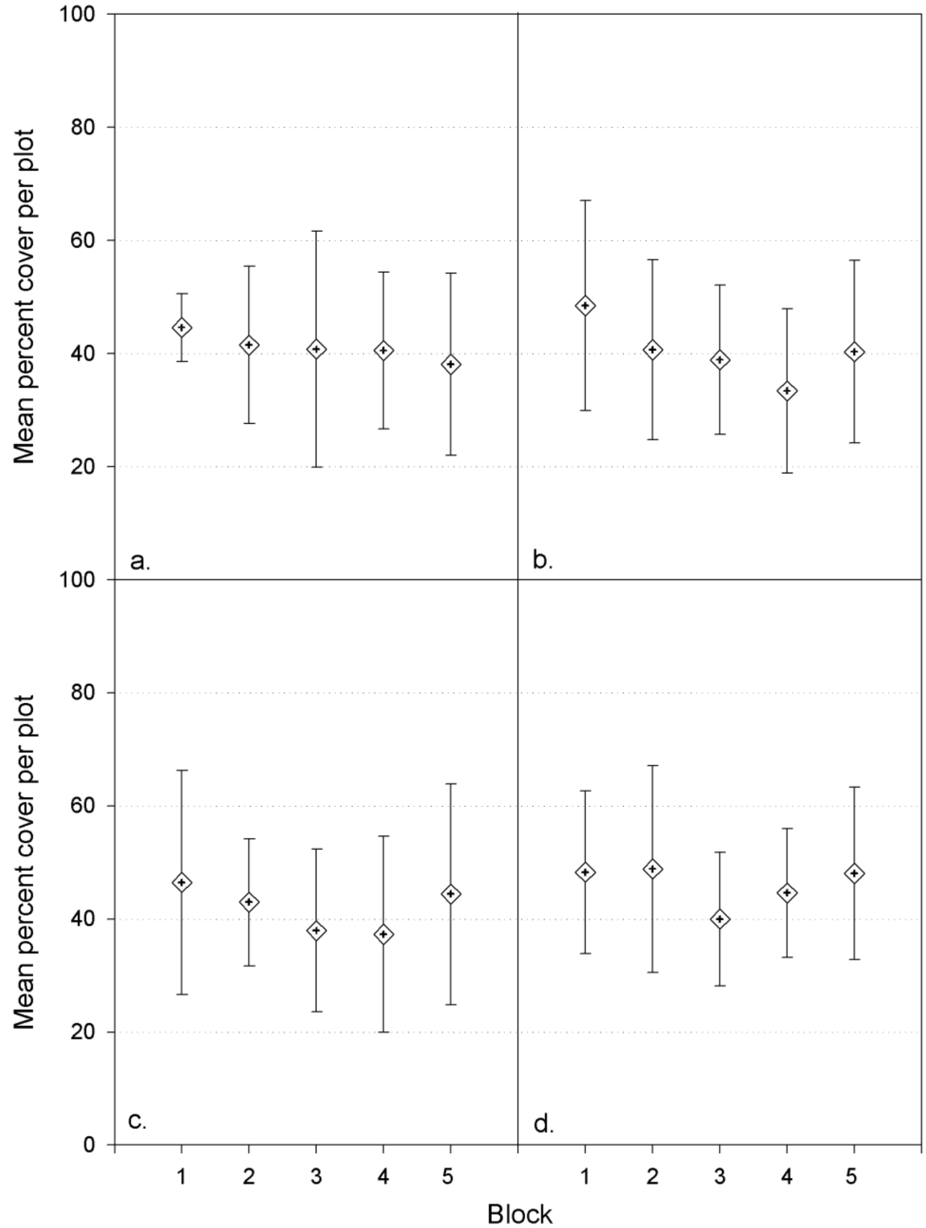

Figure 4-8. Plant cover among blocks on the Tranquillity HRS plots. Bars represent one standard error. Key: a. 1999; b. 2000; c. 2001; d. 2002.

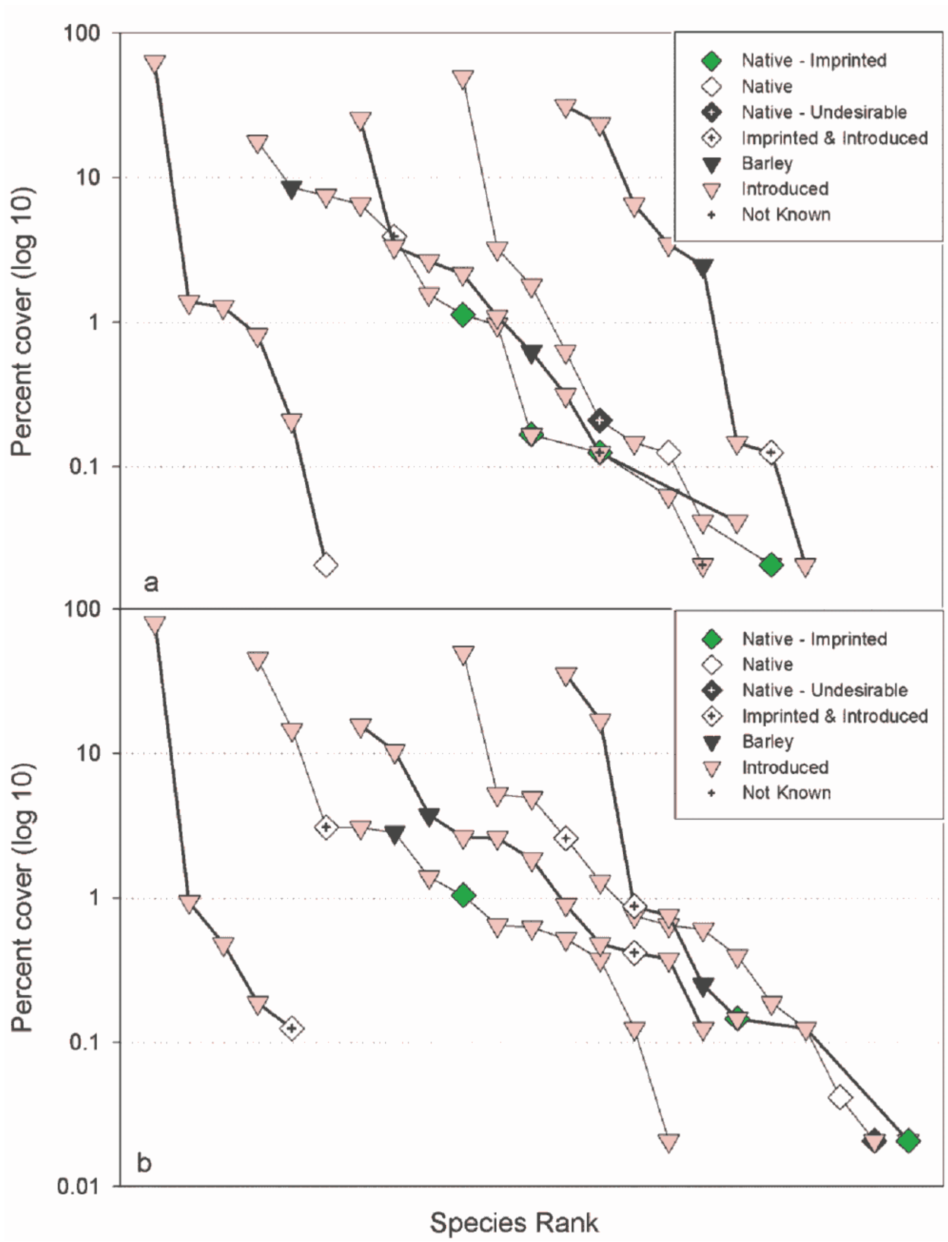

Figure 4-9. Species rank-abundance by treatment, Tranquillity HRS plots 2002. a. contoured, but not imprinted (CN); b. neither imprinted nor contoured (NN). See text for an explanation of the x-axis.

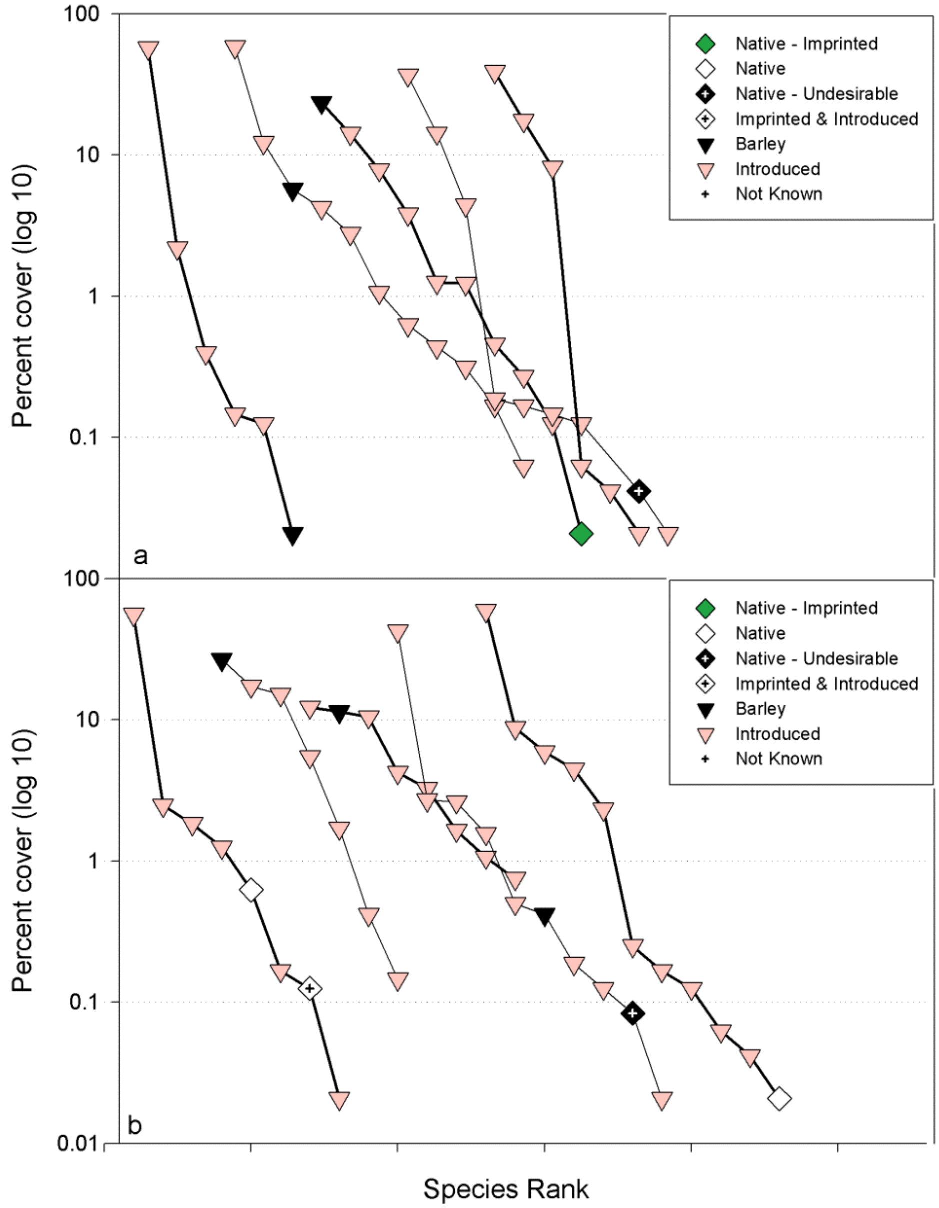

Figure 4-10. Species rank-abundance by treatment, Tranquillity HRS plots 2002. a. contoured, but not imprinted (CN); b. neither imprinted nor contoured (NN). See text for an explanation of the x-axis.

4.1.2.1.3. Species level

A few species appear to be driving the direction of the plant restoration on the plots. Principle among these are *Sisymbrium irio*, *Bromus madritensis*, and *Atriplex argentea*. In the following discussion and associated tables, all means and standard deviations were derived from arcsine transformed data; the data presented have been back-transformed (Fowler et al. 1998).

In the driest, most saline areas of the study site (e.g., Section 10 and, to a lesser extent, Block 4), *Bromus madritensis* (Figure 4-11) tended to dominate large portions of the landscape. This species is a Mediterranean annual grass that is a troublesome winter weed in California (Fischer 1998). The frequency in which this species was encountered (i.e., the number of quadrats in which it occurred) was fairly consistent throughout the first 3 years of sampling (1999-2001, Table 4-7). During these years, most occurrences were in Block 1, with a small proportion occurring in Block 4. The frequency of occurrences outside of blocks 1 and 4 was fairly low during this period; however, in 2002, both frequency and the number of additional plots on which *B. madritensis* was encountered increased markedly. The yearly increase in mean percent cover of *B. madritensis* in Block 1 is even more indicative of a trend towards dominance by this species in the northern end of the study site. During the first 4 years of monitoring, the mean percent cover of red brome on this block increased remarkably, increasing from 1.42 in 1999 to 66.26 in 2002 (Table 4-7). At the sitewide level, *B. madritensis* was not nearly so dominant as on Block 1; nevertheless, by 2002 the species had become established on a number of additional plots and blocks (Table 4-7). In particular, the northern plots of blocks 2 and 4 (i.e., those closest to Section 10) showed the greatest increases.

Figure 4-11. Spring vegetation monitoring on a plot dominated by *Bromus madritensis* (red brome). The frame visible in the photograph constitutes about one-half of one of the 35 x 70 cm quadrats used for sampling.

Table 4-7. Frequency and abundance of *Bromus madritensis* in the Tranquillity HRS plots, 1999-2002.

Year	Quad[1]	Plots[2]	Frequency Block 1	2	3	4	5	Mean Block 1	Std. dev. Block 1	MN[3]	Std. Dev.[4]
1999	94	5	84	0	0	10	0	1.42	0.08	0.07	0.25
2000	89	5	88	1	0	0	0	15.42	3.98	0.66	3.34
2001	94	8	84	1	1	1	6	24.64	9.58	1.18	5.91
2002	121	13	96	10	1	8	6	66.26	1.53	4.41	14.02

[1] Number of quadrats in which the species was noted.
[2] Number of plots in which the species was noted.
[3] Sitewide mean percent cover.
[4] Standard deviation around the mean of the sitewide data.

Broadly speaking, in all other areas of the study site, *Sisymbrium irio* (London rocket) was dominant. This species is another winter annual weed that has become widespread in California (Fischer 1998, Whitson et al. 2000). As with *Bromus madritensis*, the frequency in which *S. irio* was encountered was fairly consistent during the first 3 years of sampling (1999-2001, Table 4-8); during this time, the highest frequencies were on Block 5. An assumed incompatibility between red brome and London rocket is indicated by the very low frequencies of the latter species on Block 1. Although *S. irio* was present in approximately 10% of the quadrats from Block 1 in 1999, it was not noted on this block in the three subsequent years of sampling (Table 4-8). Nevertheless, as evidenced by its presence in 345 of a potential 384 quadrats (89.8%), this species predominated on much of the on the remaining four blocks by 2002.

Table 4-8. Frequency and abundance of *Bromus madritensis* in the Tranquillity HRS plots, 1999-2002.

Year	Quad[1]	Plots[2]	Frequency Block 1	2	3	4	5	Mean Block 5	Std. dev. Block 5	MN[3]	Std. dev.[4]
1999	230	18	9	52	9	84	76	2.06	0.12	0.65	0.60
2000	261	15	0	72	22	74	93	31.85	3.68	5.42	5.80
2001	264	16	0	77	42	60	85	25.03	4.12	5.29	4.33
2002	345	16	0	81	83	89	92	38.11	2.28	17.21	8.89

[1] Number of quadrats in which the species was noted.
[2] Number of plots in which the species was noted.
[3] Sitewide mean percent cover.
[4] Standard deviation around the mean of the sitewide data.

Generally, *S. irio* also was most abundant on Block 5. By 2000, this species had achieved a mean percent cover of 31.9. In 2002, the percent cover of *S. irio* was estimated to be 38.1. The total mean percent cover for these plots in 2002 was estimated to be 62.7; hence, this species accounted for approximately 60% of the vegetation on these plots. An abundance of *S. irio* was not wholly unexpected, as the land directly to the south was dominated by this species. At the sitewide level, by 2002 *S. irio* (17.2%, Table 4-8) was much more abundant than *Bromus madritensis* (4.41% Table 4-7).

A third species of import is the tumbleweed *Atriplex argentea*. Results from the vegetation sampling are presented in Table 4-9. In contrast to *Bromus madritensis* and *Sisymbrium irio*, which are both winter annuals, *A. argentea* is a species which generally achieves it maximum growth well after the time of the spring vegetation surveys. Therefore, the abundance values, and most likely the frequency values, presented in Table 4-9 clearly under-represented the contribution of this species to overall vegetation abundance.

At the time of spring vegetation monitoring in 1999 (i.e., at the time that the plots were all planted to barley), *A. argentea* was noted on a single plot (Table 4-9). In six of the seven quadrats from this plot in which *A. argentea* was noted, the estimated cover was only 0-1%; the estimated cover for the remaining quadrate was in the 1-5% class. By the time of the next year's monitoring, the species was present in 20.2% of the quadrats . At that time, the species also had achieved its highest recorded mean cover (0.12%). By 2001, frequency had dropped to just 50 quadrats, although the mean cover was slightly higher (0.13%) than in 2000. In 2002, both frequency (13 quadrats) and mean percent cover (0.001) had dropped considerably.

From our observations on the plots, it does indeed appear that *A. argentea* is diminishing in dominance. Nevertheless, as noted, the data appear to significantly under-represent the influence of this species. Late in the growing season following imprinting (i.e., 2000) *A. argentea* was dominant over a large portion of the plots. The extent of this dominance is well-represented in the photographic vouchers (see Methods section 4.1.1.3) taken of the plots in late September 2000. The photo below (Figure 4-12) was selected as being representative of a plot (Plot 13) that was severely "infested" with tumbleweeds. At the time of spring vegetation monitoring (late April to early May, 2000), *A. argentea* was noted in little more than a third (9) of the quadrats from this plot, the fifth highest frequency noted for this species at this time. However, Plot 13 possessed the highest mean cover of *A. argentea* (10.62%). At the time during which the photograph was taken, the abundance of this species appears to have increased by nearly an order of magnitude (Figure 4-12). Although *A. argentea* is currently not nearly so abundant as in previous years, there is a constant threat of new propagules being transported into the site (Appendix 4-6).

Table 4-9. Frequency and abundance of *Atriplex argentea* in the Tranquillity HRS plots, 1999-2002.

Year	Quad[1]	Plots[2]	Frequency Block 1	Block 2	Block 3	Block 4	Block 5	MN[3]	Std. Dev.[4]
1999	7	1	7	0	0	0	0	0.000	0.003
2000	14	97	37	12	1	35	2	0.12	0.23
2001	14	50	21	1	13	13	2	0.13	0.427
2002	5	13	0	0	1	12	0	0.001	0.003

[1] Number of quadrats in which the species was noted.
[2] Number of plots in which the species was noted.
[3] Sitewide mean percent cover.
[4] Standard deviation around the mean of the sitewide data.

Figure 4-12. *Atriplex argentea* (tumbleweed) on Plot 13, Tranquillity HRS, September 26 2000.

Although *A. argentea* declined in abundance in subsequent years, the repercussions from this initial phase of dominance were severe. Principally, although *A. argentea* is an annual, its biomass resists degradation. Hence, in the year following the tumbleweeds' senescence the "skeletons" of the previous year's plants remain on site and limit the germination of other species. Two species which are able to successfully become established under these conditions are the mustards *Brassica nigra* and *Sisymbrium irio*. During spring vegetation monitoring in 2002, these two species, along with a small number of individuals of *Sonchus oleraceus* (prickly mustard), represented the only species that were observed germinating beneath *A. argentea*. One of the most troublesome species on the Tranquillity HRS site is *S. irio*, and it appears that its ascendancy to dominance can be partially attributed to the presence of *A. argentea*.

In contrast to the weedy species described above, imprinted annuals have not flourished. In 2002, only three such species, *Bromus carinatus* (California brome), *Lasthenia californica* (goldfields), and *Vulpia microstachys* (small fescue) occurred within the quadrats. In all cases, both frequency and abundances were very low. Additionally, in most cases, both frequency and abundance of the imprinted annuals have decreased each year. Likewise, none of the imprinted herbaceous perennial species (*Heliotropium curassavicum*, heliotrope; *Leymus triticoides*, creeping wild rye; and *Sporobolus airoides*, alkali sacaton) have become well-established on the plots, with the exception of a few small areas. These patterns suggest that the prognosis for the establishment of both these groups of species is poor, unless more suitable restoration techniques can be developed. These plant species are very likely desirable considering the habitats and resource requirements of vertebrates native to the San Joaquin Valley.

4.1.3. Shrub Monitoring

In the following discussion, the term shrub when enclosed in quotation marks is used to refer to both shrub and shrub-like species, as noted previously. Data were collected from all "shrubs" that intersected the transects, regardless of whether the individuals were alive or dead. However, for woody perennials, only those individuals that were still clearly alive were included in the analyses. An exception was the analysis of mortality of the imprinted woody species where both living and dead individuals were included. Some care had to be taken in the censusing of the shrub-like annuals, as at the time of monitoring the great majority of these individuals were either dead or well into senescence. Furthermore, a portion of the biomass from the previous year's individuals had persisted on the plots. Nevertheless, it was generally possible to differentiate between the two year's individuals.

It also proved difficult to accurately determine how many individuals of a species of shrub-like annual (particularly *Atriplex argentea* and *Salsola tragus*) were present at a particular point. This differentiation was particularly problematic when the majority of the individuals were young. Therefore, the frequency data presented for the shrub-like annuals should be thought of as representing "shrub-like assemblages" rather than discrete individuals. It was much easier to differentiate between individuals of the various woody species, and the frequency data for these species can be interpreted as representing single individuals.

Of the 320 transects employed in the monitoring 237 (74.1%) did not intersect any "shrubs". On the imprinted plots, 98 of the 160 transects (61.3%) were without "shrubs". Eight "shrub" species were encountered during monitoring (Table 4-10); of these, all but one species (*Isocoma acradenia*, Asteraceae) were in the Chenopodiaceae (Goosefoot family). The imprinted *Atriplex polycarpa* occurred on the greatest number of plots (7), was present on the greatest overall number of transects (33), and was present on the greatest number of transects on a single plot (15; Table 4-11). The undesirable native, *A. argentea*, was the most abundant species (i.e., encountered with the greatest frequency (Table 4-11), and represented the species with the greatest number of individuals on a single transect.

Table 4-10. Species encountered during Shrub Monitoring in the Tranquillity HRS plots, 2002. See Methods section 4.1.1.2 for a discussion of the criteria upon which species' inclusion was based.

Species	Common Name	Code	Category[1]
Allenrolfea occidentalis	Iodine bush	ALOC	N-I
Atriplex argentea	silverscale saltbush	ATAR	N-U
Atriplex polycarpa	allscale saltbush	ATPO	N-I
Atriplex semibaccata	Australian saltbush	ATSEM	I
Bassia hyssopifolia	fivehook Bassia	BAHY	I
Isocoma acradenia	goldenbush	ISAC	N-I
Salsola tragus	Russian thistle	SATR	I
Suaeda moquinii	bush seepweed	SUMO	N-I

[1] Key to Species Categories: N-I, Native - Imprinted; N-U, Native - Undesirable; I, Introduced. Taxa are ordered in decreasing order of their frequency in the imprinted plots.

Table 4-11. Sitewide shrub monitoring data, Tranquillity HRS, 2002.

	All Plots		Imprinted Plots				
Species	Plots	Freq.[1]	Plots	Freq.[1]	Max. ndv.[2]	Max. Trans.[3]	Total Trans.[4]
Atriplex argentea	6	142	4	125	28	10	23
Atriplex polycarpa	7	87	7	87	13	15	33
Suaeda moquinii	6	37	6	37	7	10	18
Salsola tragus	5	66	2	15	13	8	25
Atriplex semibaccata	1	1	1	1	1	1	1
Allenrolfea occidentalis	1	1	1	1	1	1	1
Isocoma acradenia	1	1	1	1	1	1	1
Bassia hyssopifolia	1	6	-	0	3	3	3

[1] The total number of individuals recorded during monitoring (i.e., the total that intersected the transects).
[2] The maximum number of individuals on a single transect.
[3] The maximum number of transects on a single plot on which the species occurred.
[4] The total number of transects on which the species occurred.

It is clear from the data as well as from observations on the plots that the imprinted woody perennials were more successfully established than the imprinted herbaceous species. The relative contribution of the imprinted species is apparent in the rank-abundance curve plotted from the frequency data (Figure 4-13). Although the undesirable *Atriplex argentea* was the most frequently encountered "shrub-like" species, the imprinted *Atriplex polycarpa* and *Suaeda moquinii* were both well-represented. Considering just the imprinted plots, *A. polycarpa* and *S. moquinii* represented the second and third most prevalent "shrub" species. Two other imprinted shrubs, *A. occidentalis* and *I. acradenia*, were noted during sampling; each was encountered just a single time.

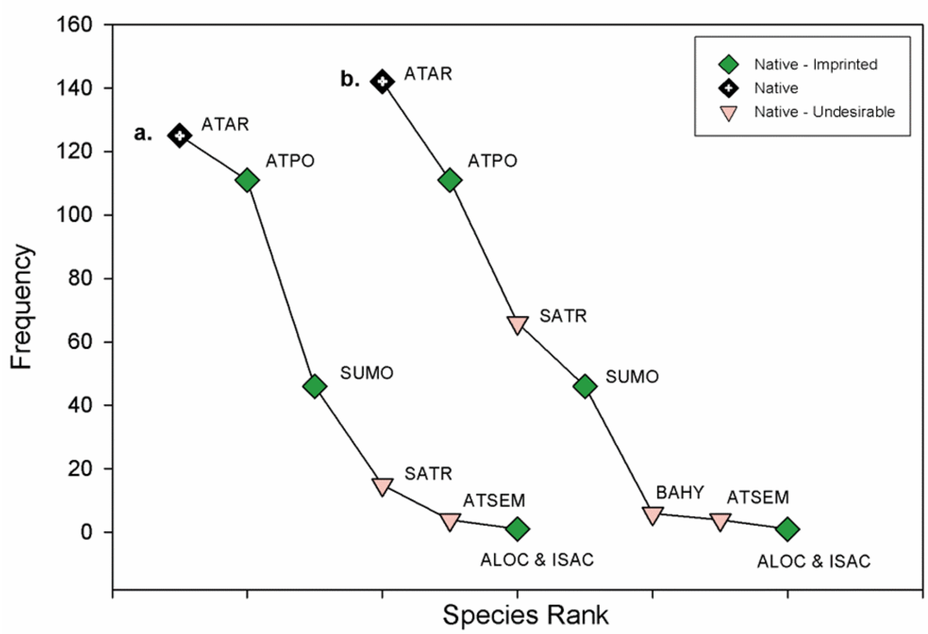

Figure 4-13. Species rank-abundance of shrubs and "shrub-like" species, Tranquillity HRS plots 2002. a. data from only the imprinted plots; b. data from all plots. Frequency is equal to the total number of individuals that intersected the transects. Species codes are given in Table 4-10.

Differences in "shrub" richness and abundance were particularly pronounced at the block level (Table 4-12). As the primary interest was to determine how well the imprinted species had become established, this discussion is limited primarily to those species. A particular focus is given to the two most abundant species, *Atriplex polycarpa* and *Suaeda moquinii*.

Table 4-12. Frequency of *Atriplex polycarpa* and *Suaeda moquinii* on the imprinted plots, Tranquillity HRS, 2002. Numbers to the left indicate living individuals, those to the right indicate dead individuals.

Species	Total[1]	Block 1		Block 2		Block 3		Block 4		Block 5	
		Plot		Plot		Plot		Plot		Plot	
		1	2	5	7	11	12	13	16	17	20
Atriplex polycarpa	87/24	1/0	1/0	1/0	64/20	7/1	11/2	2/1	0	0	0
Suaeda moquinii	37/9	1/0	6/0	0/0	2/0	25/0	2/0	1/9	0	0	0

[1] The total number of individuals from all plots.

The nearly complete absence of living *A. polycarpa* and *S. moquinii* on blocks 4 and 5 is immediately apparent (Table 4-12). This paucity of shrubs resulted, in large part, from a severe infestation of false chinch-bugs (*Nysius* sp.) during early summer 2000 (Uptain et al. 2001). Although these insects caused damage in a number of areas, the impact was clearly most severe on Block 5. Although it was hoped at the time that the perennials would be able to recover from this infestation, clearly that has not been the case on Block 5.

The number of surviving individuals of *A. polycarpa* and *S. moquinii* on Block 4, which also was hard hit by chinch bugs, was quite low. Additionally, this block has been increasingly "colonized" by *Bromus madritensis* (red brome; Table 4-8), which may have contributed to the limited establishment of woody species on this block. Likewise, on Block 1 which is dominated by *B. madritensis*, few shrubs have become established on either of the restored plots (Table 4-12).

Of particular interest was the difference in shrub establishment and survival on the berms and their associated "trenches" (i.e., the shallowly excavated area at the base of the berms, Figure 4-14). Although the blocking differences (as discussed above) were too great for this association to be demonstrated statistically, the correlation between the created microtopography (and associated microcatchments) and surviving shrubs was unmistakable in the field (Figure 4-15).

Also worth noting was the absence of native shrubs on any but the imprinted plots. As with the herbaceous species, this absence suggests a paucity of remaining viable native seed in the seedbank. A few additional patterns are worthy of comment. In contrast to the numerous non-native herbaceous species that have plagued the site, non-native woody species have not been problematic to date. The sole non-native woody species noted during shrub monitoring was *Atriplex semibaccata* (Australian saltbush), which occurred on two transects.

Additionally, a few surviving iodine bush were noted during monitoring, with a single individual intersecting a survey transect and three other individuals observed off-transect. Although seed of *A. occidentalis* has been included in many of the seed mixes used in the trials and restoration efforts, to date this species has shown limited potential for becoming established by imprinting. The individuals noted during shrub monitoring were all associated with shrub islands—the groups of transplanted seedlings that were established on the plots during Spring 2000 (Uptain et al. 2001). Interestingly, all observed individuals of *A. occidentalis* were limited to Block 1 (i.e., the area of the study site with the harshest conditions).

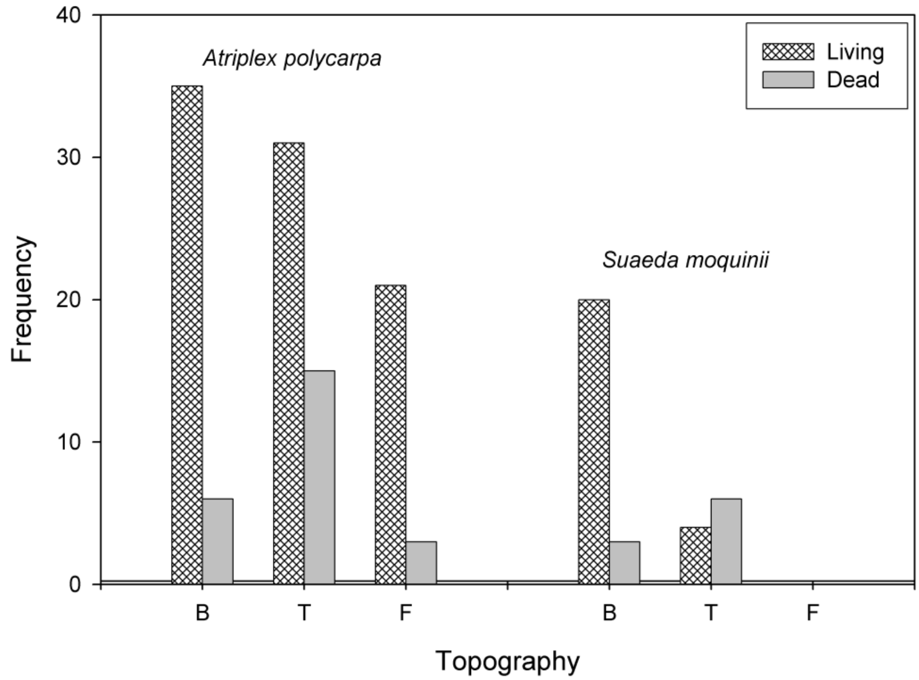

Figure 4-14. Frequency of two imprinted shrubs, *Atriplex polycarpa* and *Suaeda moquinii* on the Tranquillity HRS plots, 2002. Key to topography: B, Berm; T, Trench; F, Flat.

Figure 4-15. Biologist Justine Kokx conducting shrub sampling on the Tranquillity HRS plots. The strong association of the imprinted shrubs (in this photograph, primarily *Atriplex polycarpa*) with the berms and trenches are evident in the linear groupings of the shrubs. Note: this aspect of the photograph is much better seen in color than in black and white.

One factor associated with shrub dieback is the extreme motility of the shrink-swell clays that are typical of the Tranquillity site. During the dry season, substantial cracking occurs in the soil. We observed that if a large crack developed in the rooting area of a shrub, it frequently introduced sufficient stress such that the shrub was severely damaged or killed (Figure 4-16).

Figure 4-16. Severe cracking in the shrink-swell clay soils at the Tranquillity HRS site. White plastic tubes were used in watering the plants in the shrub islands (see Uptain et al. 2001). The dead shrub at the end of the crack is a 3-year old *Atriplex polycarpa*.

4.2. TRANQUILLITY SITE RESTORATION TRIALS

– Adrian Howard

Before conducting restoration trials in 2002, certain modifications were made to the seed imprinter to increase its efficiency. These modifications are detailed in Appendix 4-2. Additionally, the technique for determining seeding rate was evaluated and found to be inadequate. We have altered the reporting of seeding rate from pounds per acre to number of pure live seeds per square foot (PLS/ft^2). Hence, seeding rates presented from trials installed in winter of 2001 will be given as lbs/acre; seeding rates for trials installed in winter 2002 will be given as PLS/ft^2. The justification for this is provided in Appendix 4-3.

4.2.1. Berm and Mycorrhiza Trial

4.2.1.1. Materials and methods

Previous trials and restoration efforts have shown that creating some micro-topography in the form of berms aids in the establishment of plants after imprinting and may benefit certain species of wildlife. The installation of berms on past trials and restoration efforts focused on creating identical berms to eliminate sampling bias. Berms were compacted and rebuilt so that when imprinted, the final berm height would not decrease. To do this required substantial time and effort. When considering large-scale restoration efforts, it might be more economically feasible to create a greater quantity of berms of lesser quality. To make this determination we devised this trial to test whether it is better to make two passes and compact the berms, or if simply making a berm with only one pass works just as well.

The Tranquillity project site has been in agricultural production for decades. Scraping and disking during agricultural operations and during the creation of berms can eliminate the beneficial mycorrhizal fungi in the soil. Accordingly, we incorporated the addition of mycorrhiza fungi as a second factor in this study design. Mycorrhiza—the symbiosis between the roots of a plant and beneficial soil fungi—aids in the uptake of nutrients for many species of plants. Half of the plots were inoculated with commercial mycorrhizal fungi purchased from ConservaSeed of Walnut Grove, CA. The mycorrhizal fungi were applied by mixing with the seed before imprinting the plots at an application rate of 60 lbs/acre.

This trial occupied 10 acres in five replicated blocks, each with four 0.5-acre plots. A stratified random blocking design was used (Figure 4-17). The blocks are located in Section 15 (Figure 4-17). Each plot contains seven evenly spaced berms oriented east to west. Berms are spaced 30 ft apart from their centers and begin 10 ft from the north edge of each plot. A buffer of barley was planted to the north and south of the plots. Plots are separated on the eastern and western sides by approximately 85-ft-wide strips of barley. The berms run through the adjacent plots (i.e., the berms do no stop within the plot boundaries, but continue into adjacent plots).

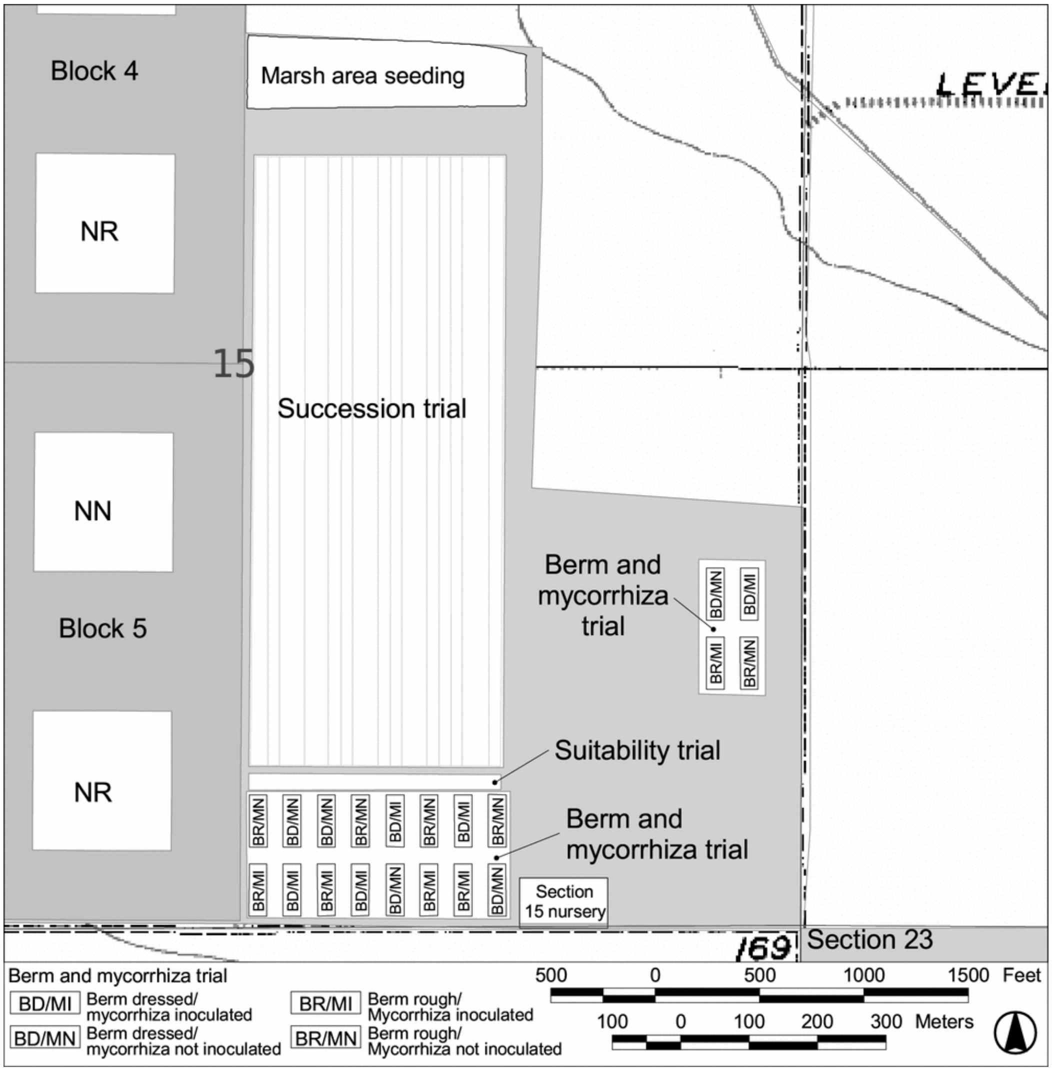

Figure 4-17. Locations of restoration trials on the Tranquillity project site, 2002.

The location and layout of the plots were mapped using a geographic information system (ArcView GIS). Coordinates of the plots where transferred to a global positioning system (GPS) receiver and data storage unit (Trimble ProXRS). Using the GPS receiver and data storage unit, the plot corners were located and marked out using rebar pounded into the ground. Then the ground was springtoothed twice before planting. Treatments applied to the plots were randomized (Table 4-13).

Half of the plots were dressed (compacted) using a springroller/cultipacker that was attached off-center behind a tractor. By attaching the springroller off-center, it was possible to drive the tractor alongside the berms without having to run over them. If compacting the berms is determined to be beneficial, then the springroller could be attached behind the border maker. This would allow berm construction to be completed in a single pass. The gaps between the berms were disked to fill in the furrow that was left beside the berms.

Table 4-13. Design of the Berm and Mycorrhiza trial.

Block	Plot	Tractor passes	Berm treatment	Mycorrhiza	Treatment code
1	1	2	Dressed	Not Inoculated	BD/MN
1	2	2	Dressed	Inoculated	BD/MI
1	3	1	Rough	Inoculated	BR/MI
1	4	1	Rough	Not Inoculated	BR/MN
2	5	1	Rough	Not Inoculated	BR/MN
2	6	2	Dressed	Not Inoculated	BD/MN
2	7	1	Rough	Inoculated	BR/MI
2	8	2	Dressed	Inoculated	BD/MI
3	9	2	Dressed	Not Inoculated	BD/MN
3	10	1	Rough	Not Inoculated	BR/MN
3	11	1	Rough	Inoculated	BR/MI
3	12	2	Dressed	Inoculated	BD/MI
4	13	2	Dressed	Inoculated	BD/MI
4	14	1	Rough	Not Inoculated	BR/MN
4	15	2	Dressed	Not Inoculated	BD/MN
4	16	1	Rough	Inoculated	BR/MI
5	17	2	Dressed	Inoculated	BD/MI
5	18	1	Rough	Not Inoculated	BR/MN
5	19	1	Rough	Inoculated	BR/MI
5	20	2	Dressed	Not Inoculated	BD/MN

For dressed berms, a second pass was required with the border maker to add more soil and a final disking was needed alongside the berms to fill in the furrows. The berms were not springrolled a final time because the imprinter compacted the berms during seeding. It was expected that the one-pass berms would be lower and more loosely compacted than the two-pass berms. We were also concerned that the compacted berms might prove to be somewhat more difficult for the plants to root compared to the looser soil in the one-pass berms.

Once all the berms were constructed, the plots that would only receive the seed from the restoration mixture were imprinted at a seeding rate of 50 lbs/acre (Table 4-14). The highest setting on the imprinter is 52, which delivers 55 lbs/acre of restoration mixture. Because the mycorrhiza inoculum was to be delivered at 60 lbs/acre and the seed at 50 lbs/acre, it would require two passes with the imprinter. Unexpectedly though, the inoculum was so fine-textured that it clung to the seed making it heavier, and resulting in an accelerated delivery through the seed hopper. The first two plots were seeded at setting 52, but this was quickly changed so we would not run out of seed. For the third plot, the setting was moved to 30. We finished the remaining the plots using setting 30, and then re-imprinted the final eight plots a second time. With these alterations, the correct amount of seed and mycorrhiza was added to each plot. The plots were imprinted in the following order: 7, 8 (setting 52), 11, 12, 16, 19, 17, 13, 2, 3, 3, 2, 17, 13, 19, 16, (setting 30). Imprinting was completed by the second week of February in 2002.

Table 4-14. Seeding rates of the various native plant species used in the Berm and Mycorrhiza trial.

Species	Seeding rate (lbs/acre)
Allenrolfea occidentalis	3.00
Atriplex polycarpa	3.00
Atriplex spinifera	2.25
Bromus carinatus	4.50
Frankenia salina	0.75
Heliotropium curassavicum	0.75
Hemizonia pungens	0.15
Isocoma acradenia	1.00
Lasthenia californica	0.75
Leymus triticoides	3.00
Sporobolus airoides	1.50
Suaeda moquinii	0.75
Vulpia microstachys	3.00

On 21 March and 20 April 2002, plots 5 through 20 were irrigated. The plots on Block 1 were not irrigated because we where unable to deliver water to that block. Accordingly, the plots occurring on Block 1 were excluded from analysis.

Plots were sampled using fifteen 0.5-meter quadrats (35 cm by 70 cm). Percent cover of all species was estimated within each quadrate. Data were entered into a relational database. Data were analyzed by generating rank-abundance curves based upon percent cover values derived from the database.

4.2.1.2. Results and discussion

Weeds clearly dominated over the imprinted species in all treatments (Figure 4-18, Figure 4-19, Figure 4-20, Figure 4-21). One weed in particular, *Atriplex argentea*, dominated the area during sampling, and subsequently created almost 100% cover in the weeks following sampling. When *A. argentea* matures and flourishes, as was the case in this trial, it grows to about 3 ft and is shrub-like, shading the ground and eliminating competition from other species.

Although the plots all were dominated by weeds, there was great heterogeneity among the plots. Plot 19 had large numbers of healthy *Suaeda moquinii*, mostly growing in the southern half of the plot. The surrounding plots had few *S. moquinii*. It is possible that the success of *S. moquinii* in the southern area of Plot 19 is due to a difference in soil type. This portion of the plot contains Ciervo clay, whereas the rest of the plot and most of the Tranquillity project site contain Tranquility clay.

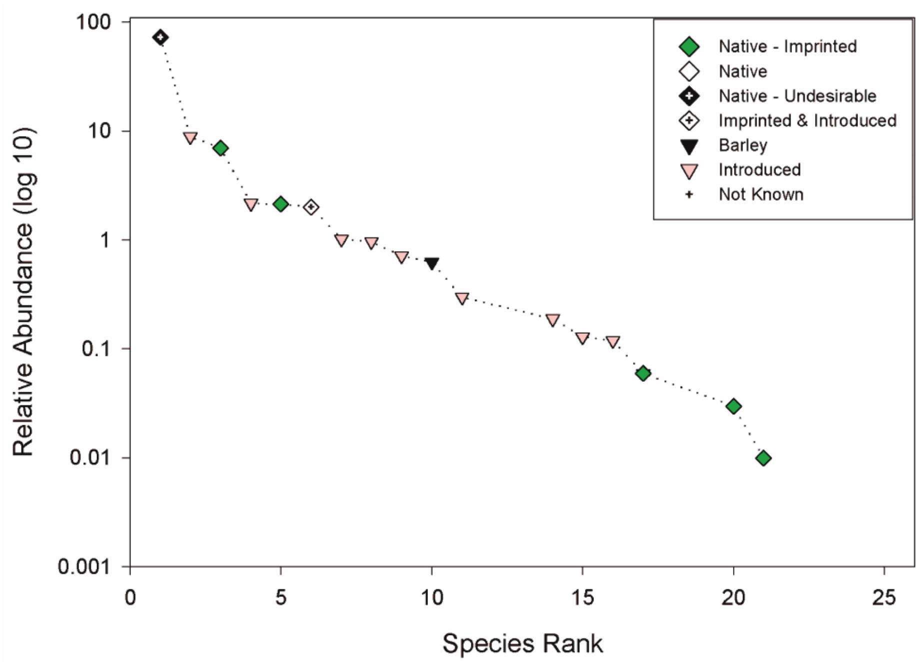

Figure 4-18. Rank abundance curve of the BR/MN treatment for the Berm and Mycorrhiza trial. See Table 4-13 for an explanation of treatment codes.

Another major form of heterogeneity occurred between Block 1 (plots 1-4) and the other blocks (plots 5-20). Plots 1-4 were not irrigated, resulting in minimal plant growth (both imprinted species and weeds). The other plots were irrigated and had nearly 100% vegetative cover. This implies that supplemental irrigation is needed for plant growth when the ground is dry from lack of rain. In the following year (2003), native plants still did not germinate on those plots, although weeds did exceedingly well.

The addition of supplemental irrigation water also resulted in unexpected changes in the plant communities. In the irrigated plots, there were a total of 55 plant species found during sampling. This is more species per unit-area than had been previously recorded at the Tranquillity site. Nineteen of the species found had not been previously identified at the site. It is not known whether these additional species were present in the soil as persisting seed, or if the seed had been imported with irrigation water. Representatives from Westlands Water District remarked that weed seeds are not present in irrigation water because that water is imported via pipes, not open canals. A number of these 19 species have since been found in other locations on the project site, but for the majority this is still the only recorded occurrence.

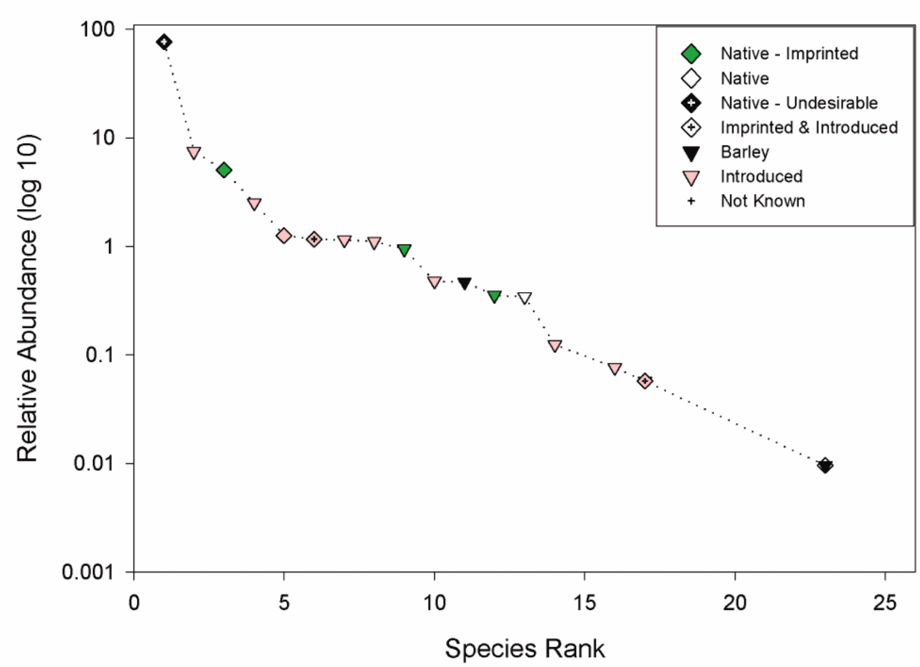

Figure 4-19. Rank abundance curve of the BR/MI treatment for the Berm and Mycorrhiza trial. See Table 4-13 for an explanation of treatment codes.

The results of this trial and other trials that have been conducted at the site, illustrate the need for aggressive weed control. Weeds dominate the vegetation on the study and make it impossible to accurately determine treatment effects. Accordingly, effective weed control will be an essential component in determining appropriate and large-scale restoration techniques.

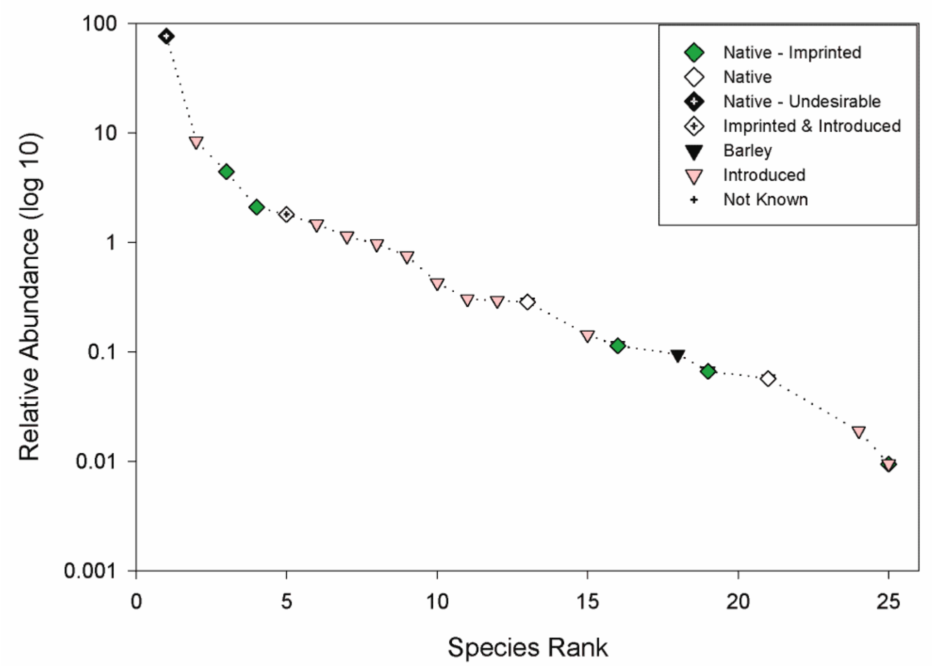

Figure 4-20. Rank abundance curve of the BD/MN treatment for the Berm and Mycorrhiza trial. See Table 4-13 for an explanation of treatment codes.

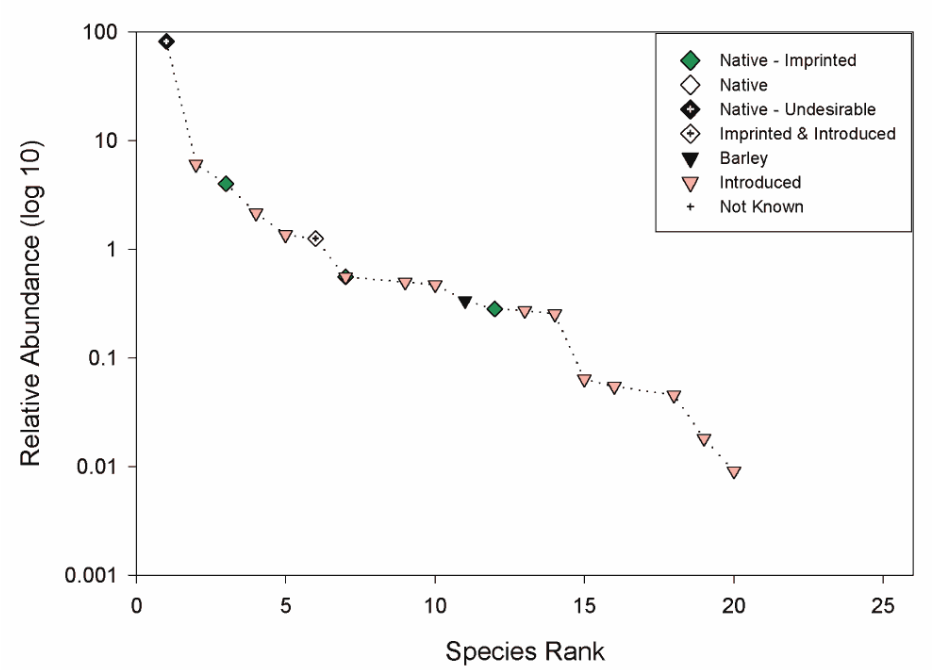

Figure 4-21. Rank abundance curve of the BD/MI treatment for the Berm and Mycorrhiza trial. See Table 4-13 for an explanation of treatment codes.

4.2.2. Marsh Area Seeding

A seasonal wetland created by agricultural runoff formed on lands just north of the study area. This area is not owned by the LRDP, but water would often overflow into LRDP property, forming a wet, marshy area. In 2000, this area was imprinted with a native seed mixture consisting of plants naturally occurring in mesic conditions and upland habitats. In 2001, a local farmer inadvertently disked this area. Therefore, in January 2002, 9.6 acres of this area were re-imprinted (using setting 12 seed-delivery rate) using the same seed mixture used in 2000. (Table 4-15).

Table 4-15. Marsh Area seed mixture.

Species	**Common name**	**Source**	**Pounds per acre**
Atriplex polycarpa	valley saltbush	Fresno county	0.13
Dichelostemma capitatum	blue dick	Camp Pendleton	0.38
Eleocharis macrostachya	spikerush	Grass Valley	0.13
Frankenia salina	alkali heath	San Diego – coastal	0.38
Heliotropium curassavicum	heliotrope	Temecula	0.38
Isocoma acradenia	goldenbush	Indio	0.25
Juncus balticus	Baltic rush	Unknown	0.25
Lasthenia californica	goldfields	Hemet	0.25
Leymus triticoides	creeping wild rye	Fresno county	1.13
Lupinus bicolor	miniature lupine	California Valley/Carrizo Plain	1.25
Mimulus guttatus	monkeyflower	Bakersfield	0.25
Poa secunda	bluegrass	W. Lower Central Valley	1.25
Sporobolous airoides	alkali sacaton	Unknown	0.5
Suaeda moquinii	bush seepweed	Lakeside	0.25

No qualitative sampling was conducted on this area because virtually no plant cover developed. Not even weeds germinate on this soil; it remained barren, but for divot marks from the imprinter.

There could be several reasons why plants did not germinate in this soil, including soil compaction from several imprinting attempts and the possibility that the soils were affected from the area previously being used as an agricultural drainage sump. While it was thought that heavy rains could cause the area to flood once again, that has not yet been the case. Accordingly, it is not recommended that additional seeding of facultative wetland plants occur in this area in the future.

4.2.3. Suitability trial

To broaden the selection of species used in our restoration activities, an analysis of the suitability of a variety of species was initiated.

4.2.3.1. Materials and methods

A list was compiled of species that had been used in other restoration projects or which seemed to be likely candidates for inclusion in restoration activities. The resulting 43 potential species were then ranked based on a series of criteria (presented here in alphabetical order):

- Ability to withstand high levels of sunlight
- Active growth period
- Adapted for clay soil
- Availability (from suppliers)
- Cost per pound of PLS (pure live seed)
- Drought tolerance
- Fire tolerance
- Growth rate
- Known from the county
- Known from nearby reserves
- Legal weed status
- Life history (e.g. annual/perennial)
- Life-form (e.g. shrub, forb, etc.)
- Mature height
- Minimum precipitation requirement
- Mycorrhizal status
- Pretreatment requirements
- Salt tolerance

Based on this evaluation, four grasses, *Elymus glaucus*, *E. multisetus*, *Nassella cernua* and *N. pulchra*, and a single broadleaf species, *Eriogonum fasciculatum* (Polygonaceae), were selected for planting. *Bromus carinatus*, a grass that has been used in earlier trials at the Tranquillity site was selected to serve as a control. The species evaluated for this trial are listed in Appendix 4-4. The seeding rate was standardized so that there would be 35 PLS seeds imprinted per square foot (Table 4-16). Wheat bran was mixed with the seed 2:1 to float the seed and fill the hopper because we were working with such small amounts.

Table 4-16. Seeding rate for various species used in the Suitability trial. Seeding rates are expressed in number of pure live seeds per square foot (PLS/ft^2).

Species	Species code	Seeding rate	Lbs seed
Bromus carinatus	BRCA	35	8.3
Elymus glaucus	ELGL	35	4.0
Elymus multisetus	ELMU	35	5.3
Eriogonum fasciculatum	ERFA	35	15.6
Nassella cernua	NACE	35	5.3
Nassella pulchra	NAPU	35	5.3

Imprinting occurred on 15 March 2002. Each species in this trial was planted in a single plot measuring 12 ft x 1200 ft or roughly one-third of an acre. All plots were configured in an east-west orientation. The imprinter was run twice over the same plot for each species. Because the amount of seed in the hopper was so small, it required people on the back of the imprinter to stir the seed manually with sticks to keep it flowing. Imprinting began on the western edge going east, turned around and returned. On the western edge of the plots, the highest seeding density began approximately 100 feet into the plot because it took several revolutions of the imprinter to start feeding the seed through the hopper and onto the roller. Seed left over in the hopper from earlier species was found imprinted in the first 100 feet. Seed from each species also was collected and grown in pots at California State University, Fresno to aid with identification during sampling.

Plots in this trial were irrigated starting on 21 March 2002 and continuing for 7 days, and a second time starting on 20 April 2002 for 4 days. We used sprinkler irrigation to apply a total of approximately 9-10 inches of water.

Sampling for the Suitability trial took place from 18-20 June 2002. The grasses were mature enough to identify to genus, but not species. However, because the planting order was known, and no two species from the same genus were side by side, we identified the grasses to species based upon their location. Most of the grasses were no more than 4-5 inches in height, while the weeds, particularly *Atriplex argentea*, were 12-18 inches in height. All other imprinted plants were identifiable to species.

A 1200-ft transect was located through the center of each 12-ft-wide plot. A randomly determined sampling point was selected along each 30-ft section of the transect. Each successive sample was taken from an alternate side of the transect. Percent total cover, percent total weed cover, and percent imprinted species cover were estimated within a 35 by 70 cm quadrat, with the short side of the quadrat placed along the transect. Due to the irregularities with the first 100 ft of the planted plot, the first three samples were eliminated from the analysis.

4.2.3.2. Results and discussion

In all cases, weed species out-performed imprinted species (Figure 4-22). Imprinted species that were the best performers were *Bromus carinatus*, *Nassella cernua*, and *Nassella pulchra*.

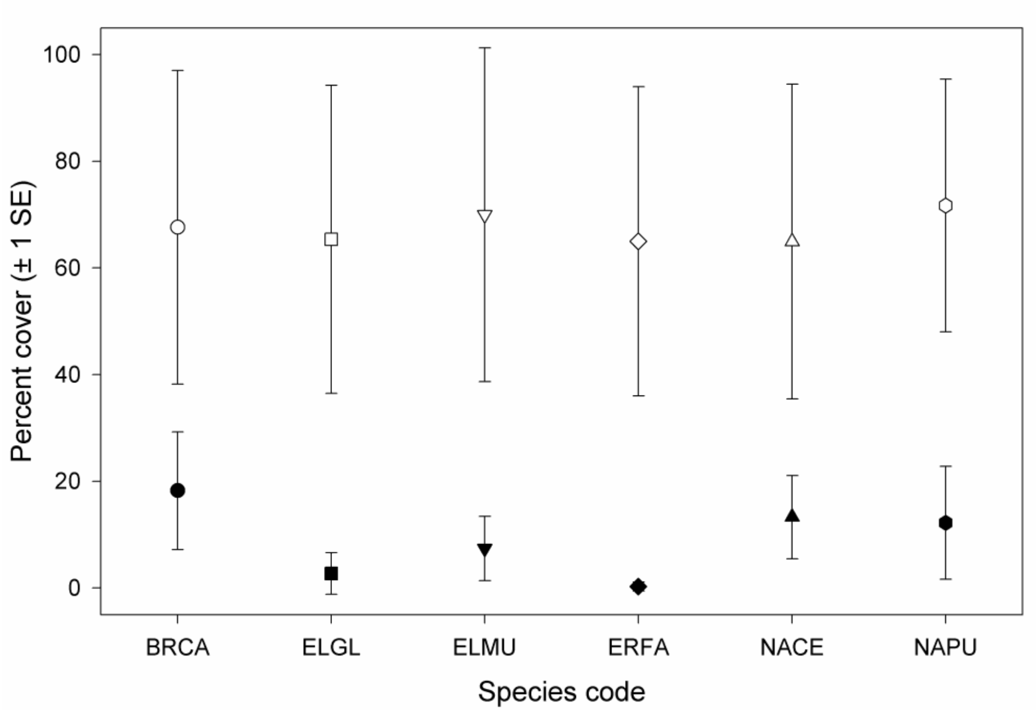

Figure 4-22. Mean percent cover for imprinted and weed species in each plot of the Suitability trial. Black-filled symbols indicate native species cover, while open symbols indicate weed cover. Species codes are presented in Table 4-16.

In 1999, *Bromus carinatus* was included in the seed mixture and planted in the HRS plots. Germination of this grass was initially successful, but in subsequent years, its abundance and contribution to vegetative cover declined. Based upon the results of this trial, it appears that *B. carinatus* is one of the top performing grasses and we suspect that the other grasses would fare no better than *B. carinatus* under typical restoration conditions. The *Nassella* and *Elymus* grasses grew more slowly than *B. carinatus* and perhaps in subsequent years they would contribute more to the vegetative cover. Increased performance of all of these grasses might be achieved by using locally collected seeds, rather than seeds obtained from outside of the San Joaquin Valley, such as were used in this trial. However, we suspect that increased performance over time and the use of locally collected seeds would not contribute greatly to establishment of grasses given the extreme dominance of weeds. This trial, and other trials that we have conducted, illustrate the need for aggressive weed control.

4.2.4. Succession Trial

4.2.4.1. Materials and methods

Since the inception of the Land Retirement Demonstration Project, barley (*Hordeum vulgare*) has been used as a cover crop at the Tranquillity project site to control weeds and prevent soil erosion (Selmon et al 2000). Barley is a preferred cover crop because it is capable of maintaining a mycorrhizal soil network, unlike bare soils or weed-dominated environments (Ted St. John pers. comm.). However, because barley requires yearly management (each year in late summer it needs to be shredded, harrowed, and replanted) a better cover crop may be provided by a select group of native plants, especially grasses.

This trial was designed to examine the mobility (dispersal) of three different types of seed mixtures: barley, barley and native grasses, and our restoration mixture. Two factors were examined: the ability of native grasses to become established when imprinted over an existing barley crop; and the relative abilities of barley and imprinted native grasses to spread beyond the confines of their seeded area.

It is important to note that while cover cropping with native plants would provide better habitat with less maintenance, it is not likely that it would be maintenance free. It may be necessary to occasionally mow, graze, burn, or otherwise manage the cover crop in ways that would mimic conditions that would have occurred historically, but are now absent from the ecosystem.

An 80-acre trial using three different planting designs was installed north of the Berm and Mycorrhiza trial, and south of the marsh mixture planting area at the Tranquillity project site (Figure 4-17). In February 2002, the trial area was delineated using a DigiRoller Plus roller wheel, and marked using white paper bags. The plots were configured in a north-south orientation, in five blocks with three plots each. Using a complete random block design, plots were assigned one of three treatments (Table 4-17): barley only; barley and native grasses in a 50/50 mixture; and, restoration mixture (Table 4-18). The 50/50 mixture was comprised of equal parts (10 lbs/acre) of *Bromus carinatus*, *Hordeum depressum*, *Leymus triticoides*, and *Vulpia microstachys*. The barley monoculture covered 40 acres; thus, each plot was 120 ft wide. The other two treatments covered 20 acres each and were 60 feet wide.

Table 4-17. Succession trial planting plan. Figure 4-17 shows the location of the trial.

Reference point	Block	Plot	Seed mixture	Plot width
Western edge	1	1	Barley and native grasses	60 ft
	1	2	Restoration mixture	60 ft
	1	3	Barley	120 ft
	2	1	Barley	120 ft
	2	2	Barley and native grasses	60 ft
	2	3	Restoration mixture	60 ft
	3	1	Barley	120 ft
Mid-point	3	2	Restoration mixture	60 ft
	3	3	Barley and native grasses	60 ft
	4	1	Barley	120 ft
	4	2	Restoration mixture	60 ft
	4	3	Barley and native grasses	60 ft
	5	1	Barley and native grasses	60 ft
	5	2	Barley	120 ft
Eastern edge	5	3	Restoration mixture	60 ft

Table 4-18. Restoration mixture used in the Succession trial.

Species	Seeding rate (lbs/acre)
Allenrolfea occidentalis	3.00
Atriplex polycarpa	3.00
Atriplex spinifera	2.25
Bromus carinatus	4.50
Frankenia salina	0.75
Heliotropium curassavicum	0.75
Hemizonia pungens	0.15
Isocoma acradenia	1.50
Lasthenia californica	0.75
Leymus triticoides	3.00
Sporobolus airoides	1.50
Suaeda moquinii	0.75
Vulpia microstachys	3.00

Barley had previously been planted as a cover crop in this area in the fall of 2000, then thrashed and harrowed in 2001, and therefore was already germinating at the time of planting. Consequently, the 120-ft plots assigned to be barley were not replanted.

In the 60-ft areas to be planted with barley and native grasses, it was unnecessary to disk and replant barley because barley already was germinating. We imprinted the grass seed mixture directly over the existing stand of barley at a rate of 40 lbs/acre. This created seeded imprints, with barley growing on the ridges of the imprints. For the areas seeded with the restoration mixture, the plots were disked and allowed to dry so that the barley would not be replanted during imprinting. One extra pass through the middle of each plot was required to maintain the correct pounds-per-plot ratio, as the highest setting on the imprinter could not feed out the seed quickly enough. Disking began on 12 February 2002. Seeding began on 13 February and was completed by 15 February.

4.2.4.2. Results

Germination of native plants did not occur on the plots. We suspect that this was because imprinting was completed later in the season than required. Only the barley, which had been planted the previous summer, was growing. As a result, we did not sample this trial. Inspections will be done in 2003 to determine if germination of the native plant seed occurred later. If natives are present, we will conduct appropriate sampling.

4.2.5. *Suaeda moquinii* Salvage

On 8 April 2002, it was learned that State Route 180 (Whitesbridge Ave.) was being widened along a portion of the highway between the north and south portions of the Kerman Ecological Reserve. This stretch of the highway has shoulders of approximately 30-ft on each side. Along these shoulders are many native plants that have become established from the adjacent Ecological Reserve. Because much of this area was to be cleared of brush within 2 weeks, we salvaged as many shrubs as possible. Due to conflicting tasks and the need to obtain appropriate collecting and encroachment permits from the California Department of Transportation, only 1 day was spent salvaging shrubs before construction activities. Eight laborers were hired from F&F Contracting to assist with transplanting. Only *Suaeda moquinii* were transplanted because there were hundreds of individuals available and many were small enough (6-12 inches in height) to transplant. Although many *Atriplex polycarpa* also were present, most were exceedingly large and they would have been difficult to transplant.

An area in the Native Plant Nursery (see Section 4.3) was prepped for the transplants on 16 April. All the weeds were mechanically removed from the northernmost two rows in the nursery to accept the transplants. Transplanting began on 18 April 2002. The soils from the donor site were hard clay and very dry, which proved problematic. The soil would crack when a shovel was put into the ground and fall away from the plant, leaving broken bare roots. Care was taken to dig around the plants in an attempt to remove them with the soil intact, but this was generally not possible. The root ball was wrapped in a burlap sheet cut to size and then kept moist until transplanted. A few plants were taken bare root.

Plants were moved by truck to the nursery, planted, and given approximately a gallon of water. Plants under 6-8 inches in height were planted two or three to a hole. On 19 April, the plants were watered using existing furrows to provide deep moisture to the plants.

A total of 140 plants were transplanted into 70 holes. None appeared to be alive when surveyed on 22 July 2002. Likewise, a survey conducted after the onslaught of fall rains indicated that there were no survivors. It is likely that the timing of transplanting was incorrect and that survivorship could have been increased if certain precautions could have been taken. For instance, soaking the soil around all the plants to be transplanted provides more soil moisture and helps to keep the soil from breaking away from the plant. Transplanting while the plant is dormant also reduces the shock from transplanting, as does giving the plants an opportunity to harden in a lath house or greenhouse. Salvage operations should be considered earlier in construction projects so that these factors can be considered in timing of the salvage.

4.2.6. Growth-form and Herbicide Trial

Vegetation restoration criteria on retired farmlands in the San Joaquin valley should include the establishment of a mosaic of native plant communities that would provide sufficient cover and productivity to prohibit invasion by weedy species and be resistant to natural disturbances. Many native plants, especially long-lived and desirable species such as grasses, have low reproductive rates and are slow to germinate and grow. Weeds in the Tranquillity project area typically germinate faster than native seeds and have higher fitness in disturbed communities. This gives them a competitive advantage whereby the weeds overtop and out compete desired native species. An ideal native species mixture would germinate quickly, grow higher and faster than the weeds, and produce seeds to maintain or increase native plant cover in successive years. These plants should also act as nurse crops for additional native species that could be over-planted in successive years, leading to increased overall biodiversity of native plants. However, native plants that are weedy would not be desirable because they would potentially limit the future introduction of other native species. Furthermore, certain negative interactions can occur in a typical mixed-species and mixed-growth-form seed mixture. For instance:

- Annual grasses can grow faster and overtop perennial grasses.
- Perennials planted alone may not establish quickly enough to out-compete the quicker-growing annual weeds.
- Herbaceous plants may grow quickly but be too small for the surrounding weeds.
- Native plants that germinate in the spring or summer may not get a chance to germinate if the winter weeds already are completely dominating a site.

This trial investigated how creating a specific seed mixture for use with different herbicides could produce good ground cover, lower the competition from weeds, and ultimately affect long term planting success. The primary weeds that grow in the area include *Avena fatua*, *Beta vulgaris*, *Brassica nigra*, *Erodium cicutarium*, *Hordeum murinum*, *Hordeum vulgare*, *Melilotus indica*, *Phalaris minor*, and *Sisymbrium irio*. Herbicides were selected based upon the need to control these weed species. Weedar 64 (2,4-D) kills broad-leaved species, Poast (Sethoxydim) kills grasses, and Roundup (Glyphosate) kills most green growing plants.

This trial was located in the northwest quarter of Section 23 (Figure 4-24). The plots were spaced in two rows with eight columns. Four replicates configured in a random block design with sixteen 0.5-acre plots (a total of 8 acres). Three seed mixtures (Table 4-19) were planted over two acres each and were sprayed with an appropriate herbicide. We intended to imprint the Native Grass mixture, but due to the long awns on some of the seeds, they would not feed properly through the imprinter hopper. Therefore, the seeds were hand-broadcasted over the plots and then run over with the imprinter; this resulted in some areas of the plots not being seeded evenly.

The final two acres were the control plots, with no planting or herbicide treatment (Figure 4-24). The buffer area between plots was planted in barley. The entire area was disked in the spring and no further weeds germinated due to the drought.

Table 4-19. Species and seeding rates for the Growth-form and Herbicide trial. Seeding rates are expressed in PLS/ft^2.

Species	Seeding rate		
	Native grass mixture	Forb and shrub mixture[1]	Late season mixture[2]
Allenrolfea occidentalis	—	—	14.03
Atriplex polycarpa	—	—	4.88
Aristida ternipes var. hemulosa	10.17	—	—
Bromus carinatus	9.92	—	—
Eschscholzia californica	—	7.2	—
Frankenia salina	—		14.52
Gilia tricolor	—	12.63	—
Grindelia camporum	—	—	10.04
Heliotropium curassavicum	—	—	10.27
Hemizonia pungens	—	9.79	—
Lasthenia californica	—	15.62	—
Lupinus bicolor	—	12.76	—
Nassella cernua	7.4	—	—
Nassella pulchra	17.05	—	—
Phacelia ciliata	9.43	—	—
Sporobolus airoides	16.07	—	—
Suaeda moquinii	—	—	4.96
Vulpia microstachys	8.78	—	—

1 This mixture consists of species that are quick to germinate in the winter after the first rains of the year and will hopefully be competitive with the annual weeds.

2 Late season mixture, these species generally will not germinate until late winter/early spring.

Plots were seeded on 20 November 2002. The imprinter was run empty through the non-seeded plots. Monitoring for the correct timing of the herbicide applications will continue through the winter. Sampling of this trial will occur in spring 2003 and results will be presented in the final study report.

4.2.7. Mowing Trial

An experiment intended to test the effectiveness of mowing to control weeds has undergone several changes before reaching its final incarnation. The objective was to discover if mowing after seeding native species prevents weeds from going to seed and aids in the establishment of imprinted natives.

Originally, on the southwest portion of the North Avenue Parcel (Figure 1-2), sixteen 0.5-acre plots were installed on 25 September 2002. They were oriented in a four by four square of plots and treatments were aligned east to west in four blocks (Figure 4-24). After installation, sheep from a neighboring property illegally grazed the southernmost block. Therefore, the trial was moved north a few hundred feet and reinstalled on 14 October. Within a few days, the new area was also illegally grazed by sheep from a neighboring property.

It was decided to move the entire trial to the northeastern portion of the North Avenue Parcel, far away from the grazing. On 18 October 2002, a new location was chosen, but when the crews arrived to reinstall the trial, this site had been illegally grazed as well. Unfortunately, enough of the North Avenue Parcel had then been grazed that there was no longer room to situate the trial and subject all plots to the same pre-treatment conditions.

On 13 November, the Mowing trial was installed east of the herbicide and growth form trial, on the northwest quarter of Section 23 (Figure 4-24). This area has received the same weed treatment as the rest of Section 23. Seeding will take place in January of 2003.

The trial will involve mowing when the weeds are overtopping the natives or are preparing to set seed. Ideally, after the first rains there will be a large flush of weeds that arrive before the imprinted natives germinate. These can be mown to keep the area more open and allow more light to reach the natives. In vegetables, if an area can be weed free for the first quarter or third of their growing season, then the later growing weeds affect them much less (Diver 2002). Furthermore, the later emerging weeds often do not significantly increase the residual seedbank to affect the following year (Swanton et al. 1999).

As time passes, weeds can continue to be mown at a height higher than the seeded plants. Once the desirable annuals go to seed, and when the late growing species are still small or waiting to germinate, the weeds should be mown down again. What is not known is if the mown weeds will act as mulch and prevent the germination of seeded species.

The final incarnation of the trial consists of 16 plots in an 8 by 2 configuration (Figure 4-24), running east west, a similar configuration to the herbicide and growth form trial to the west. Treatments were assigned using a randomized complete-block design, with four plots oriented in groups of four blocks with four treatments (Figure 4-24). The seed mixture is presented in (Table 4-20); the buffer area between plots will be planted in barley.

Table 4-20. Species and seeding rates for the Mowing trial. Seeding rates are expressed in number of pure live seeds per square foot (PLS/ft^2).

Species	Seeding rate
Grindelia camporum	16.49
Heliotropium curassavicum	4.11
Hemizonia pungens	17.69
Phacelia ciliate	17.09
Sesuvium verrucosum	5.35

Prior to imprinting, the area will be disked. The entire section has been previously disked for weed control and additional disking would not greatly impair the site. The site will then be imprinted in January 2003 with the imprinter run empty through the non-seeded plots.

4.2.8. Section 10 Burn Trial

In 2001, a lit cigarette tossed onto the roadside along State Route 180 (Whitesbridge Ave.) adjacent to the Alkali Sink Ecological Reserve (Figure 1-2) caused a fire that spread through an area dominated by Mediterranean grasses. In this area were some native species, including *Allenrolfea occidentalis*, *Sporobolus airoides*, *Hemizonia pungens* and *Lasthenia californica*, but they were growing in much lower numbers compared to the non-native plants.

The following year the burned area had some of the best native plant cover in the entire reserve. In addition to the four species already mentioned, *Frankenia salina*, *Spergularia atrosperma*, *Lasthenia chrysantha* and *Gilia tricolor* germinated and were doing exceptionally well. Furthermore, the Mediterranean grasses did not recover the year following the fire, and composed only a very small percentage of the cover. Most of the perennials were stump sprouting and the annuals carpeted the ground.

Late spring fires can be used to good effect in areas where there is an accumulated thatch layer (Pollak and Kan 1998), as on Section 10 of the Tranquillity project site. In another study (Wilson and Stubbendieck 2000), spring burning resulted in a 50% decrease in *Bromus inermis* (smooth brome). Haines et al. (2002) reports that *B. madritensis* is fire adapted, returning in higher densities after fire events, potentially due to a nutrient pulse.

Because it appeared that some native species were performing exceptionally well after a fire, a trial using a controlled burn in a non-native grass community seemed appropriate. Unfortunately, acquiring the appropriate burn permits is complex and takes time.

In June of 2002, a fire was set on Section 10 of the Tranquillity site by a lit cigarette tossed onto the roadside of Adams Ave. (south of Section 10). Because Section 10 was dominated with *Bromus madritensis* and a layer of thatch, we took the opportunity to plant some of the seemingly fire-adapted native species to see their establishment after a burn.

Because the brome might return strongly the first year after a burn, a second treatment, mowing, was added to the trial. Therefore, should the weeds start growing well, the mowing will give the imprinted species an extra opportunity to compete.

The burned area (Figure 4-23) was mapped using a global positioning system receiver in June, and on 22 November the plots were imprinted with the Section 10 burn seed mixture (Table 4-21) and the imprinter was run empty over the non-seeded plots. Plots were not laid out in a simple matrix; rather, plot locations were chosen to minimize differences in the burn intensity among the treatments.

Table 4-21. Species and seeding rates for the Section 10 Burn trial. Seeding rates are expressed in number of pure live seeds per square foot (PLS/ft^2).

Species	Seeding rate
Allenrolfea occidentalis	7.01
Atriplex spinifera	4.48
Frankenia salina	10.06
Hemizonia pungens	9.83
Lasthenia californica	15.62
Sesuvium verrucosum	5.35
Sporobolus airoides	8.03

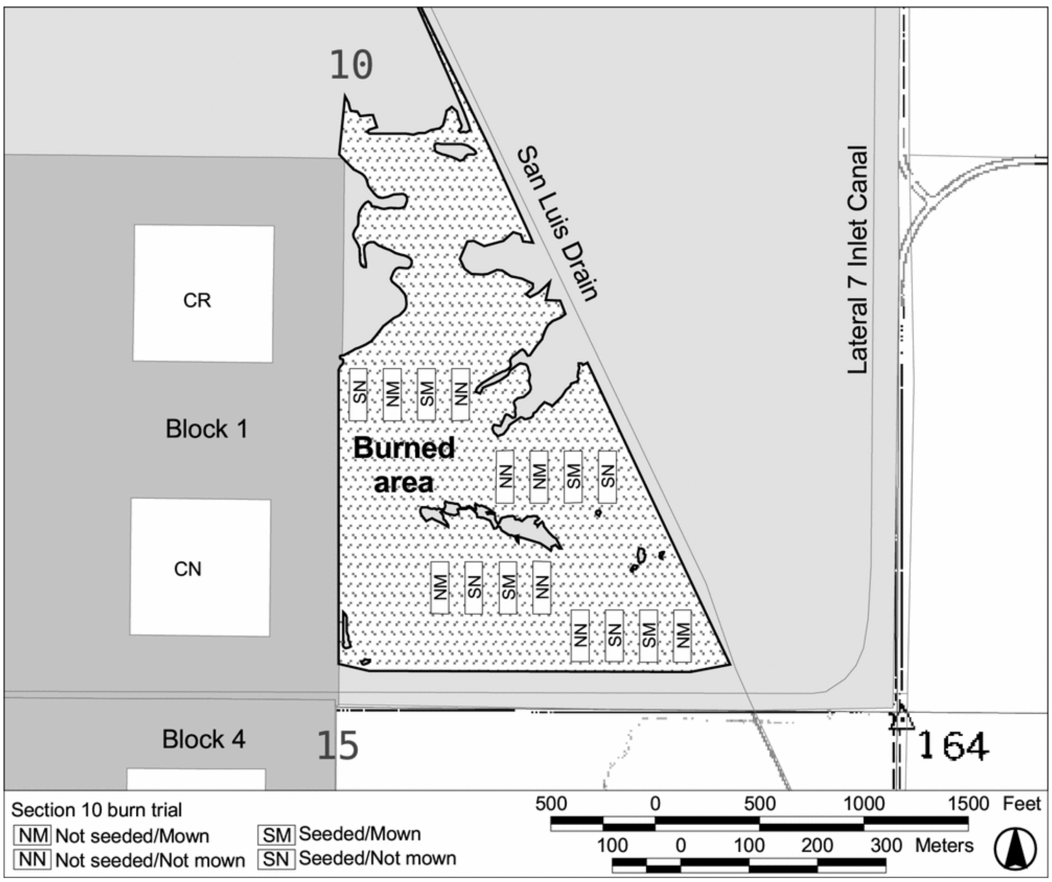

Figure 4-23. The Section 10 Burn trial.

4.2.9. Pre-irrigation Trial

During the installation of the 2002 Native Plant Nursery (see section 4.3), the soil was pre-irrigated to try to bring up as many weeds as possible before planting. Within a month, weeds were covering the majority of the nursery. They where removed, only to have a second flush arrive that also necessitated removal. Using pre-irrigation to induce early weed germination was so successful that it needed further investigation.

Two treatments were chosen, pre-irrigated (PI) and control (N), and a complete random block design was assigned to the eight plots. All plots were seeded with the same mixture (Table 4-22), with species that should do well with a little extra water.

An area along the southern edge of Section 23, and east of the 2002 Native Plant Nursery was prepared for use on September 3 2002, by installing beds in eight 0.5-acre plots (Figure 4-24). *Brassica nigra, Hordeum vulgare and Beta vulgaris* dominated this area during the previous year. During the winter of 2001-2002, the area was disked for weed control. Irrigation was applied from 7-9 September.

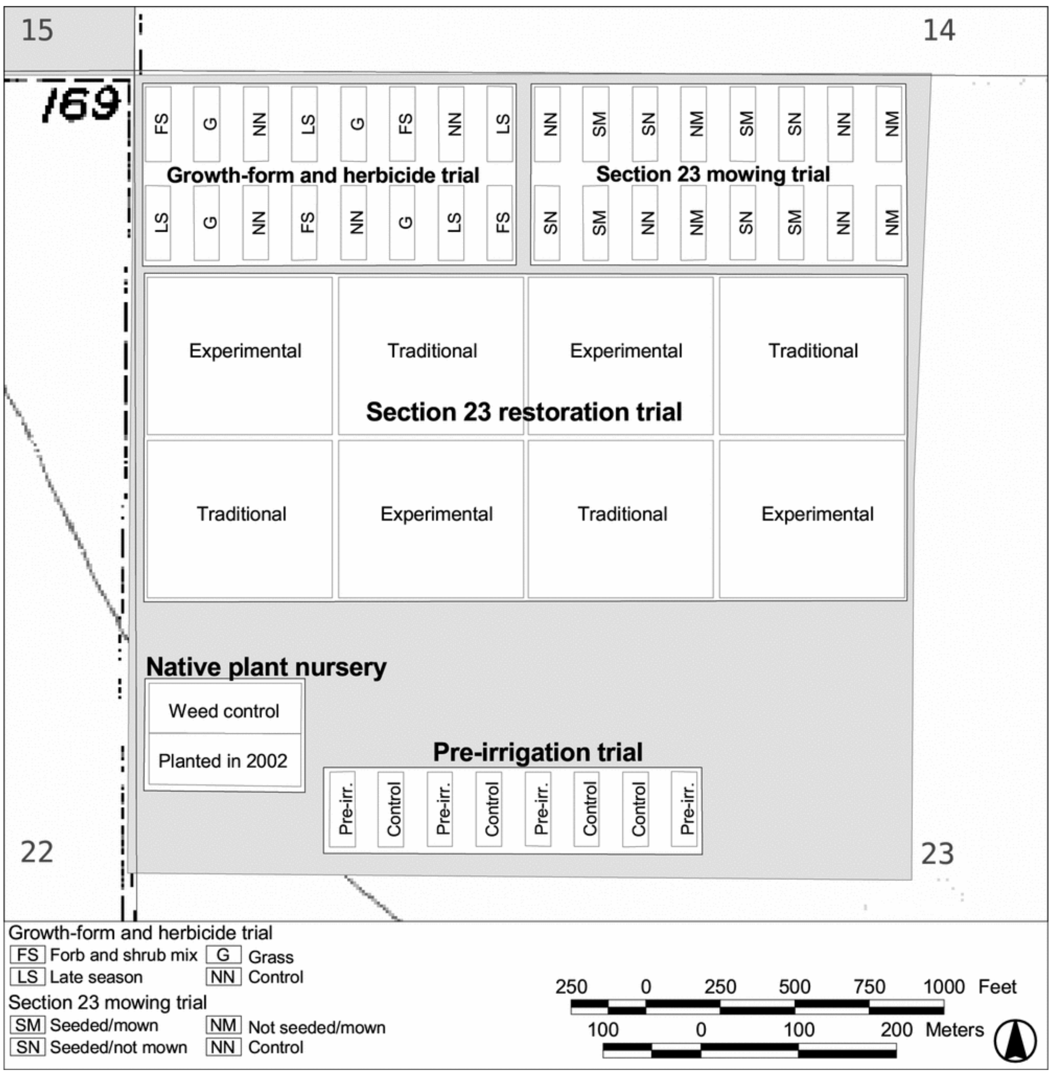

Figure 4-24. Restoration trials in Section 23, and the 2002 native plant nursery.

During the week of 14 October, the plots were disked for weed control, as the pre-irrigated plots had a large flush of weeds. The most common weeds where beets, mustard, and a grass too small to identify.

On 19 November, the plots were imprinted. The plots will be sampled in 2003 for plant cover and analyzed for differences between the pre-irrigated and control plots to see if eliminating the first flush of weeds the natives will have an advantage.

Table 4-22. Seed mixture for the pre-irrigation trial. Seeding rates are expressed in number of pure live seeds per square foot (PLS/ft^2).

Species	Seeding rate
Allenrolfea occidentalis	7.01
Atriplex polycarpa	2.44
Frankenia salina	2.51
Hemizonia pungens	2.45
Lasthenia californica	7.81
Sesuvium verrucosum	2.68
Suaeda moquinii	18.31
Vulpia microstachys	5.12

4.2.10. Section 23 Restoration Trial

As noted, many of the restoration efforts at the Tranquillity HRS have demonstrated limited success. The relatively poor performance of many of the species used in these efforts may be at least partially attributable to the low levels of rainfall that were characteristic during the first three years of the project (see Section 2.1.3). Winter rainfall for 2002 through 2003 was predicted to be fairly abundant (i.e., mild El Niño conditions were predicted). Therefore, in an attempt to evaluate species' performance in an above average rainfall year, an experiment was devised in which two species mixtures were compared. The first, the "traditional mixture" (Table 4-23), was composed of 9 of the 13 species that were applied to the HRS Plots. The second, the "experimental mix"(Table 4-23) incorporated various species that had been used to some success in other restoration trials at Tranquillity,, augmented by a few species that had demonstrated restoration potential elsewhere in California.

The Seciton 23 restoration trial was situated on a 70-acre portion of Section 23, due south of the growth form and herbicide trial and the Mowing trial (Figure 4-24). This area had received some weed control and was the largest contiguous block available. The trial was composed of eight, 7.5 acres (526 x 620-ft) Plots, in an array of four Blocks, and randomized by treatment.

As noted, results from vegetation monitoring on the Tranquillity HRS plots suggested that the establishment of perennial vegetation was positively correlated with the presence of berms. Hence, micro-topographic contouring was incorporated in the study design of this trial. Berms were aligned east to west and were the full length of the plot. Berm spacing was 30-ft, such that part of a flat and half of a berm would be imprinted in a single pass and with a final pass through the middle of a flat, there would be no overlap in seeding. In this manner, the berms were also compacted slightly.

Due to the size of the plots, the corners were mapped using a geographic information system (ArcView GIS) and measured in the field 20 November 2002 using a GPS receiver and data storage unit (Trimble ProXRS) to aid in installation. On 20 November 2002, the plots were delineated in the field. Imprinting was scheduled to follow soon after. However, rainfall during this period precluded the use of heavy equipment throughout December. Given proper soil conditions this trial will be imprinted in January 2003.

Table 4-23. Species and seeding rates used in the "traditional" and "experimental" seed mixtures for the Section 23 restoration trial. Seeding rates are expressed as pure live seed per square foot (PLS/ft^2). Trad = Traditional, Exp = Experimental.

Species	Common name	Family	Seeding rate	
			Trad	Exp
Allenrolfea occidentalis	iodinebush	Chenopodiaceae	9.4	9.4
Aristida ternipes var. hamulosa	Spreading threeawn	Poaceae	-	6.1
Atriplex polycarpa	allscale saltbush	Chenopodiaceae	10.3	4.7
Bromus carinatus	California brome	Poaceae	8.5	-
Frankenia salina	alkali heath	Frankeniaceae	6.2	-
Gilia tricolor	bird's-eye gilia	Polemoniaceae	-	20.5
Grindelia camporum	gumplant	Asteraceae	-	11.8
Hemizonia pungens	common spikeweed	Asteraceae	1.5	1.4
Lasthenia californica	California goldfields	Asteraceae	29.2	35.4
Lupinus bicolor	bicolored lupine	Fabaceae	-	3.4
Nassella pulchra	purple needlegrass	Poaceae	-	8.9
Phacelia ciliata	Great Valley phacelia	Hydrophyllaceae	-	1.0
Sporobolus airoides	alkali sacaton	Poaceae	15.0	-
Suaeda moquinii	bush seepweed	Chenopodiaceae	1.9	-
Vulpia microstachys	small fescue	Poaceae	18.2	-

4.2.11. Hedgerow Seeding

One common problem with the planting trials is the lack of rain during the past few years (see section 2.1.3). The easiest, lowest cost method to deliver water to a site is simply by running a ditch from the nearest water pump. Therefore, it was decided to try planting next to an irrigation ditch and see how the native species fare with some extra water.

There were examples around Tranquillity where ditch bank hedgerows were successful, but in many cases unintended. Surrounding many of the farmers' irrigation ditches are native plants growing in abundance. This trial was installed in an attempt to replicate this success.

While planning the location of the hedgerows, we learned that the winds predominantly arrive from the northwest. Hedgerows planted along the north and west sides of blocks 2 and 4 and on the Manning Avenue Parcel should help in preventing tumbleweeds and other weed seeds from entering the property.

During the last weeks of November, ditches were dug along the west and northern sides of blocks 2 and 4, and on the northern edge of the Manning Avenue Parcel. The ditches were constructed with extra soil built up in-between the ditch and the road to allow water to overflow toward the center of the blocks, where the soil would be imprinted with native species.

On 3-4 December 2002, some chaff from seed collecting and small amounts of left over commercial seeds were hand broadcasted along all the hedgerows (Figure 4-25, Table 4-24). On 4 December, these areas were imprinted using two different mixtures (Table

4-25). The hedgerows will be watered as needed during the first year and monitored for success.

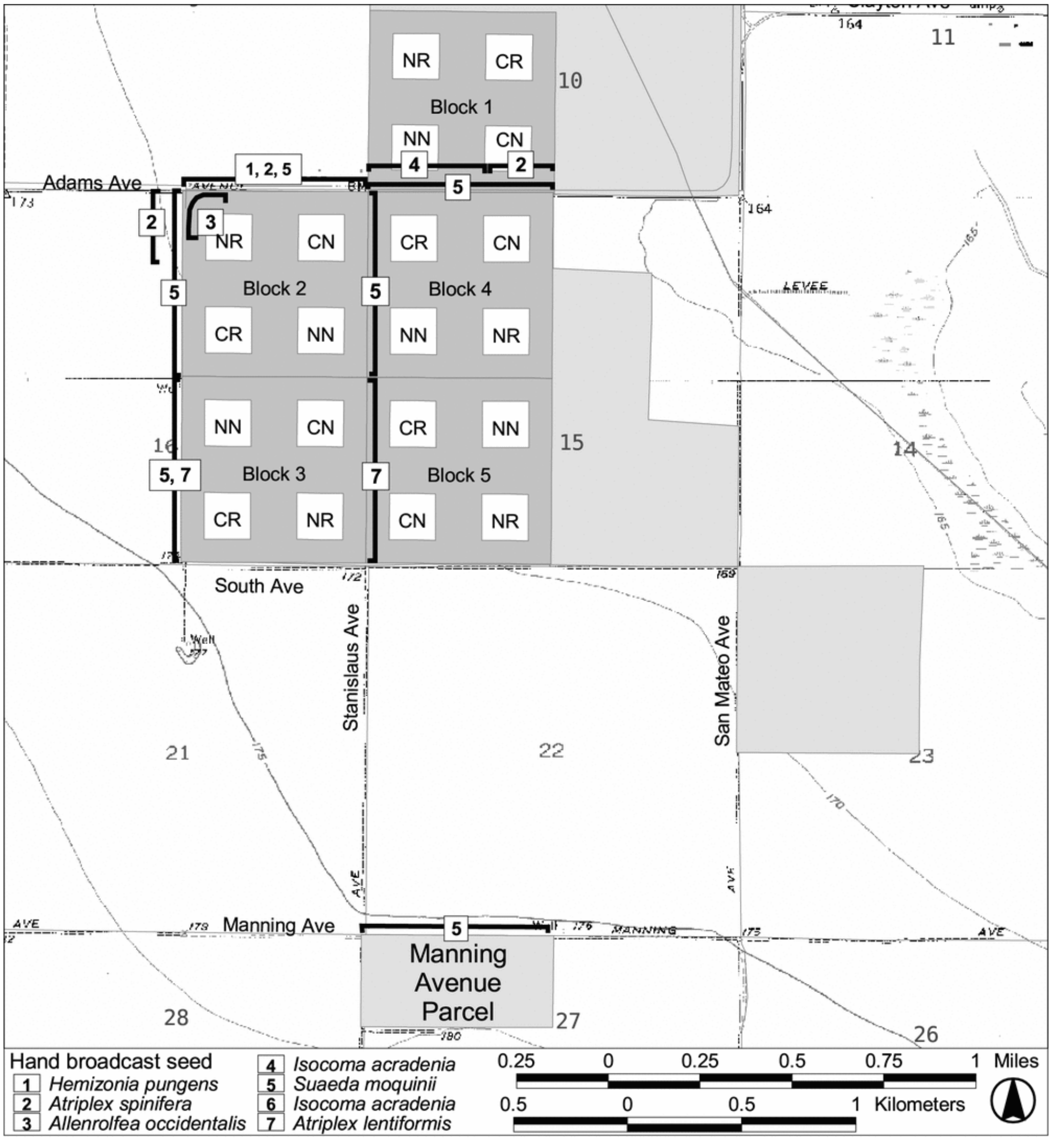

Figure 4-25. Areas hand seeded using chaff and left over seed in the hedgerows.

Table 4-24. Amount of seeds (primarily chaff and left over seeds) hand broadcast along the hedgerows before and after imprinting. Seed amounts are not reported in PLS/ft^2 because no seed analysis was conducted on this material.

Species	Total amount broadcast
Hemizonia pungens	22.50 lbs.
Atriplex spinifera	5.00 lbs.
Allenrolfea occidentalis	1.50 lbs.
Isocoma acradenia	21.75 lbs.
Suaeda moquinii	Unknown
Atriplex lentiformis	Unknown

Table 4-25. Seed mixture and seeding rates for the hedgerow imprinting. Seeding rates are expressed in number of pure live seeds per square foot (PLS/ft2).

Species	Adams[1]	Manning[2]
Achillea millefolium	23.13	20.24
Atriplex polycarpa	5.81	5.08
Eschscholzia californica	49.89	48.03
Gilia tricolor	12.03	10.53
Helianthus annuus	5.59	4.89
Lasthenia californica	357.02	312.4
Lupinus nanus	7.23	6.13
Suaeda moquinii	40.36	36.39

1. Adams Hedgerow seed mixture, planted on the north and west sides of blocks 2 and 4.
2. Manning Hedgerow seed mixture, planted on the north side of the Manning Avenue Parcel.

4.2.12. *Atriplex spinifera* Planting

- Emily Magill

4.2.12.1. Materials and methods

Strategies for the introduction of native vegetation into a community dominated by *Bromus madritensis* ssp. *rubens* (red brome) have been a priority of our restoration research. *Atriplex spinifera* (spiny saltbush), a shrub in the Chenopodiaceae (goosefoot) family, is an important component of San Joaquin Valley saltbush scrub communities because it provides cover and forage for a variety of wildlife species. Additionally, *A. spinifera* represents the only species of native shrub that has managed to become established on the fallow land of Section 10 of the Tranquillity site, an area characterized by non-native grassland dominated by *B. madritensis.*

While mature *A. spinifera* shrubs grow on the area directly north of Section 10, no seedlings have been identified during the 4 years of restoration efforts in the area. Although *A. spinifera* seed has been included in the seed mixtures used in various restoration activities at the Tranquillity and Atwell project sites, there has been little indication that this species can be successfully introduced by imprinting.

In an attempt to investigate other means of establishing *A. spinifera* on restored land, Ray LeClerge, owner of Intermountain Nursery in Auberry (Fresno County, California) was contracted to propagate *A. spinifera* from cuttings taken from existing shrubs on Section 10 (Figure 4-26). To maximize the number of individuals produced from the original cuttings, cuttings were rooted, then maintained as stock plants at the Intermountain Nursery.

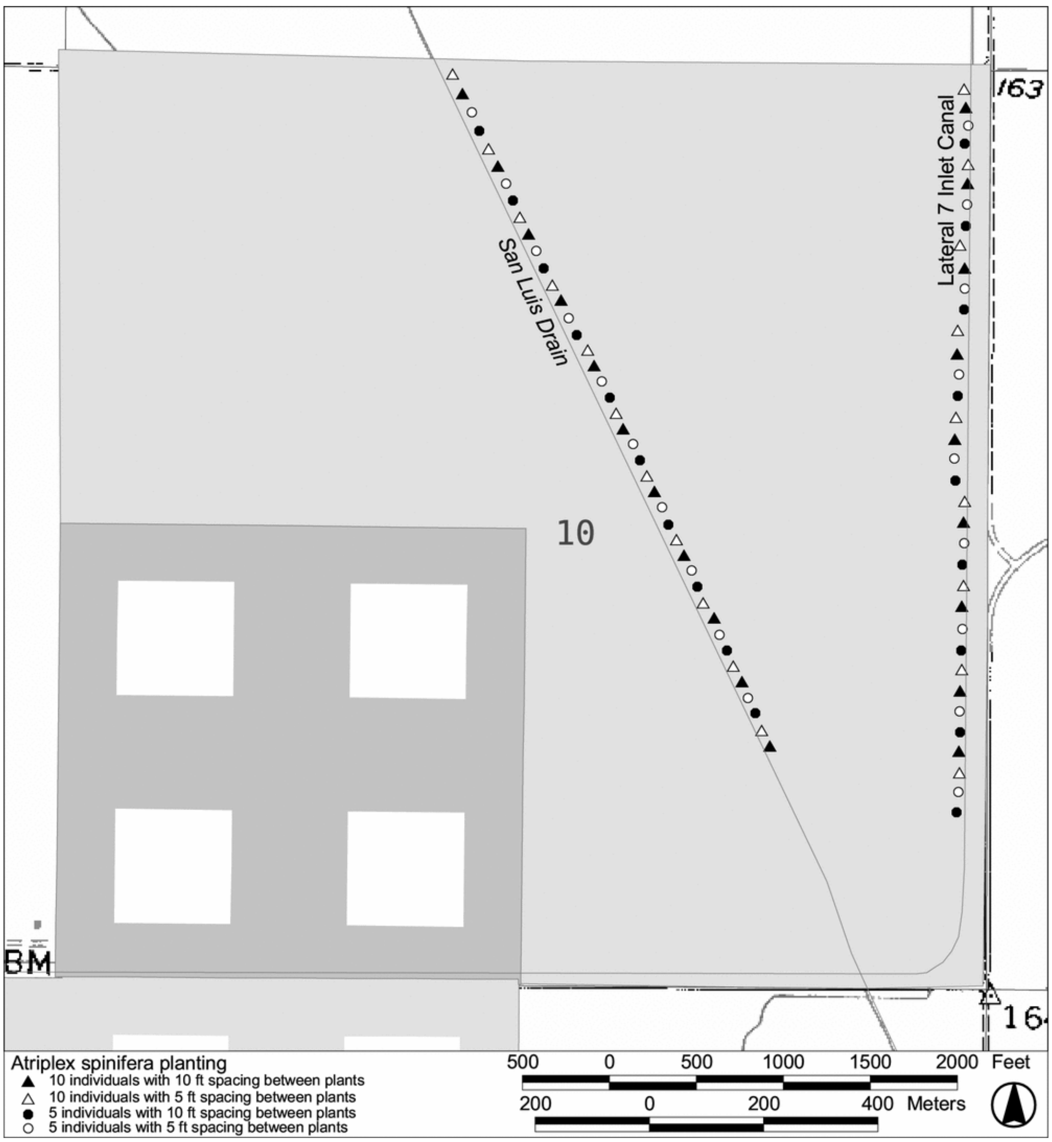

Figure 4-26. Layout of the *Atriplex spinifera* planting.

Once a viable group of stock plants was established, cuttings were taken and used to produce additional plants. Five hundred and ninety plants of different cohorts (age classes) were grown and transplanted to Section 10 of the Tranquillity Project site. Plants were maintained in gallon-sized peat pots until transplanting, and were watered as deemed appropriate (bi-weekly) while in the nursery.

Shrubs where transplanted in groups (shrub islands) of four different configurations:

- 10 individuals with 10-ft spacing between plants;
- 10 individuals with 5-ft spacing between plants;
- 5 individuals with 10-ft spacing between plants; and,
- 5 individuals with 5-ft spacing between plants.

We classified all individual plants into two age groups, “old” and “young”. Old plants were easily distinguished from young plants because they had been rooted before summer, 2001. Their foliage had developed the summer-dormant appearance of spiny saltbush, their stems were woody, and their root systems were developed enough to hold soil for transplanting. Young plants were composed of several cohorts resulting in non-specific identifying characteristics. These plants were rooted during the summer of 2001 and had less root mass than their counterparts. This made it necessary to leave some of the youngest plants in pots when transplanted. In these instances, pots were slashed vertically at three to four locations and the bottom of the pot was removed to allow taproot growth. In general, shrub islands were planted with individuals from a single age class; any departures from this were noted and mapped. Shrub islands were spaced approximately 100 ft apart along the east side of the San Luis Drain, and along the west side of the Lateral 7 Inlet Canal (Figure 4-26; Figure 4-27).

Figure 4-27. Biologists Justine Kokx and Kimberly Kreitinger planting islands of *Atriplex spinifera*. The extreme conditions that characterize the northern end of the site are obvious from this photo.

We removed plants from their pots and planted them up to the plants' potting-soil level. A berm was created around each plant in order to concentrate water around the plant. Plants that were not removed from their pots were buried to the level of the potting soil. The upper lips of the pots served as wells to collect water. All plants received water when planted and every week after that until the site received soil-soaking rains in late December. Transplanting was conducted 14-29 November 2001 and growth was monitored in April, July, and December of 2002.

During each monitoring event, individuals were categorized as either "alive", "dead", "missing", or "dormant". Dormant plants had brown leaves with no new growth. These plants were extremely dry but still showed signs of life. Most of the deaths and dormancy's of *A. spinifera* occurred during times of minimal rainfall (i.e., late spring through summer). The leading cause of death among the plants was browsing by small mammals; the greatest amount of browsing was attributable to *Sylvilagus audubonii* (desert cottontail). These animals live at the base of the San Luis Drain, which is near the location of the browsing. Many of the dead plants had been browsed down to the base of the plant. Many dormant plants had been browsed, but not severely enough to cause death.

Most of the plants classified as "alive" showed signs of growth. Many first year plants produced seeds and grew to 3 feet in height. The most favorable growth was along the western planting strip, farther away fro the San Luis Drain. Sixty-one plants were removed by human interference (e.g., traffic and maintenance of adjacent dirt roads).

4.2.13. Large-scale Restoration Efforts

4.2.13.1. Manning Avenue Parcel Restoration

An 80-acre parcel located south of Manning Ave. was imprinted as part of the annual 160-acre seeding efforts in Tranquillity. This was the first area to be imprinted at Tranquillity in 2002, and because we had the flexibility to change the seeding rates, we decided to use this area to calibrate the imprinter. During the last week of January 2002 the area was disked, then imprinted the first week of February.

There were only two known seeding rates for the imprinter: one from imprinting the HRS plots in Atwell Island (setting 20; 25 lbs/acre), and one from BLM, who had used it earlier (setting 30; 33.2 lbs/acre).

Using these two rates and assuming a linear trend, four settings were chosen for the imprinter. We divided the 80-acre parcel east to west into four equal 20-acre plots (Figure 4-28) and seeded at the selected rates. The northernmost plot along the road would be seeded at the highest rate, decreasing down to the lowest rate in the southernmost plot.

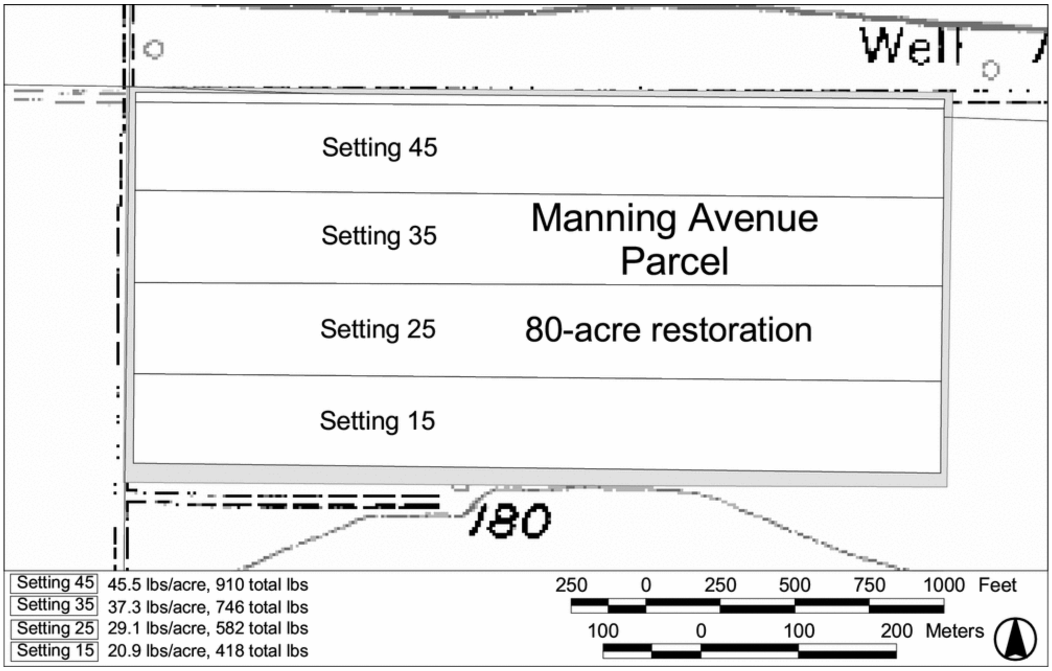

Figure 4-28. Plot layout for the imprinter calibration on the Manning Avenue Parcel.

In practice, a slightly different setting is needed to seed at the lb/acre rates in Figure 4-28. The revised formula for the imprinter seeding rate is: setting + 3 = lbs/acre. However, the formula only holds true for settings above 20 lbs/acre, and using the 2001-restoration mixture. Smaller or heavier seeds feed faster through the imprinter than the mixture we used. We found that changing the seed mixture drastically altered the required setting, and more data will be required before calibration curves for different seed lots can be constructed. Long thin seeds such as grasses can clog the imprinter. Keeping the imprinter at a setting higher than 20 helped to alleviate this problem somewhat, but did not solve it.

This seeding, done while the ground was wet, resulted in a large amount of soil compaction. Few plants germinated and it was not possible to even push a shovel into the ground. Due to the high level of compaction, it was decided to start over on this parcel, so the entire parcel was disked on 12 October 2002 to loosen the soil.

On the Tranquillity HRS plots, the majority of shrubs were growing on the berms or in the trenches. However, because the berms were installed in straight lines, the shrubs also are found in straight lines. By installing winding berms, we hoped to mask that and create the illusion of a more natural growing pattern.

Berms winding east to west across the field were created on 14 October. Berms were spaced 30-ft apart to allow enough room for the tractor and imprinter to run perpendicular to the berms, navigating one berm at a time during planting.

In the first week of November, when the area was to be imprinted, rain fell in the area so we postponed the imprinting to allow the soil to dry. Seeds were imprinted on 24-30 November. Driving perpendicular to the berms, with the constant up and down motion, required slow driving and resulted in increased wear and tear on the equipment.

Moreover, the imprinter would push the berms before finally driving over them, and this filled in the trench on one side, lowering their overall heights.

4.2.13.2. North Avenue Parcel seeding

As part of the efforts to restore 160 acres each year in Tranquillity, an 80-acre parcel at the north end of the North Avenue Parcel was bermed and imprinted by 10 December 2002. The area is bounded by roads on the west and north sides, and the San Luis Drain on the east. The south side of the 80 acres is 1,340 feet from the north edge. An area 175 by 300-ft in the northwest corner was excluded from planting because it had become rutted by heavy equipment that had trespassed onto the site. The rutting was sufficient to prevent us from moving our equipment in to seed the area. This seeding effort differed from the seeding of 80 acres on Manning Ave. in the soil preparation, berm spacing, and imprinting direction.

Before the berms were installed, any large annual saltbushes present were shredded to just above ground level, but the area was not disked before planting. The soils here were slightly moist and loose, which allowed for a good imprint without preparation. The only exception to this was in areas where the thatch of Mediterranean grasses was so thick that it prevented a solid imprint from forming.

The berms run east to west and wind a serpentine path 20-ft wide across the field. Berms were spaced on 20-foot centers and run the length of the field.

These berms were imprinted in the same direction as the berm rather than perpendicular to them. One edge of the imprinter rested on the top of the berm, and the roller extended halfway into the flat between berms. This imprinted the berm and flat well, but often missed 1-2 feet next to the trench. Seeds dropped loosely onto the ground in this area without being pressed into the soil. This method better retained the trench on both sides of the berm and maintained the berm height than running the imprinter perpendicular to the berms.

By seeding parallel with the berms, it also was possible to space the berms closer together. Previously berms had a minimum 30-ft spacing to allow the tractor and imprinter to fit perpendicularly in-between, without driving up one berm as the imprinter comes down another. Besides having more berms per unit area, installation is quicker because the tractor can be driven in a higher gear, reducing cost. Not going over the berms also extends equipment life. This area will be monitored during the growing season and sampled in the spring.

4.3. NATIVE PLANT NURSERY

4.3.1. Native Plant Nursery, 2001 Season

Locating sufficient sources of native seeds of local genotypes has proven extremely problematic. Remnant native seed sources in the Central Valley, such as in ecological reserves and wildlife preserves, are rare and are generally quite limited in size. Furthermore, commercial suppliers of native seed often have limited supplies, are expensive, and offer seeds collected from geographically disjunct locations.

A potentially serious problem exists when seeds or plants of different genotypes are introduced. Genetic mixing of populations adapted to different regions can occur. The introduction of non-local genotypes can produce individuals that competitively displace the local variety, or which respond to environmental cues differently than locally adapted plants. Hence, it is important to use local seed stock to the maximum extent when implementing restoration projects. In order to circumvent these limitations on seed availability and suitability, the establishment of a native plant nursery was begun in 2001 at the Tranquillity site.

Ten acres were set aside for the nursery. The nursery beds were installed in November 2001. Beds were approximately 4 feet wide with 8-inch deep furrows on either side, providing enough space for a bed of annuals or room for shrubby perennials to grow. The nursery was designed to accommodate flood irrigation as needed.

On 12 December, 2.3 acres of the nursery were planted using the seeds collected during the previous 2 years. Seeds were sown by hand then lightly covered by soil by raking it in. Each bed was staked with the species and lot number for later identification.

By 17 January 2002, we noted *Phacelia ciliata* (referred to in Uptain et al. 2002 as *P. distans*), *Lasthenia chrysantha*, *Hemizonia pungens*, *Atriplex polycarpa*, *Spergularia macrotheca*, and *Amsinckia menziesii* growing. Unfortunately, weeds also were present, and included *Sisymbrium irio* and *Melilotus indica*.

Near the end of January, the nursery soil had begun to dry out from a lack of rain. By then the following species were growing: *Hemizonia pungens*, *Spergularia macrotheca*, *Lasthenia chrysantha*, *Amsinckia menziesii*, *Phacelia ciliata*, *Dichelostemma capitatum*, *Atriplex polycarpa*, *Isocoma acradenia*, *Castilleja exserta*, *Suaeda moquinii*, and *Wislizenia refracta*. *Atriplex argentea,* a troublesome weed also was growing.

On 20 February, the nursery was irrigated using gated pipe. It took 3 days to completely irrigate the nursery. The Tranquility clay soils are prone to cracking when dry and take large amounts of time and water to fill. Unfortunately, by the time of this irrigation many of the plants had died because of the lack of expected rain. Yet, *Helianthus annuus* had started to appear, and a week later *Phacelia ciliata* and *Lasthenia chrysantha* were in bloom.

By 11 March, *Castilleja exserta* seedlings had started to appear, a few in flower, but the nursery soil was dry. Over the next few weeks crews hand weeded or weed whacked the *Sisymbrium irio*, *Melilotus indica*, *Atriplex argentea*, and *Hordeum vulgare*. The only exception was the *A. argentea* was not removed from beds with *Atriplex polycarpa*, because of possible misidentification.

A month later, many of the plants were being overtopped by weeds, despite all the efforts spent controlling them. Seed collection began for many species, including *Phacelia ciliata*, *Hemizonia pungens*, and *Lasthenia chrysantha*. Later in the year a small amount of *Isocoma acradenia* seeds were also collected.

By the end of May, the nursery was mostly overgrown by *Atriplex argentea*. While it was possible to collect seed from several species, others that had germinated were no longer found. *Eremocarpus setigerus* and *Trichostemma lanceolatum* are notable examples of plants we expected would germinate later but did not.

Atriplex argentea was extremely abundant in the seeded areas, while *Sisymbrium irio* dominated the region of the nursery that was not planted. Various hypotheses were considered, including that the disturbance of planting and the weed whacking of the *S. irio* released *A. argentea* seedlings. However, what was evident in the Berm and Mycorrhiza trial was that irrigating promotes growth of *A. argentea*. The areas of the nursery that were not planted were not irrigated, thus the most logical reason *A. argentea* was so successful in planted areas was due to irrigation.

Stands of mature *Atriplex argentea* are generally unsusceptible to the use of Roundup at the standard household concentration of 2%. At 6.25% it will kill the shrubs in 2-3 weeks. However, the biomass remains and continues to shade out the desired plants. Therefore, if *A. argentea* is to be removed, it should be done early, before it begins to affect the native plants and before it builds up a large amount of biomass. This presents a problem in that when it is small, it would not be possible to apply Roundup without spraying non-target species and therefore would require hand weeding.

There were many lessons learned in establishing the nursery. The most important was the need for an effective weed control strategy. Occasional weeding was not sufficient. To increase seed quantities from the nursery, herbicides should be used where appropriate. Although it would be preferable to not need herbicides, hand weeding requires a large amount of labor.

Second was the need to work on the nursery when needed, not when labor was available or the site accessible. When the roads were wet and impassable, access was cut off. A week could make the difference between managing weeds and having them overrun, or the difference between harvesting a good seed crop or losing it during a wind and rainstorm.

Third was the need for irrigation at the proper time. Currently, irrigation requires the reinstallation of irrigation pipe each time watering is needed, due to a high rate of theft of farm equipment in unguarded fields.

Furthermore, furrow irrigation is not the preferred method of irrigation for a nursery because of the amount of labor required. Additionally, furrow irrigation causes the accumulation of salts closer to the surface of the soil, potentially reducing long-term viability. Rainwater leaches salts down through the soil profile, and sprinkler irrigation more closely simulates the leaching effect of rainwater. Having a permanent installation of sprinkler pipe also would allow for irrigation on an as-needed basis, without the need for set-up labor. Watering with even coverage can be achieved while unattended.

4.3.2. Native Plant Nursery, 2002 Season

Building on the successes of the previous nursery, a more ambitious nursery was developed in the summer of 2002.

A new area (Figure 4-24) was chosen on the west side of Section 23. This area had a number advantages to the 2001 native plant nursery location such as:

- Better soil **–** it appears to have a slightly larger-grained texture, with less cracking. The soil also works up better than in the previous location.

- Better fall line – the 2001 nursery was being watered uphill. Here, the land falls away from the water pump.
- Closer to irrigation – this new location is located just north of a water pump so irrigation is less of a problem.
- Opportunity for weed preparation – because nothing is currently growing on the land, there is the opportunity for intensive weed management.
- Space to expand – the surrounding area was planted, but because the plants were trespass grazed by sheep, there is room for future development.

On 23 July 2002, the new nursery was mapped out on the ground, and pre-irrigated days later. Pre-irrigation was used to cause germination of the winter weeds so they could be eliminated. Within a month, the entire nursery was growing in weeds, mostly black mustard. The area was disked for weed control on 30 August.

The nursery was then left to sit and a second flush of weeds arrived weeks later. On 7 November, the beds were installed, which also killed the second flush of weeds. Fifty-five beds were made, with each bed being approximately 4 by 510-ft.

Planting should have followed bed construction, but large rainstorms made the area inaccessible, so planting will occur as soon as it is possible in 2003. Species that are potentially available for planting are listed in section 4.3.3.

Species will be planted using two methods; broadcasting the seed and lightly raking it in, or by using a small "seed bike", a device that drops the seed into a small trench it creates and then covers up with soil.

A wire-mesh fence was installed over 14-19 November to keep tumbleweeds out of the nursery. Because the field to the west is fallow, the area could be a large source of weed seed in the coming months.

4.3.2.1. Ancillary activities in the nursery

On 21 November, Intermountain Nursery donated some grasses in 1-gallon pots. A total of 124 *Sporobolus airodes* and 1 *Distichlis spicata* were planted. Each plant was assessed for bound roots and if so, the roots and above ground growth were trimmed before planting. They were watered by hand until the next natural rainfall. In addition, some *Distichlis spicata* rhizomes were donated by the Plant Materials Center in Lockeford, CA. Using a 20 by 20 grid, 392 holes were dug and planted at 1-ft spacing with the rhizomes on 23 September 2002. They were watered during planting, and irrigated regularly until the fall rains began. They will be monitored for success the following year.

4.3.3. Seed Collection

- Nur Ritter

The need for developing local seed resources has been understood since the inception of the Land Retirement Demonstration Project. As noted in the section on the Native Plant Nursery, seed collected from local sources is far preferable to commercially obtained seed. Nevertheless, in the first three years of the project a priority was necessarily placed on establishing the HRS plots, conducting plot monitoring, and developing and initiating a variety of restoration trials (Uptain et al. 2001, 2002). To date, locating sufficient sources of native seed of local genotype has been very problematic. To this end, a much greater effort was applied to seed collecting in 2002. Consequently, site reconnaissance, seed collecting, collecting inventorying, and seed processing constituted a fairly significant portion of the work undertaken for the Land Retirement Demonstration Project.

To maximize the genetic diversity represented in the nursery, priority was given to locating additional populations of desirable native species. In previous years, sites were ideally located within 15 miles of the HRS site; however, in an effort to amplify the number of collecting sites the potential collecting range was increased to 30 miles. A number of strategies were utilized in the search for new sites. In order to maximize the likelihood of encountering additional remaining fragments of native habitat, an effort was made to drive different routes between the ESRP office (Fresno, CA) and the Tranquillity site. Historical records for species of interest were reviewed for information on population locations. The principal source for this type was the CalFlora database (http://www.calflora.org), which provided specimen data from catalogued herbarium specimens. Topographic and highway maps were scrutinized, and likely areas were visited. This approach was particularly fruitful in identifying likely seed collection sites in the foothills of the Coastal Range. Information was sought from other botanists working in the area, principally those employed with the California Department of Water Resources and the California Department of Fish and Game. Additional conversations with local residents and with agricultural laborers also provided leads to potential sites. In 2001, seed collecting was limited to seven collection sites; in 2002, seed was collected from 23 sites (Table 4-26, Figure 4-29), twenty of which had not been utilized in 2001. Additionally, seed was collected from the Native Plant Nursery that had been established on the Tranquillity site in 2001. Two of the sites from which seed was collected in 2001 were not revisited in 2002 (Table 4-26). We anticipate that in 2003, we will continue a concerted search for seed collection sites.

Permission and any required permits were obtained from private landowners and government agencies. The health of the population was assessed prior to collection. Collecting was restricted to five percent of the seed crop for sensitive species and for common taxa that were poorly represented in the area, or less of the 2003-2004 seed crop for sensitive species, and no more than 50% of the seed crop for non-sensitive, well-represented species. In 2001, nine species were collected; in 2002, these (excluding *Suaeda moquinii*, which was not collected in 2002) were augmented by an additional 24 species (Table 4-27).

Table 4-26. Seed collection locations, 2002 location codes, and collecting status in 2001 and 2002.

Site Name	Code	2001	2002
Alkali Sink Ecological Reserve	ASER	+	+
Fancher and Belmont	-	+	-
Fresno West Golf Course	FWGC	+	+
Highway 180, San Mateo Avenue	180-SMA	-	+
Highway 33, Firebaugh Area	33-FRB	-	+
Highway 33, south of Dos Palos	33-DP	-	+
James Avenue, Site A	JAMES-A	-	+
Jensen Avenue Evaporation Ponds	NAP-EVAP	-	+
Kerman Ecological Reserve, North	KER-N	+	+
Kerman Ecological Reserve, South	-	+	-
Lanfranco Property	LANFR	+	+
Lateral 7 Inlet Canal	LAT7	-	+
Little Panoche Road, Site A	LPR-B	-	+
Little Panoche Road, Site B	LPR-B	-	+
Main Canal at Firebaugh	MC-FRB	-	+
Mendota Wildlife Area	MWA	+	-
Old Friant Road, Site B	FRIANT-B	-	+
San Joaquin River, San Mateo Road	SJR-SMR	-	+
San Luis Drain, Jefferson Avenue	SLD-JA	-	+
San Luis Drain, south of turkey farm	SLD-TF	-	+
Tranquillity Site, Auxiliary Site 1	TR-AUX1	-	+
Tranquillity Site, HRS	TR-HRS	+	+
Tranquillity Site, Native Plant Nursery	TR-NPN		+
Tranquillity Site, North Avenue Parcel	NAP	-	+
Tranquillity Site, Section 10	TR-SEC10	-	+
Yuba Avenue Habitat	YUBA	-	+

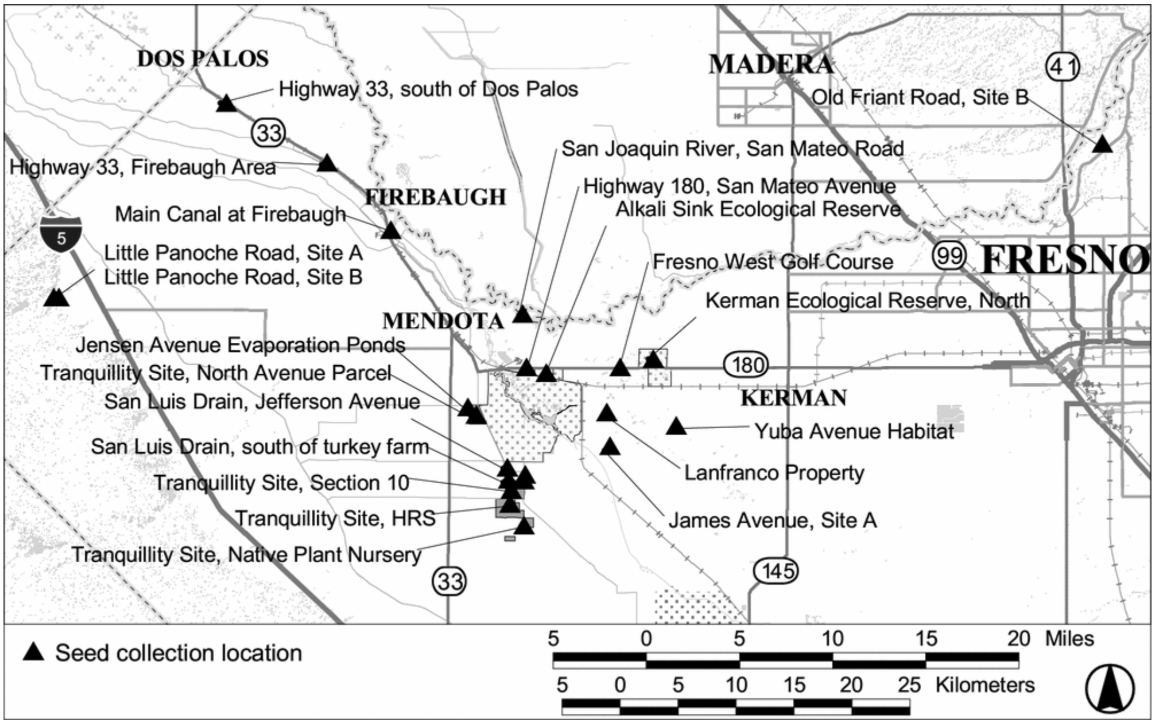

Figure 4-29. Seed collection locations

In addition to a shortage of potential collecting sites, seed collecting in the San Joaquin Valley is confounded by a number of factors. The timing of seed collection is critical, and the extremely variable springtime temperatures and rainfall patterns in the San Joaquin Valley confound scheduling. Time of collection is particularly critical for short-lived annual species.

Seed harvesting typically begins in the spring and lasts through late fall. Species in the genera *Lasthenia*, *Castilleja*, and *Dichelostemma* tend to reach maturity by early spring; hence, seed-collecting can commence as early as late March or April. Late blooming shrubs such as *Atriplex polycarpa*, *Isocoma acradenia*, and *Allenrolfea occidentalis* generally don't attain fruiting condition until late summer or early fall, thereby extending collecting into November and, at times, into December.

Seed collecting (Figure 4-30) was conducted from mid-March to early December 2002, and took the form of 123 "collecting events" (the collecting of a particular species at a particular site on a particular date). For example, the collection of *Lasthenia chrysantha* from the Fresno West Golf Course site on March 20th constitutes a single collection event; likewise, the collection of *Lepidium dictyotum* from the same site on the same date constitutes another collection event. An overview of 2002's collections is presented in Table 4-28; a more complete account (including collection dates) is presented in Appendix 4-5.

Figure 4-30. Biologists Foung Vang (background) and Justine Kokx collecting *Monolopia stricta* near the San Luis Drain. At this site, *M. stricta* is competing extremely well in a *Bromus madritensis* (red brome) dominated landscape.

Seed was stored in paper bags, labeled with identifying codes (species, seed-lot, etc.), and dried at the ESRP lab. Both a low temperature convection cabinet and a modified herbarium specimen dryer (forced air) were used to facilitate drying and dried in a seed dryer at the ESRP lab.

The dried seed was cleaned using a variety of techniques. Initially, stems, large leaves, and other coarse material were removed from the collected seed. Most material was then “worked” with a rolling pin in order to break up seed heads and to free seed from any restraining structures (e.g., capsule walls). At times, mechanical methods were used to facilitate this stage of the processing. A blender with dull blades (reasonably successful) and a food processor (depressingly unsuccessful) were applied to this end. The seed and associated biomass were then run through a series of (successively finer) hand-held sieves. In mid-August, a power winnower (SeedTech Systems STS-WM2 Lab Precision Separator) was acquired. This device greatly improved the degree to which seed could be cleaned and improved seed cleaning efficiency.

Table 4-27. Native plant species, species codes, and collecting and collecting status in 2001 and 2002.

Species	CODE	2001	2002
Allenrolfea occidentalis	ALOC	–	+
Amsinckia menziesii	AMME	–	+
Asclepias fascicularis	ASFA	+	+
Atriplex fruticulosa	ATFR	–	+
Atriplex polycarpa	ATPO	+	+
Atriplex spinifera	ATSP	–	+
Castilleja exserta	CAEX	+	+
Castilleja sp.	CA_SP	–	+
Cressa truxillensis	CRTR	–	+
Epilobium brachycarpum	EPBR	–	+
Frankenia salina	FRSA	+	+
Gilia tricolor	GITR	–	+
Grindelia camporum	GRCA	–	+
Helianthus annuus	HEAN	–	+
Heliotropium curassavicum	HECU	–	+
Hemizonia fitchii	HEFI	–	+
Hemizonia pungens	HEPU	+	+
Holocarpha obconica	HOOB	–	+
Isocoma acradenia	ISAC	+	+
Isomeris arborea	ISAR	–	+
Kochia californica	KOCA	–	+
Lasthenia californica	LACA	–	+
Lasthenia chrysantha	LACH	–	+
Lepidium dictyotum	LEDI	–	+
Malacothrix coulteri	MACO	–	+
Monolopia stricta	MOST	–	+
Phacelia ciliate	PHCI	+	+
Sambucus mexicana	SAME	–	+
Sesuvium verrucosum	SEVE	–	+
Sporobolus airoides	SPAI	+	+
Spergularia atrosperma	SPAT	–	+
Spergularia macrotheca	SPMA	–	+
Suaeda moquinii	SUMO	+	–
Trichostema lanceolatum	TRLA	–	+
Trichostema ovatum	TROV	–	+
Wislizenia refracta	WIRE	–	+

Table 4-28. Species collected in 2002 for the Native Plant Nursery, Tranquillity HRS. A key to location codes is given in Table 4-26. A key to species codes is presented in Table 4-27.

Species code	ASER	FWGC	180-SMA	33-FRB	33_DP	JAMES_A	NAP-EVAP	NKER-N	LANFR	LAT7	LPR-A	LPR-B	MC-FRB	MWA	FRIANT-B	SJR-SMR	SLD-JA	SLD-TF	TR-AUX1	TR-HRS	TR-NAP	TR-NPN	TR-SEC10	YUBA
ALOC	1	–	–	1	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
AMME	–	2	–	–	–	–	–	–	2	–	–	–	1	–	–	–	–	–	–	–	3	–	–	–
ASFA	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–
ATFR	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
ATPO	–	–	–	–	–	–	–	1	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–
ATSP	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
CA_SP	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
CAEX	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
CRTR	–	–	–	–	–	1	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–
EPBR	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
FRSA	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GITR	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
GRCA	1	–	–	2	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–
HEAN	–	–	–	–	1	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	2	–
HECU	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
HEFI	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	–	–	–	–	–	–	–
HEPU	6	4	–	–	–	–	–	2	2	–	–	–	–	–	–	–	–	–	–	–	–	6	–	1
HOOB	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
ISAC	1	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	1	–	–
ISAR	–	–	–	–	–	–	–	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–
KOCA	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
LACA	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
LACH	–	4	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
LEDI	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
MACO	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
MOST	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–	–	–
PHCI	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	3	1	1	5	1	–
SAME	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
SEVE	–	–	–	–	–	–	4	1	1	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–
SPAI	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SPAT	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SPMA	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TRLA	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TROV	2	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
WIRE	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	**16**	**13**	**1**	**4**	**3**	**1**	**4**	**12**	**5**	**2**	**3**	**13**	**1**	**6**	**2**	**1**	**1**	**7**	**3**	**1**	**5**	**13**	**5**	**1**

4.4. THE HABITAT RESTORATION STUDY PLOTS – ATWELL ISLAND

- Nur Ritter

4.4.1. Study Design

The Habitat Restoration Study at Atwell Island was originally envisioned as a single study area, similar in design to its sister study in Tranquillity but comprised of sixteen 2-acre plots. Later, the decision was made to increase the number of plots to 48, with these arrayed in three, spatially disjunct groupings of 16 plots (Figure 4-31). Data from both the pre-project inventory (April 2000; Selmon et al. 2001) and from the first year's monitoring of the plots (Uptain et al 2002) were analyzed as if these three areas constituted a single study area. As the vegetation on the plots developed, and as data analysis proceeded, it became increasingly obvious that the three areas were tremendously heterogeneous. Differences among the areas were sufficiently pronounced to preclude any meaningful analyses of the vegetation data (i.e., blocking effects would have obscured any treatment effects). Therefore, each of the three areas is now considered to constitute a single study area; with each study area containing four blocks (replicates) of four plots (Figure 4-31).

As with the Tranquillity HRS, barley was sown on the three study areas in the year prior to plot installation. The barley was irrigated as needed during the growing season, with Study Area 1 flood-irrigated and the other two areas sprinkler irrigated. In December 2001, the plots were disked and microtopographic contours (berms) were installed. Berms (Figure 4-32) were constructed in a similar fashion to those at the Tranquillity HRS site (Uptain et al 2002); however, only forty-nine berms were installed on each plot at Atwell Island. By contrast, the larger (10 acre) plots at Tranquillity each had 240 berms.

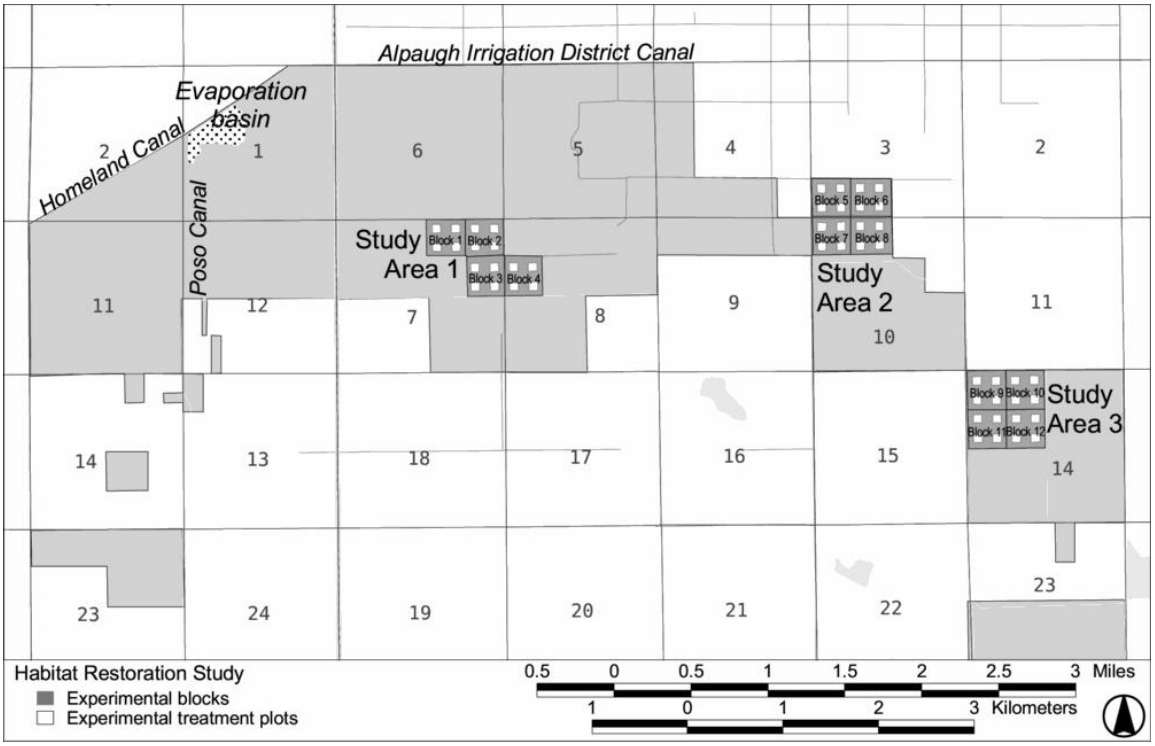

Figure 4-31. Location of the three Atwell Island study areas.

Figure 4-32. Photographic voucher from Plot 16, Atwell Island HRS site (18 March 2002). The transverse light-colored patches are the berms (microtopographic contouring).

Seed was imprinted onto the Atwell Island plots in late December 2001; the thirteen species included in the seed mixture were those used on the Tranquillity HRS plots (see Section 4.1). Likewise, the gross seeding rate and species' proportions were based on those used at Tranquillity. In reality, the seed mixture at Atwell Island can only be considered to approximate that used at Tranquillity, as seed germination potential and purity, and seed collection locations varied between the two mixtures. Because of the poor rate of seedling establishment on the Tranquillity plots, as well as the high associated costs, no seedlings were transplanted onto the Atwell Island plots.

4.4.2. Materials and Methods

As with the HRS site in Tranquillity, two rounds of quantitative vegetation monitoring ("vegetation monitoring" and "shrub monitoring") were conducted on the Atwell Island HRS plots in 2002. It is intended that these two regimes will be continued throughout the duration of monitoring at the Atwell Island site.

4.4.2.1. Spring monitoring

Spring monitoring on the Atwell Island HRS plots was conducted during March 11, 12, 15, and 20. As with the Tranquillity HRS site, the very dry conditions of 2002 resulted in an early senescence of the annual species on the Atwell Island study plots. Hence, it was necessary that monitoring be conducted much earlier in the year than anticipated. Data were collected from twelve quadrats (35 x 70 cm) on each plot; this methodology differed from that employed in 2001, in which only eight quadrats were sampled per plot. A stratified random sampling approach was employed, with plots divided into fourths and three sampling points randomly selected within each section. In all other particulars, data collection followed the protocols described for the Tranquillity HRS site.

In order to document species that were present on the plots but which did not fall within the quadrats, a running list was compiled of all species noted on the plot. These additional species were not included in the estimates of plot species richness; rather, they were used to assess the effectiveness of the sampling methodology. Additionally, by taking note of these species we were able to compile as complete a record as possible of the species occurring on site. All plant species noted during monitoring were included in the catalog of species encountered on the Atwell Island HRS site (Appendix 4-7).

4.4.2.2. Shrub monitoring

In contrast to shrub monitoring at the Tranquillity HRS site—in which a point-transect sampling methodology was employed—shrub monitoring at Atwell Island was accomplished using a quadrat-based methodology. Sampling procedures generally followed those outlined for the spring vegetation sampling, but differed in that a much larger quadrat frame (2m x 3m) was used.

Shrub monitoring was conducted during September and October, 2002 (Sep 26; Oct 2; Oct 4; Oct 10; Oct 16-17). As with shrub monitoring at the Tranquillity HRS both shrubs and "shrub-like annuals" were included in the census. Nomenclatural conventions followed those outlined for the Tranquillity HRS (e.g., the term "shrub" in quotations is used to refer to both shrubs and shrub-like annuals).

Many of the species encountered during shrub monitoring at Atwell Island were also encountered during monitoring at Tranquillity. An important addition to the "shrub" flora at Atwell was *Sesuvium verrucosum* (western sea purslane), a perennial herb that would not normally be thought of as particularly "shrublike." Nevertheless, at Study

Area 1, *S. verrucosum* grew to impressive size (diameter ca. 7'; height ca. 15"; Figure 4-33).

Figure 4-33. An individual of *Sesuvium verrucosum* encountered during shrub monitoring of Study Area 1, Atwell Island HRS (October 2002). The sampling frame seen in the photograph is 2 meters wide (along the y-axis).

4.4.2.3. Photo points

The protocols employed in compiling and storing photographic vouchers of the study plots at the Atwell Island HRS generally followed those described for the Tranquillity section (4.1). Protocols at Atwell Island differed from those at Tranquillity in that photographs (one 35-mm and one digital) were taken from a single point on each plot: the southern end of the Avian transect (i.e., the approximate midpoint of the southern edge of the plot). Photographic vouchers were collected during four different periods in 2002: January 8-9; March 18-20; June 4-6; and, September 18-20. Examples of various digital photographic vouchers are presented in this section (e.g., Figure 4-32, Figure 4-41).

4.4.2.4. Data storage and analysis

In general, procedures for data storage and analysis followed those outlined for the Tranquillity HRS. As with the analysis of the Tranquillity data, species were grouped by category. The "Imprinted and Introduced" category was assigned to genera that were represented in both the "Native - Imprinted" and "Introduced" categories, but which: 1) were infertile during the period of vegetation monitoring; or, 2) contained a large proportion of infertile individuals during this period. At Atwell Island, two complexes of species ("*Bromus* spp. and *Vulpia* spp.) were included in this category. It was necessary to group these species in this manner because at the time of sampling a great many individuals were not yet fertile. Hence, it was frequently not possible to confidently determine which species were represented in a particular quadrat or plot. The genus *Bromus* was represented by three species: *B. carinatus* (imprinted), and *B. diandrus* and *B. madritensis* (introduced). The genus *Vulpia* was represented by *V. microstachys* (imprinted) and *V. myuros* (introduced).

4.4.3. Results and Discussion

4.4.3.1. Sitewide patterns

As noted, differences among the three study areas were pronounced. Data analyses indicated large differences in the composition of the plot vegetation even during the initial year (i.e., when all plots were planted in barley). Following imprinting, observable differences on the plots became increasingly evident as the growing season progressed and the perennial species attained significant growth.

The differences among the vegetation of the study areas during the first year (2001) are easily seen in an ordination by Detrended Correspondence Analysis (DCA) of the vegetative cover data (Figure 4-34). As the plots at that time were dominated by barley, it was expected that all data points would be fairly closely grouped in ordination space. Nevertheless, there was a clear partitioning by study area, with the only overlap of points occurring at the interface between Study Areas 1 and 2. In the spring following imprinting, vegetative differences among the study areas were even more pronounced (Figure 4-35). At this time, the data points comprising each study area were closely grouped, with the groupings far removed from each other in ordination space. Study Area 1 demonstrated the greatest degree of uniformity (i.e., the data points were most closely grouped).

As might be hoped, the vegetative differences suggested by the ordination were clearly observable in the field. The following photographs-presented in order from the driest to wettest study area-are well-representative of the differences that had developed among the study areas by mid-summer (12 July 2002). Unless otherwise noted, the following observations and commentary pertain to the vegetation on the restored plots.

Study Area 3 was extremely dry, and by mid-summer the vegetation had shown little development (Figure 4-36). The height of the surviving vegetation was quite low (on the order of 8-12”) and plants were widely scattered. By contrast, the vegetation on Study Area 2 (Figure 4-37) was taller (on the order of 15-18”) and the vegetative cover (principally, *Atriplex argentea* and various introduced grasses) was much denser. The greatest differences in vegetative development were seen on Study Area 1 (Figure 4-38). By mid-July, a dense cover of shrubs and shrub-like annuals had developed and the vegetation was much greener and less-stressed than on the other two study areas. By the time of shrub monitoring (early October), the differences among the study areas were even more pronounced.

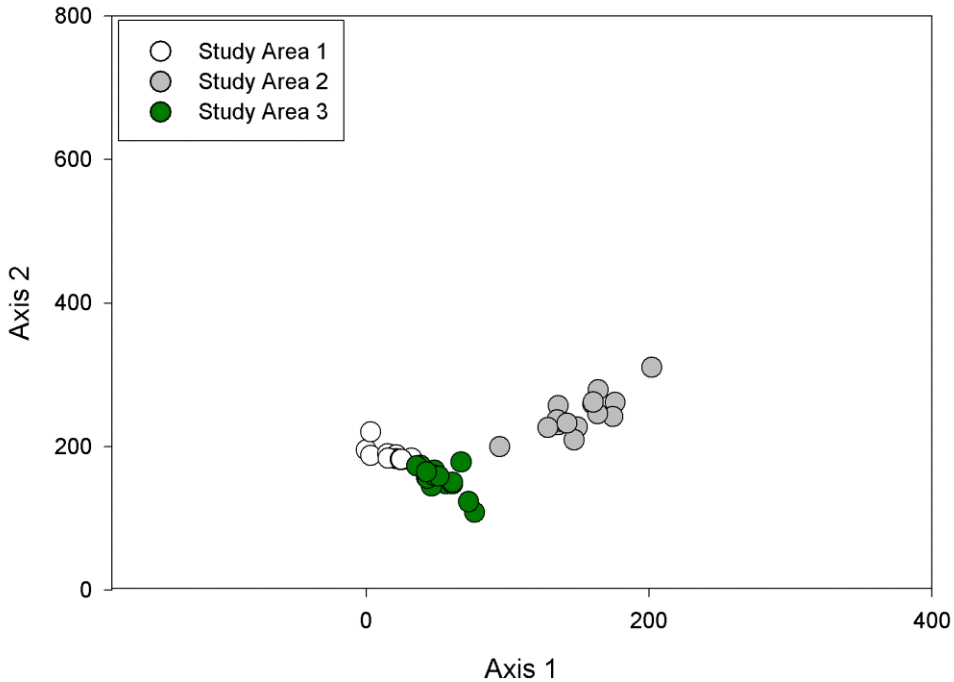

Figure 4-34. Ordination (DCA) of the vegetation data from the Atwell Island HRS, 2001 (data collected April-May, 2001).

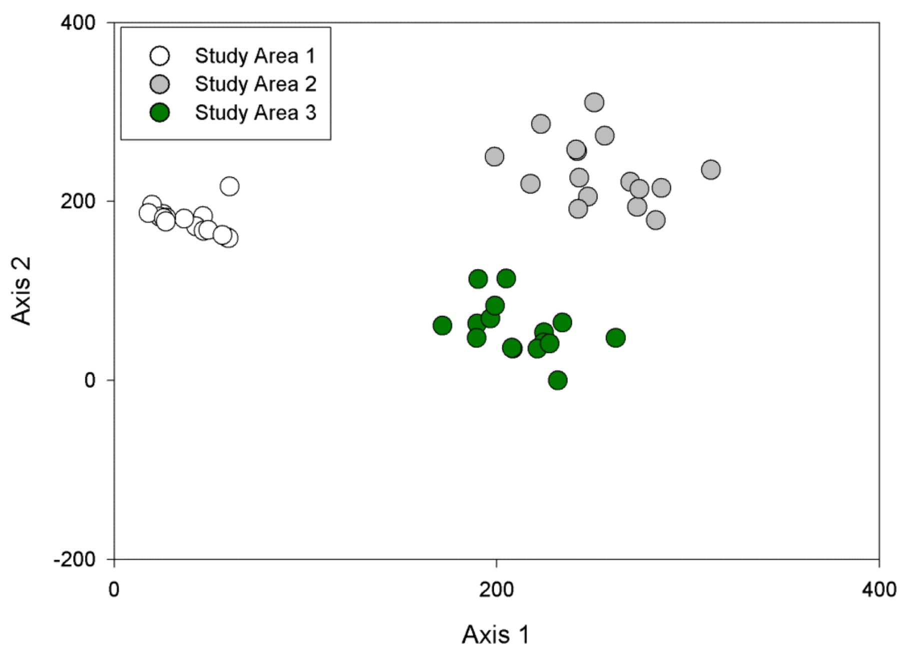

Figure 4-35. Ordination (DCA) of the vegetation data from the Atwell Island HRS, 2002 (data collected March 2002).

Figure 4-36. Study Area 3, Atwell Island HRS in mid-summer (July 2002). One of the pitfall arrays is visible near the center of thee photograph.

Figure 4-37. Study Area 2, Atwell Island HRS in mid-summer (July 2002). The plot pictured in the foreground was imprinted with native seed but did not receive contouring.

Figure 4-38. Study Area 1, Atwell Island HRS in mid-summer (July 2002). Biologist Adrian Howard is pictured standing behind a large individual of *Atriplex polycarpa*. The greatest part of the shrubs seen in this photograph were imprinted species.

The partitioning of the study areas into such clearly delineated groupings was somewhat surprising as the study areas were all situated within a few miles of each other, all had received essentially the same pre-treatment (i.e., a year planted in barley), and all had received the same treatments.

4.4.3.2. Spring monitoring

Fifty-two species in 14 families were encountered on the plots during spring monitoring (Appendix 4-7). This total includes both those species that occurred in the quadrats and those that were observed elsewhe re on the plots. Appendix 4-7 serves as the sole compilation of sitewide vegetation data; in the following sections, data will be presented by individual study area. Additionally, all subsequent analyses will be limited to only those species that occurred in the quadrats.

4.4.3.2.1. Study Area 1

Thirty-one species (see footnote, Table 4-29) in eight families were noted in Study Area 1 (Table 4-29). Six of these corresponded to species that had been imprinted (i.e., four N-I and two I-I). A single non-imprinted "desirable" native species (*Sesuvium* *verrucosum*) was noted. Barley was the most frequently encountered species. Two imprinted species were well represented, with *Vulpia* spp. (the species complex composed of *V. microstachys* and *V. myuros*) and *Lasthenia californica* the second and third most frequently encountered "species." It need be emphasized that the comparisons of frequencies at the study area level under-represent the frequency of imprinted species, as these would generally be expected only in half the plots (i.e., the imprinted plots).

Table 4-29. The species encountered during spring monitoring at Study Area 1, Atwell Island HRS site. Species are arranged in descending order by frequency. Key to species origins: N-I, Native - Imprinted; N, Native; N-U, Native - Undesirable; I-I, Imprinted and Introduced; C, Cultivar; I, Introduced; N.K., Not Known.

Species[1]	Family	Common Name	Origin	Freq.	% Freq.[2]
Hordeum vulgare	Poaceae	barley	C	188	97.92
Vulpia spp.	Poaceae	fescue	I-I	102	53.13
Lasthenia californica	Asteraceae	California goldfields	N-I	84	43.75
Chenopodium sp.	Chenopodiaceae	–	N.K.	65	33.85
Polygonum arenastrum	Polygonaceae	dooryard knotweed	I	64	33.33
Lactuca serriola	Asteraceae	prickly lettuce	I	45	23.44
Spergularia bocconii	Caryophyllaceae	Boccone's sandspurry	I	39	20.31
Bromus spp.	Poaceae	brome	I-I	26	13.54
Bassia hyssopifolia	Chenopodiaceae	fivehook Bassia	I	17	8.85
Sonchus spp.	Asteraceae	prickly lettuce	I	17	8.85
Polypogon monspeliensis	Poaceae	rabbitsfoot grass	I	15	7.81
Sisymbrium irio	Brassicaceae	London rocket	I	9	4.69
Cynodon dactylon	Poaceae	bermuda grass	I	7	3.65
Atriplex polycarpa	Chenopodiaceae	allscale saltbush	N-I	6	3.13
Poa annua	Poaceae	annual bluegrass	I	5	2.60
Hemizonia pungens	Asteraceae	common spikeweed	N-I	4	2.08
Capsella bursa-pastoris	Brassicaceae	shepherd's purse	I	4	2.08
Atriplex argentea	Chenopodiaceae	silverscale saltbush	N-U	2	1.04
Sesuvium verrucosum	Aizoaceae	western sea-purslane	N	2	1.04
Avena spp.	Poaceae	oats	I	2	1.04
Hordeum murinum	Poaceae	foxtail barley	I	2	1.04
Suaeda moquinii	Chenopodiaceae	bush seepweed	N-I	1	0.52
Annual Atriplex	Chenopodiaceae	–	N.K.	1	0.52
Carthamus tinctorius	Asteraceae	safflower	I	1	0.52
Melilotus indica	Fabaceae	sourclover	I	1	0.52
Stellaria media	Caryophyllaceae	common chickweed	I	1	0.52

The species list represents 31 species because of the contribution of the various multi-species "complexes": *Bromus* spp., 3 species; *Vulpia* spp., 2 species; *Avena* spp, 2 species; and, *Sonchus* spp., 2 species.

"% Frequency": the percentage of quadrats (out of a possible 192) in which a species occurred.

In order to evaluate the contribution of "desirable" vs. undesirable" vegetation, species were identified by origin (e.g., native, introduced, etc.) and rank-abundance curves were generated for each plot, with the plots grouped by treatment (Figure 4-39; Figure 4-40).

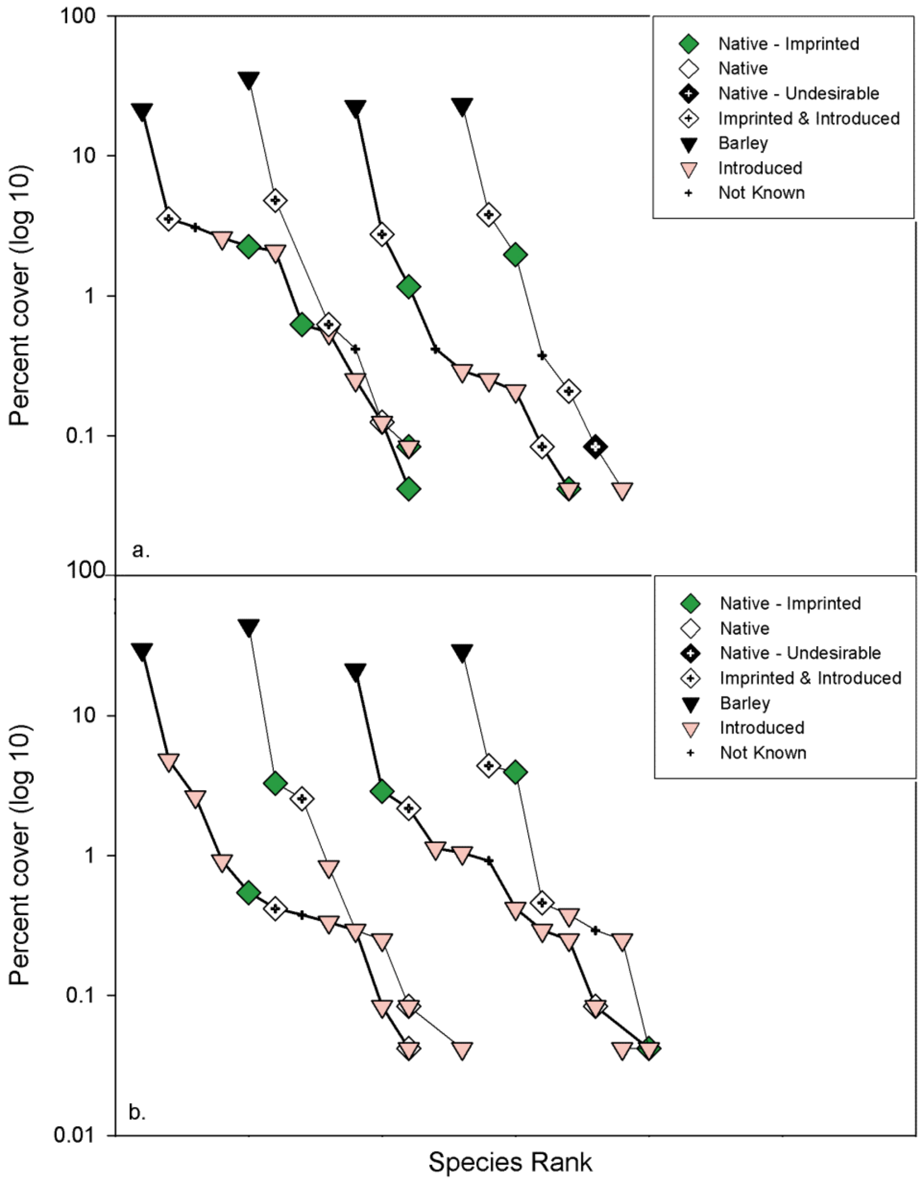

Figure 4-39. Species rank-abundance by treatment, Study Area 1, Atwell Island HRS plots 2002. a. contoured and imprinted (CR); b. imprinted, but not contoured (NR).

Plots were ordered sequentially by block number within each graph; hence, the leftmost curve represents the plot from Block 1, the second to the left, Block 2, etc. Rank-abundance curves were plotted along the x-axis in this way to minimize overlap. Thus, no ordinal scale is presented along the x-axis; rather, the curves are interpreted such that the leftmost data point represents the 1st ranked species, with subsequent data points representing the 2nd ranked species, etc.

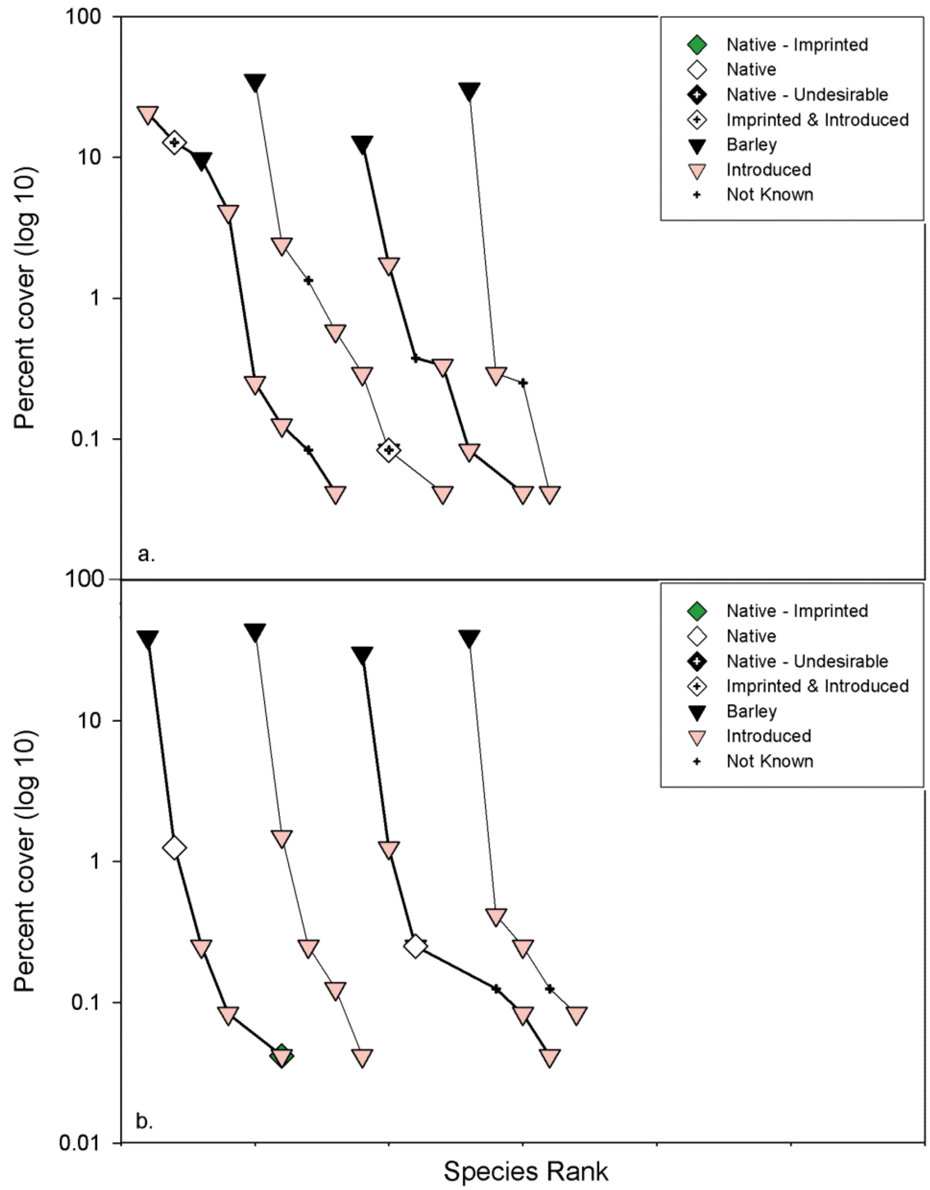

Figure 4-40. Species rank-abundance by treatment, Study Area 1, Atwell Island HRS plots 2002. a. contoured, but not imprinted (CN); b. neither imprinted nor contoured (NN).

With the exception of Plot 1 (the lefthand-most curve on Figure 4-40), Barley was the most abundant species on all plots (Figure 4-39; Figure 4-40). The relatively low abundance of barley on Plot 1 may be attributable to the “irrigation strips” that were characteristic on Study Area 1. These areas corresponded to the berms that had been constructed for flood irrigating the barley in 2001 and were subsequently graded flat before the plots were imprinted. Most often, barley was scarce on these strips (Figure 4-41). Likewise, *Spergularia bocconii*, the most abundant species on Plot 1 was generally extremely abundant in these areas.

Figure 4-41. An "irrigation strip" on Plot 5, Atwell Island HRS site Study Area 1 (18 March 2002). The light-colored strip to the left of the photograph indicates one of the former berms constructed for flood irrigation.

Lasthenia californica (goldfields) was the most abundant imprinted species (on all rank-abundance curves, the first representation of a N-I species corresponds to *L. californica*). In all case, the slopes of the curves were more gradual for the restored plots than for the non-restored plots. This pattern suggests that vegetation on the restored plots had achieved a greater evenness.

By mid-summer, some of the imprinted annual species appeared to be well-established on Study Area 1. *Lasthenia californica*, in particular, had produced abundant seed. In some areas, substantial accumulations of *L. californica* seed (and senescent floral parts) were evident in the depressions created by the imprinted (Figure 4-42). In contrast to the soils at the Tranquillity HRS, the soils at Atwell Island appeared to be more stable; hence, the prognosis for the reestablishment of imprinted annuals appears hopeful.

Figure 4-42. Seed and floral parts of *Lasthenia californica* (goldfields) accumulated in the bottom of an imprinter depression.

4.4.3.2.2. Study Area 2

Thirty-six species (see footnote, Table 4-30) in 10 families were noted in Study Area 2 (Table 4-30). Five of these corresponded to species that had been imprinted (i.e., three N-I and two I-I); additionally, five non-imprinted "desirable" native species were noted. The non-native forb *Sisymbrium irio* (London rocket) was the most frequently encountered species, followed by various non-native grasses. In contrast to Study Area 1, where it was the most frequently encountered species, barley was only the ninth most frequent species. Neither the imprinted nor the non-imprinted desirable natives were encountered with much frequency. *Lasthenia californica* (goldfields) possessed the highest frequency of the imprinted species but was less well-represented than on Study Area 1.

Table 4-30. The species encountered during spring monitoring at Study Area 2, Atwell Island HRS site. Species are ordered in descending order by frequency. Key to species origins: N-I, Native - Imprinted; N, Native; N-U, Native - Undesirable; I-I, Imprinted and Introduced; C, Cultivar; I, Introduced; N.K., Not Known.

Species[1]	Family	Common Name	Origin	Freq.	% Freq.[2]
Sisymbrium irio	Brassicaceae	London rocket	I	190	98.96
Avena spp.	Poaceae	oats	I	151	78.65
Hordeum murinum	Poaceae	foxtail barley	I	143	74.48
Phalaris minor	Poaceae	littleseed canarygrass	I	125	65.10
Atriplex argentea	Chenopodiaceae	silverscale saltbush	N-U	118	61.46
Capsella bursa-pastoris	Brassicaceae	shepherd's purse	I	85	44.27
Vulpia spp.	Poaceae	fescue	I-I	85	44.27
Lasthenia californica	Asteraceae	California goldfields	N-I	84	43.75
Hordeum vulgare	Poaceae	barley	C	79	41.15
Amsinckia menziesii	Boraginaceae	Menzie's fiddleneck	N	39	20.31
Sonchus spp.	Asteraceae	prickly lettuce	I	33	17.19
Bassia hyssopifolia	Chenopodiaceae	fivehook Bassia	I	30	15.63
Erodium cicutarium	Geraniaceae	redstem filaree	I	30	15.63
Brassica nigra	Brassicaceae	black mustard	I	25	13.02
Melilotus indica	Fabaceae	sourclover	I	22	11.46
Monolepis nuttalliana	Chenopodiaceae	Nuttall's povertyweed	N	18	9.38
Lactuca serriola	Asteraceae	prickly lettuce	I	13	6.77
Hutchinsia procumbens	Brassicaceae	prostrate hutchinsia	N	11	5.73
Spergularia bocconii	Caryophyllaceae	Boccone's sandspurry	I	5	2.60
Annual *Atriplex*	Chenopodiaceae	–	N	5	2.60
Hemizonia pungens	Asteraceae	common spikeweed	N-I	3	1.56
Bromus spp.	Poaceae	brome	I-I	2	1.04
Guillenia lasiophylla	Brassicaceae	California mustard	N	2	1.04
Chenopodium sp.	Chenopodiaceae	–	N.K.	2	1.04
Malva parviflora	Malvaceae	cheeseweed	I	1	0.52
Polygonum arenastrum	Polygonaceae	dooryard knotweed	I	1	0.52
Senecio vulgaris	Asteraceae	old-man-in-the-Spring	I	1	0.52
Chamomilla suaveolens	Asteraceae	pineapple weed	I	1	0.52
Suaeda moquinii	Chenopodiaceae	bush seepweed	N-I	1	0.52
Unknown # 1	Unknown	–	N.K.	1	0.52
Unknown # 2	Unknown	–	N.K.	1	0.52

The species list represents 36 species because of the contribution of the various multi-species "complexes": *Bromus* spp., 3 species; *Vulpia* spp., 2 species; *Avena* spp, 2 species; and, *Sonchus* spp., 2 species.

"% Frequency": the percentage of quadrats (out of a possible 192) in which a species occurred.

Rank-abundance curves were generated for each Plot, and were graphed with the plots grouped by treatment (Figure 4-43; Figure 4-44). As suggested by the frequency data, barley was much less abundant than in Study Area 1; by contrast, various introduced species (*Sisymbrium irio*, *Avena* spp., *Phalaris minor*) were most abundant. Generally, neither imprinted natives, nor non-imprinted desirable natives were present in any great abundance. As with Study Area 1, *Lasthenia californica* was the most abundant of the imprinted natives (on all rank-abundance curves, the first representation of a N-I species corresponds to *L. californica*). Nevertheless, in all cases the percent cover of *L. californica* was less than 10%.

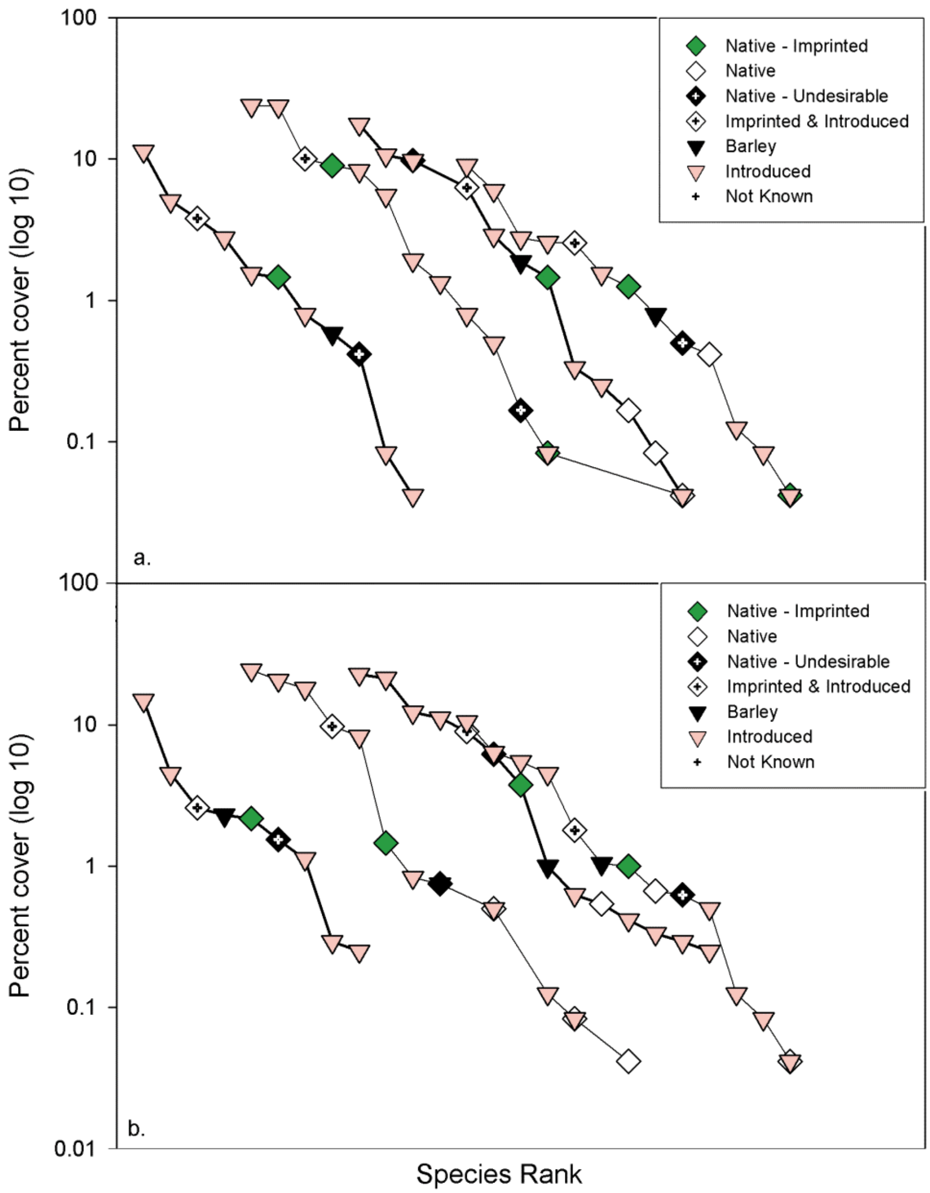

Figure 4-43. Species rank-abundance by treatment, Study Area 2, Atwell Island HRS plots 2002. a. contoured and imprinted (CR); b. imprinted, but not contoured (NR).

The rank-abundance curves from data from the restored plots were generally more gradual than those of the non-restored plots; however, this pattern wasn't nearly so apparent as on Study Area 1. Additionally, the vegetation on Study Area 2 was generally much more sparse than on Study Area 1. This difference was partly attributable to the substantial contribution of barley to overall cover on Study Area 1 (Figure 4-39; Figure 4-40).

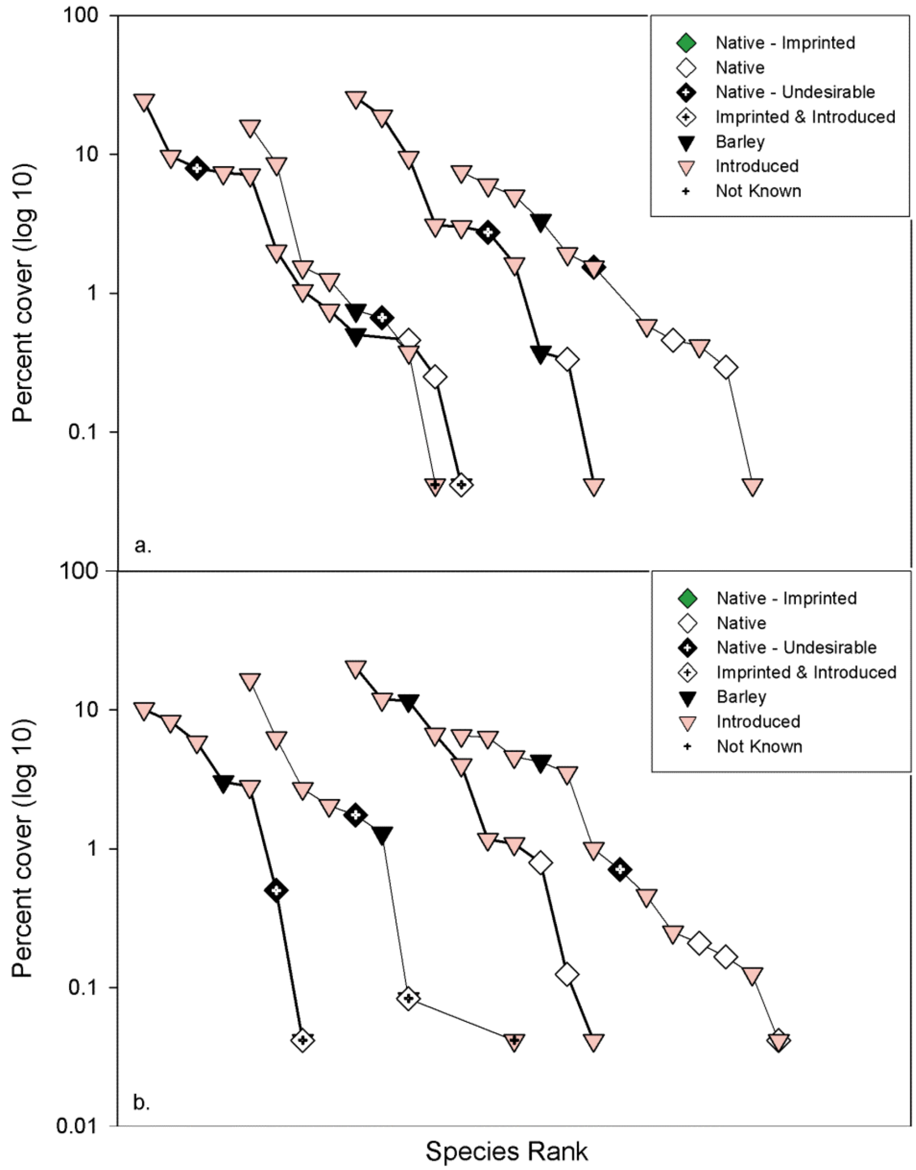

Figure 4-44. Species rank-abundance by treatment, Study Area 2, Atwell Island HRS plots 2002. a. contoured, but not imprinted (CN); b. neither imprinted nor contoured (NN).

Although non-imprinted desirable native species were well-represented with five species, none were nearly so abundant as was *Sesuvium verrucosum* on Study Area 1. Of interest was the distribution of one of these species, *Hutchinsia procumbens* (prostrate hutchinsia). This species was almost entirely restricted to the areas in which a saline scald had developed (the northwestern corner of the Study Area 2). The ability of *H. procumbens* to effectively become established under these conditions suggests that this species may have some utility for restoration activities on saline soils.

4.4.3.2.3. Study Area 3

Thirty-six species (see footnote, Table 4-31) in 12 families were noted in Study Area 3 (Table 4-31). Five of these corresponded to species that had been imprinted (i.e., three N-I and two I-I).

Table 4-31. The species encountered during spring monitoring at Study Area 3, Atwell Island HRS site. Species are ordered in descending order by frequency. Key to species origins: N-I, Native - Imprinted; N, Native; N-U, Native - Undesirable; I-I, Imprinted and Introduced; C, Cultivar; I, Introduced; N.K., Not Known.

Species[1]	Family	Common Name	Origin	Freq.	% Freq[2]
Amsinckia menziesii	Boraginaceae	Menzie's fiddleneck	N	168	87.50
Capsella bursa-pastoris	Brassicaceae	shepherd's purse	I	157	81.77
Melilotus indica	Fabaceae	sourclover	I	151	78.65
Hordeum murinum	Poaceae	foxtail barley	I	144	75.00
Vulpia spp.	Poaceae	fescue	I-I	105	54.69
Erodium cicutarium	Geraniaceae	redstem filaree	I	82	42.71
Sisymbrium irio	Brassicaceae	London rocket	I	70	36.46
Lasthenia californica	Asteraceae	California goldfields	N-I	65	33.85
Hordeum vulgare	Poaceae	barley	C	62	32.29
Bromus spp.	Poaceae	brome	I-I	50	26.04
Guillenia lasiophylla	Brassicaceae	California mustard	N	47	24.48
Annual Atriplex	Chenopodiaceae	–	N	43	22.40
Hemizonia pungens	Asteraceae	common spikeweed	N-I	36	18.75
Atriplex argentea	Chenopodiaceae	silverscale saltbush	N-U	20	10.42
Sonchus spp.	Asteraceae	prickly lettuce	I	16	8.33
Lactuca serriola	Asteraceae	prickly lettuce	I	15	7.81
Avena spp.	Poaceae	Oats	I	11	5.73
Monolepis nuttalliana	Chenopodiaceae	Nuttall's povertyweed	N	10	5.21
Plagiobothrys sp.	Boraginaceae	Popcornflower	N	9	4.69
Bassia hyssopifolia	Chenopodiaceae	fivehook Bassia	I	5	2.60
Brassica nigra	Brassicaceae	black mustard	I	4	2.08
Cressa truxillensis	Convolvulaceae	alkali weed	N	4	2.08
Atriplex polycarpa	Chenopodiaceae	allscale saltbush	N-I	3	1.56
Picris echioides	Asteraceae	bristly oxtongue	I	2	1.04
Stellaria media	Caryophyllaceae	common chickweed	I	2	1.04
Polygonum arenastrum	Polygonaceae	dooryard knotweed	I	2	1.04
Senecio vulgaris	Asteraceae	old-man-in-the-Spring	I	2	1.04
Malva parviflora	Malvaceae	Cheeseweed	I	1	0.52
Lepidium dictyotum	Brassicaceae	alkali pepperweed	N	1	0.52
Unknown Poaceae	Poaceae	–	N.K.	1	0.52
Unknown Caryoph	Caryophyllaceae	–	N.K.	1	0.52

The species list represents 36 species because of the contribution of the various multi-species "complexes": *Bromus* spp., 3 species; *Vulpia* spp., 2 species; *Avena* spp, 2 species; and, *Sonchus* spp., 2 species.

"% Frequency": the percentage of quadrats (out of a possible 192) in which a species occurred.

Amsinckia menziesii (Menzie's fiddleneck), a native annual herb, was the most frequently encountered species; however, in general, non-native species possessed the highest frequencies, with *Capsella bursa-pastoris*, *Melilotus indica*, and *Hordeum murinum* all well-represented. An additional four non-imprinted "desirable" native species were also noted; however, all were of low frequency. As with preceding study areas, *Lasthenia californica* was the most frequently encountered imprinted species. As with Study Area 2, barley was just the ninth most frequent species.

Study Area 3 was the driest of the three sites and, as would be expected, the vegetation was poorly developed (Figure 4-45). Rank-abundance curves were generated for each plot, and were graphed with the plots grouped by treatment (Figure 4-46; Figure 4-47). As with the preceding two study areas, introduced species generally comprised a large portion of the vegetation. Nevertheless, in 9 of the 16 plots, *Amsinckia menziesii*, a native annual herb, was the most abundant species. As suggested by the frequency data, barley was much less abundant than in Study Area 1.

Figure 4-45. Photographic voucher of Plot 41 (Study Area 3); Atwell Island HRS, March 18 2002. The berms (microtopographic contouring) appear as transverse, light-colored patches.

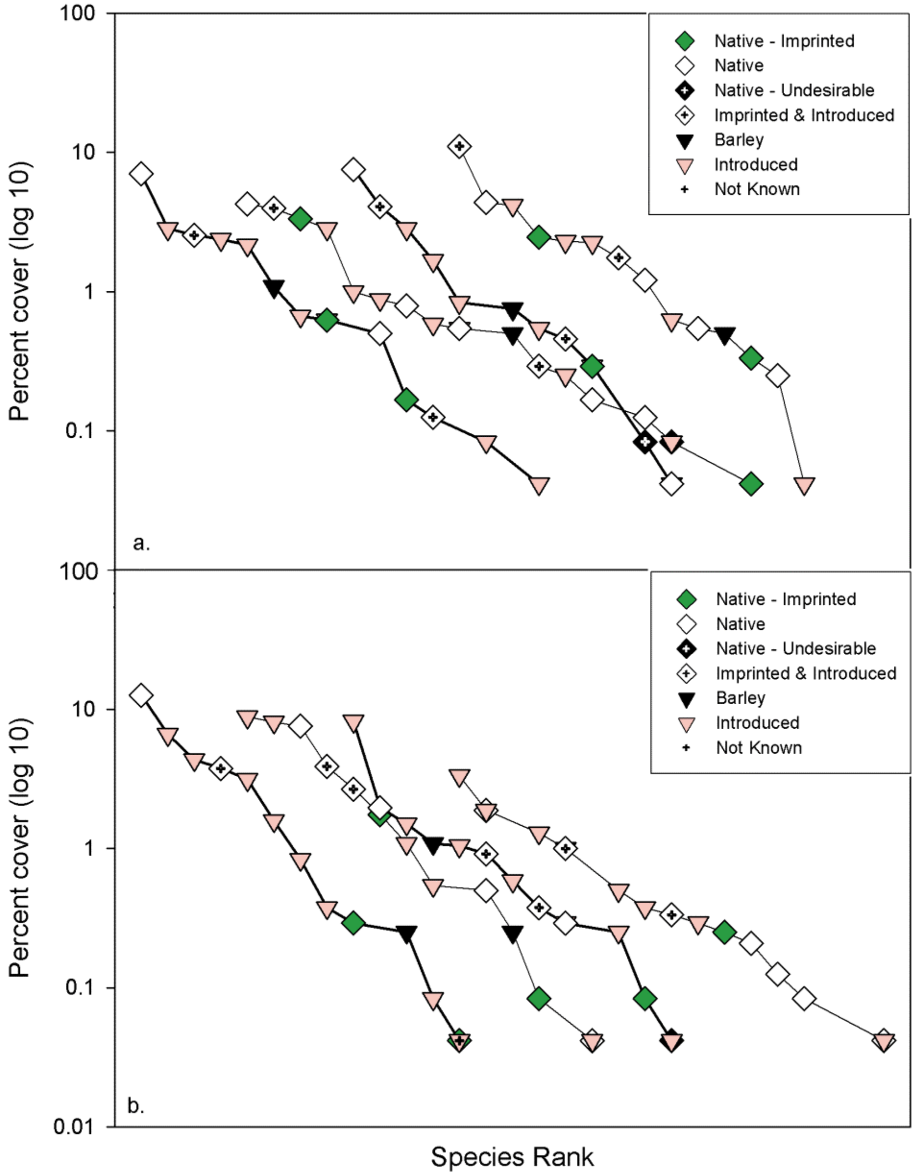

Figure 4-46. Species rank-abundance by treatment, Study Area 3, Atwell Island HRS plots 2002. a. contoured and imprinted (CR); b. imprinted, but not contoured (NR).

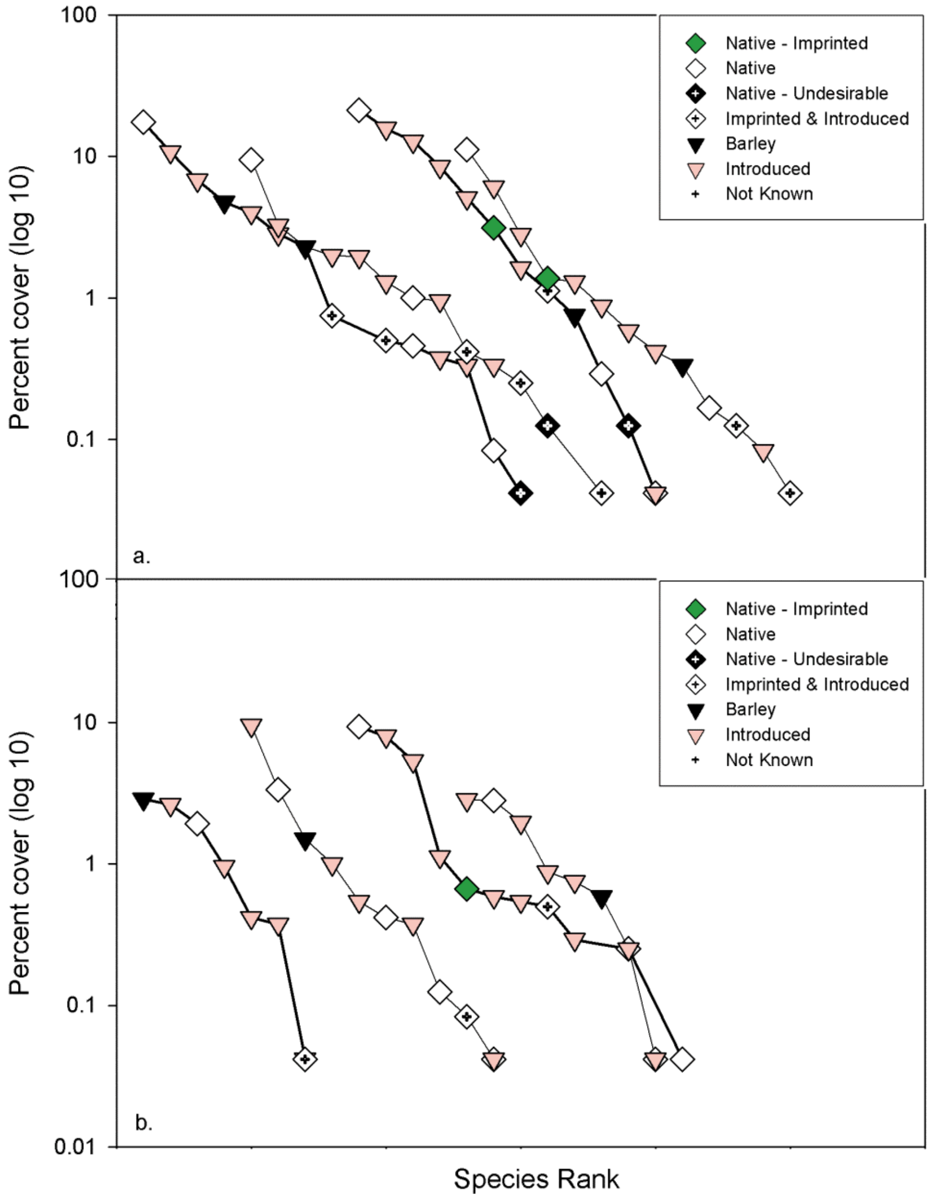

Figure 4-47. Species rank-abundance by treatment, Study Area 3, Atwell Island HRS plots 2002. a. contoured, but not imprinted (CN); b. neither imprinted nor contoured (NN).

4.4.3.3. Shrub monitoring

4.4.3.3.1. Overall Atwell HRS Site

Nine species were noted in the plots during shrub monitoring (Table 4-32). As with the Tranquillity HRS, the majority were members of the Chenopodiaceae (Goosefoot family). Four of the nine corresponded to species that had been imprinted. Nevertheless, as one of these species (*Frankenia salin*a) was frequently observed in both the non-imprinted plots, and in the buffers of Study Area 3. Hence, it appears that this species' presence could be attributed to an existing population (i.e., from existing rhizomes).

Table 4-32. Species encountered during shrub monitoring, Atwell Island HRS, 2002. Key to species origins: N-I, Native - Imprinted; N, Native; N-U, Native - Undesirable; I, Introduced.

Species	**Code**	**Common Name**	**Family**	**Origin**	**Life-form**
Atriplex argentea	ATAR	silverscale saltbush	Chenopodiaceae	N-U	annual herb
Atriplex polycarpa	ATPO	allscale saltbush	Chenopodiaceae	N-I	shrub
Atriplex serenana	ATSE	bractscale	Chenopodiaceae	N-I	annual herb
Atriplex suberecta	ATSU	peregrine saltbush	Chenopodiaceae	I	annual herb
Bassia hyssopifolia	BAHY	fivehook Bassia	Chenopodiaceae	I	annual herb
Chenopodium album	CHAL	lambsquarter	Chenopodiaceae	I	annual herb
Frankenia salina	FRSA	alkali heath	Frankeniaceae	N-I	perennial herb
Sesuvium verrucosum	SEVE	western sea-purslane	Aizoaceae	N	perennial herb
Suaeda moquinii	SUMO	bush seepweed	Chenopodiaceae	N-I	perennial herb

In contrast to the ordination of the spring vegetation data, in which the three study areas were clearly partitioned in ordination space, an ordination of the shrub monitoring data showed a certain amount of overlap among the study areas (Figure 4-48). These areas of overlap were generally attributable to the prevalence of two weedy species (*Atriplex argentea* and *Bassia hyssopifolia*) and, to a lesser degree, to occurrences of the native *Frankenia salina*.

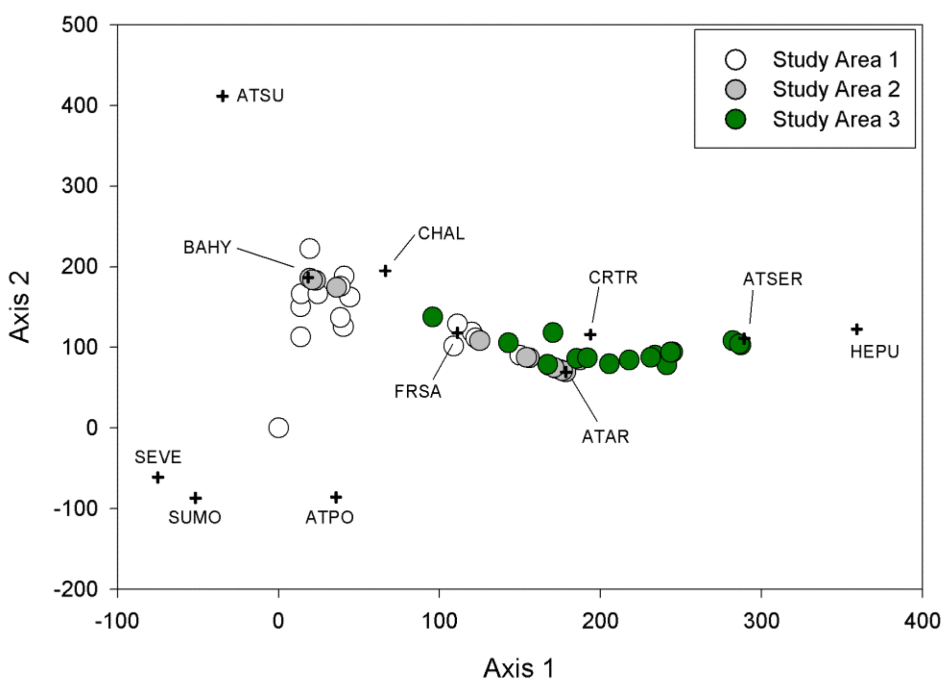

Figure 4-48. Ordination (DCA) of the shrub monitoring data from the Atwell Island HRS, 2002. Data collected Sep-Oct 2002. Species codes are given in Table 4-32.

Twelve of the plots from Study Area 1 were fairly tightly grouped in ordination space. This pattern appeared to be driven by two imprinted native species, *Atriplex polycarpa* and *Suaeda moquinii*, and by the native perennial herb *Sesuvium verrucosum*. The four plots from Study Area 1 that were disjunct from the larger grouping were the easternmost four plots (i.e., the closest to Study Area 2). The close floristic relationship between these plots and portions of Study Areas 2 and 3 appeared to be due to an abundance of *Atriplex argentea* in these areas.

Visible differences among the study areas were much more pronounced than during the spring monitoring. By the time of shrub monitoring most plant species on Study Areas 2 and 3 had either senesced or had become dormant. Exceptions were *Atriplex argentea* (Study Area 2), and *Atriplex serenana* and *Frankenia salina* (Study Area 3), which were generally still photosynthetic during this period. By contrast, most “shrubs” on Study Area 1 were quite vibrant and the vegetation had continued to grow, such that “shrubs” in some plots were above head height (Figure 4-49).

Figure 4-49. Shrub monitoring, Study Area 1, Atwell Island HRS (2 October 2002). Shown in the background is the sampling quadrat frame (2m x 3 m) suspended above the head of biologist Krista Garcia (height: 5’7”). The majority of the vegetation visible in the photograph is the weedy annual, *Bassia hyssopifolia*.

As with the Spring monitoring data, species were identified by origin, and rank-abundance curves were generated for each plot on Study Area 1 (Figure 4-50; Figure 4-51). This analysis was limited to this Study Area, as shrub establishment on the other two study areas was not sufficient to warrant additional investigation. Hence, all comments regarding species abundances are specific to Study Area 1.

In general, the imprinted plots were characterized by greater species richness and evenness than were the non-imprinted plots. Still, despite the abundant imprinted native shrubs on many of the imprinted plots (see, for example, Figure 4-38), the non-desirable native *Atriplex argentea* and the non-native *Bassia hyssopifolia* generally comprised the most abundant species. *A. argentea* was particularly abundant in the southernmost row of plots; in general, these plots were noticeably drier than those to the north. It may be that the abundance of *A. argentea* in this area resulted from these drier conditions; however, it may also be that these plots were situated nearer to a source of tumbleweeds than were the other plots. Three of four plots in the southernmost row were imprinted (two CR and one NR); hence, interpretation of the restoration efforts was confounded by the “gradient” in *A. argentea* abundance.

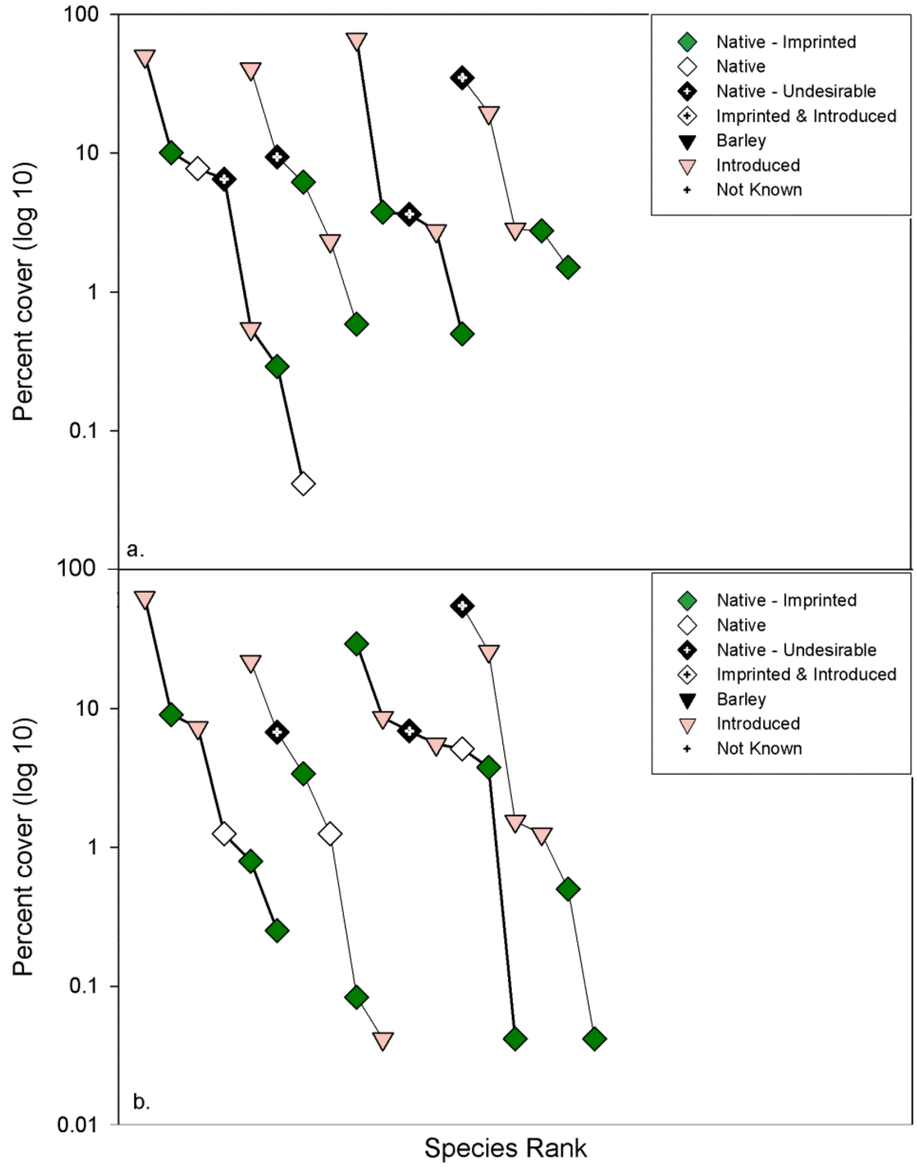

Figure 4-50. Species rank-abundance by treatment, Study Area 1: Atwell Island HRS Shrub Monitoring, 2002. a. contoured and imprinted (CR); b. imprinted, but not contoured (NR).

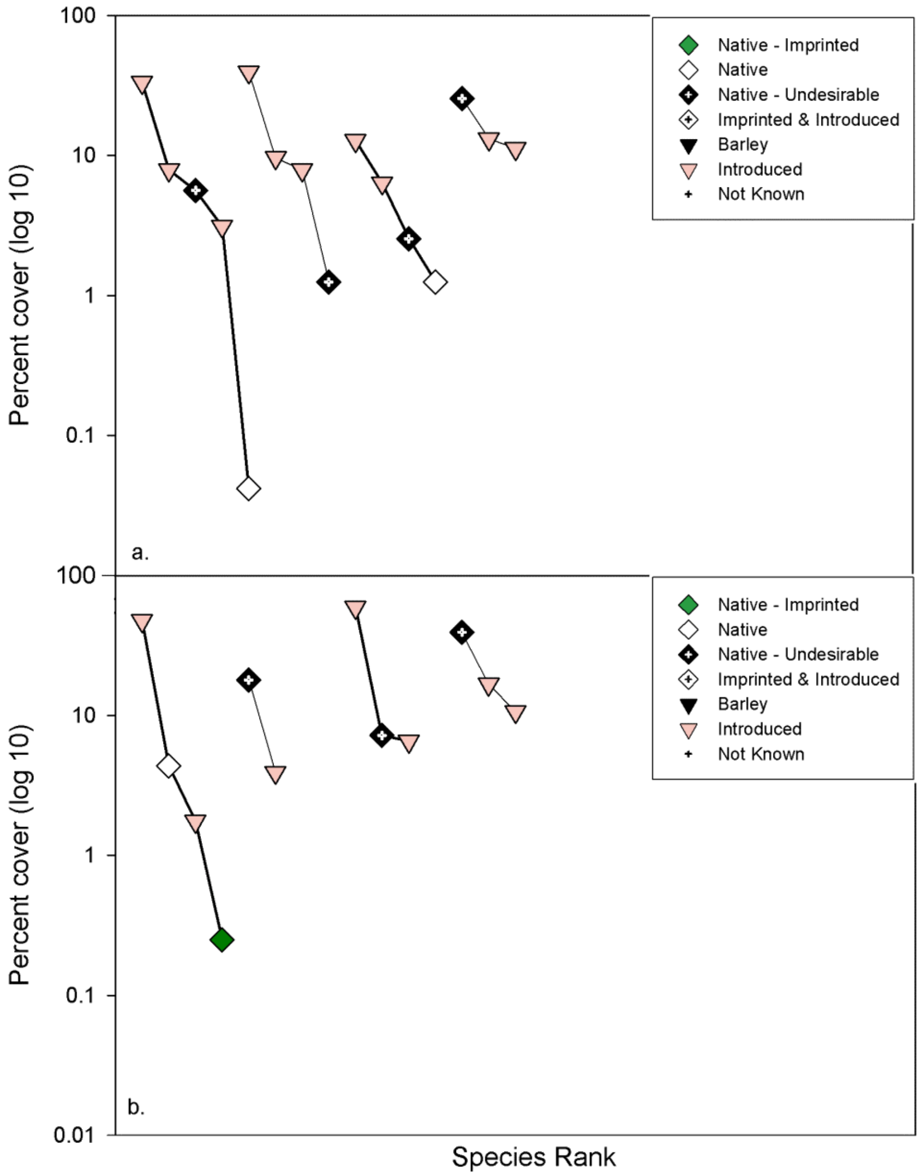

Figure 4-51. Species rank-abundance by treatment, Study Area 3, Atwell Island HRS Shrub Monitoring, 2002. a. contoured, but not imprinted (CN); b. neither imprinted nor contoured (NN).

It appears that the extreme difference in restoration response between Study Area 1 and the other two study areas was at least partially attributable to differences in soil conditions and depth to water table. As noted in Chapter 2, the soils in Study Area 1 are more conducive to capillary wicking than are the soils of the other two study areas. Hence, it seems likely that the perennial vegetation on Study Area 1 was able to utilize sub-surface water.

4.4.3.4. Atwell Island Vegetation Summary

The extreme differences in restoration response among the three study areas constituted the most striking feature of these trials. As noted, the study areas were situated within a few miles of each other, all had received essentially the same pre-treatment, and all had received the same treatments. The remarkable differences in responses should serve as a clear warning to anyone hoping for a single, broadly applied approach to restoration.

Some aggressive weedy species, particularly *Bassia hyssopifolia* and *Atriplex argentea*, were fairly abundant at Atwell Island; however, these species tend to germinate in mid- to late-spring. This delayed germination of the dominant weeds appeared to allow the imprinted species—many of which germinate during the same period—to compete. For example, the general success of the imprinted woody perennials in Study Area 1 appears to have been partially attributable to a surfeit of open ground during this period. By contrast, the "weedy flora" of the Tranquillity HRS contains a large portion of early-germinating winter annuals. These species characteristically create a dense cover, thereby reducing the suitable habitat for the later-germinating native species.

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APPENDIX 4-1. ADDITIONAL TABLES RELATING TO RESEARCH ON THE TRANQUILLITY HRS PLOTS.

Table 4-33. Plant species noted in the quadrats during vegetation monitoring in the Tranquillity HRS plots, 1999-2002. Species are ordered first by species category and then alphabetically by species. Cat = Species category, All = Data compiled from all 20 plots, Imp = Data compiled from the 10 imprinted plots. Key to Species Categories: N-I, Native - Imprinted; N, Native; N-U, Native - Undesirable; I-I, Imprinted and Introduced; B, Barley; I, Introduced; N.K., Not Known

Species	Cat	1999		2000		2001		2002	
		All	Imp	All	Imp	All	Imp	All	Imp
Atriplex polycarpa	N-I	-	-	-	-	-	-	+	+
Bromus carinatus	N-I	-	-	+	+	+	+	+	+
Frankenia salina	N-I	-	-	+	+	-	-	+	-
Hemizonia pungens	N-I	-	-	-	-	+	+	-	-
Isocoma acradenia	N-I	-	-	+	+	-	-	-	-
Lasthenia californica	N-I	-	-	+	+	+	+	+	+
Leymus triticoides	N-I	-	-	-	-	+	+	-	-
Suaeda moquinii	N-I	-	-	+	+	+	+	-	-
Amsinckia menziesii	N	-	-	-	-	+	-	+	-
Eremalche parryi	N	+	+	-	-	-	-	-	-
Hordeum depressum	N	+	+	+	+	-	-	-	-
Malacothrix coulteri	N	-	-	-	-	-	-	+	+
Malvella leprosa	N	-	-	+	+	-	-	-	-
Monolepis nutalliana	N	-	-	+	+	-	-	-	-
Phacelia ciliata	N	+	+	+	+	+	+	-	-
Solanum americanum	N	-	-	+	-	-	-	-	-
Atriplex argentea	N-U	+	+	+	+	+	+	+	+
Vulpia spp.[1]	I-I	-	-	+	+	+	+	+	+
Hordeum vulgare	B	+	+	+	+	+	+	+	+
Avena fatua	I	+	-	+	-	+	+	+	+
Bassia hyssopifolia	I	-	-	-	-	+	-	-	-
Beta vulgaris	I	+	+	+	+	+	+	-	-
Brassica nigra	I	+	+	+	+	+	+	+	+
Bromus diandrus	I	-	-	-	-	+	+	-	-
Bromus madritensis	I	+	+	+	+	+	+	+	+
Capsella bursa-pastoris	I	+	+	+	+	+	+	+	+
Chenopodium album	I	+	-	+	+	-	-	-	-
Convolvulus arvensis	I	+	-	+	+	-	-	-	-
Erodium cicutarium	I	+	+	+	+	+	+	+	+
Hordeum murinum	I	+	+	+	+	+	+	+	+
Lactuca serriola	I	+	+	+	+	+	+	+	+
Malva parviflora	I	+	+	+	-	-	-	+	+

Species	Cat	1999		2000		2001		2002	
		All	Imp	All	Imp	All	Imp	All	Imp
Medicago sativa	I	-	-	-	-	+	-	-	-
Melilotus indica	I	+	+	+	+	+	+	+	+
Phalaris minor	I	-	-	+	-	+	+	-	-
Salsola tragus	I	-	-	-	-	+	+	-	-
Senecio vulgaris	I	+	+	+	+	-	-	+	+
Sisymbrium irio	I	+	+	+	+	+	+	+	+
Sonchus sp.[2]	I	+	+	+	+	+	+	+	+
Unknown *Malvaceae*	N.K.	+	-	-	-	-	-	-	-
Unknown *Atriplex*	N.K.	+	+	+	+	-	-	-	-
Unknown *Chenopodiaceae* #1	N.K.	+	+	-	-	-	-	-	-
Unknown *Chenopodiaceae* #2	N.K.	+	+	-	-	-	-	+	+
Unknown *Poaceae* #1	N.K.	-	-	+	+	-	-	-	-
Unknown *Poaceae* #2	N.K.	-	-	-	-	-	-	+	+
Unknown *Poaceae* #3	N.K.	-	-	-	-	-	-	+	+
Unknown *Lamiaceae*	N.K.	-	-	-	-	-	-	+	+
Unknown #1	N.K.	+	+	-	-	-	-	-	-
Unknown #2	N.K.	+	+	-	-	-	-	-	-
Unknown #3	N.K.	-	-	+	+	-	-	-	-
Unknown #4	N.K.	-	-	+	+	-	-	-	-
Unknown #5	N.K.	-	-	+	+	-	-	-	-

[1] *Vulpia myuros* and *V. microstachys*

[2] *Sonchus asper* and *S. oleraceus*

Table 4-34. Vegetation species richness for the Tranquillity HRS plots. Values for each year represent the number of species observed in the twenty four 0.245 m^2 quadrats that were sampled on each plot. Plots are ordered by treatment, and then numerically by plot number. Hence, the first plot listed for any treatment is situated in Block 1, the second in Block 2, etc.

Treatment	Plot	1999	2000	2001	2002
Contoured and imprinted	2	14	15	15	6
	7	5	15	11	15
	11	4	13	10	12
	13	7	11	8	11
	17	8	17	7	9
Imprinted, but not contoured	1	17	10	12	5
	5	5	17	11	13
	12	5	10	16	11
	16	5	13	8	14
	20	6	14	5	12
Contoured, but not imprinted	4	7	13	12	6
	6	4	10	8	11
	10	6	6	9	10
	14	7	10	6	10
	19	7	5	5	7
Not imprinted or contoured	3	10	11	9	8
	8	9	9	10	7
	9	5	8	10	8
	15	6	7	8	10
	18	7	9	6	11

APPENDIX 4-2. IMPRINTER MODIFICATIONS PERFORMED BEFORE 2002-2003 TRIALS.

- Adrian Howard

One recurring problem with the LRDP imprinter is that the hopper was taken from a grain drill (Figure 4-52), and therefore is designed for use with grain rather than native seed mixtures. Commercially purchased grain typically is very clean, and the seed flows like sand. Native seed mixtures typically have greater amount of chaff and sticks, while the seeds themselves are often elongated or have awns and structures causing them to cling to each other. Wheat bran is used to float native seed mixtures so they will flow evenly and consistently, but this is not always successful. Native seed can ball up in the hopper and stop flowing completely, get caught in the tubes and clog so no seed can flow, or sort itself in the hopper during agitation, changing seed mixtures.

Figure 4-52. The imprinter hopper before modifications.

When seed is feeding correctly, it takes some time at the start of a run before the seed works its way though the hopper and begins to feed consistently. Since it takes approximately 100 feet of rolling before planting seed uniformly, another desired modification would allow the turning of the imprinter wheel while the tractor is not moving to start the seed moving through the hopper. This will be especially useful in trials with smaller plot sizes, as 10 x 100 ft may be a significant portion of the plot.

Lastly, in windy weather the seed would often be blown off the surface of the imprinter wheel before dropping to the ground into a divot. This was due to a gap of approximately 8 inches between the end of the nozzle and the imprinter wheel.

In June 2002, HCL Machineworks was contracted to modify the imprinter for use with native seed. To correct the problems of seed not feeding correctly and of seed self-sorting in the hopper, additional agitation was needed. By adding a larger paddle over the feeding holes in the bottom of the hopper, seed could be cleared away to help prevent clogging (Figure 4-53). By angling the larger paddles, seed in the hopper could be more thoroughly mixed during operation.

Figure 4-53. The imprinter hopper after modifications.

While the results were at first inconclusive, use in the field suggested that the new paddles reduced clogging of seed. However, when using any large odd shaped seed, particularly grasses with large awns, the hopper continued to clog would eventually stop feeding seed. In a few occasions, the seed had to be applied to the field by hand, then run over with the empty imprinter. It appeared that any large-scale grass plantings would require a hopper designed specifically for native seed.

To address the issue of seed not feeding at the start of an imprinting run, a socket was welded onto the end of the hopper auger. The socket can be used with a wrench when the imprinter wheel is raised off the ground to manually turn the wheel and start the feeding of seed. This solves the problem of the first 100 ft of the run not receiving seed or being unevenly seeded, but also leads to some loss of seed.

Straight tubing was attached to the nozzles and extended down to the imprinter to reduce the amount of seed blowing away before being imprinted. The new tubing was smooth inside and bunched less often than corrugated tubing. In the field, this noticeably improved imprinting. In all, the modifications improved the output of the imprinter, but did not completely solve the issues related to using the imprinter with native seed.

APPENDIX 4-3. SEEDING RATES

- Adrian Howard

In previous annual reports, seeding rates were presented in pounds per acre (lb/ac). While this gives an indication of the amount of seed planted, it does not account for variations in seed quality, making it extremely difficult to replicate actual seeding rates from year to year. This is because the quality of seed varies tremendously from year to year. Accordingly, we are now reporting the seeding rate using pure live seed (PLS) and live seeds per square foot (PLS/ft^2).

Purchasers of seed have the legal right to ask for the seed testing results for each lot of seed purchased. The Federal Seed Act and various State Seed laws set the standard for what information must be provided. Information required on a seed tags (Hoag et al 2001) includes:

- Variety and kind (Species and Common name)
- Lot number
- Origin
- Net weight
- Percent pure seed
- Percent germination (and date of test)
- Percent inert matter
- Percent other crop seed
- Percent weed seeds
- Name of restricted noxious seed (number per pound of seed)
- Prohibited noxious seeds are not allowed
- Name and address of company responsible for analysis (seller)

Although there are laws and regulations in place covering purchases of grasses and agricultural and vegetable seeds, there are none applicable to flowers, which many native plants are considered. Seed companies provide some of this information, but the remaining must come from a seed analysis report. The information in seed analysis reports is important to determine the quality of native seed being purchased. For example, it would be illegal to sell a lot of barley seed with zero percent germination. It is legal, however, to sell a lot of *Atriplex spinifera* with zero percent germination.

It is also critical to obtain a current report because the PLS of a given seed lot will change over time. While the purity should remain the same (assuming the original seed test sample was representative of the entire lot), germination can decline over time and at different rates depending on storage conditions. Likewise, while two lots of seed may be from the same source, they may have been collected in different years. Plants can produce seed of varying quality depending on the growing conditions. Seed collected during an extremely dry year can often be of much lower quality than seed collected during a normal or above average rainfall year. The purity of the seed lot can vary from year to year as conditions at collection sites change. Seed collected in different years can have different crop, weed, and noxious weed seed species and quantities. It cannot be assumed that seed from one lot that is good one year will continue to be of high quality in successive years.

While seed analysis reports are a useful tool, the information provided must be carefully scrutinized. Samples taken from the same lot of seed given to two different labs may return differing results. Purity information performed on the same lot over successive years also produces varying results. Accordingly, the most reliable way to determine the accuracy of seed tests is to average test results for each species collected from the same location over a number of successive years.

Using the information from the seller and the seed analysis reports, a standard seeding rate can be calculated in terms of pure live seed. PLS is defined as the percentage of pure seed that will germinate, expressed as a percentage of a given weight of seed. PLS can be calculated with the formula:

$$PLS = \frac{(Percent\ Purity) * (Percent\ Germination)}{100}$$

Additionally, the number of live seeds per pound is usually shown on the seed analysis report. Therefore, if the rate at which the lot is seeded is known, it is possible to calculate the number of live seeds per square foot. This is useful information because some small seeded plants can effectively be seeded at a lower lb/ac rate than a large seeded plant. In addition, when planning the seeding effort it is possible to estimate the number of plants that would occupy a square foot and plant accordingly. Planting 2,500 live seeds per square foot would waste of resources if the most plants that could reasonably be expected to grow in that area is much lower.

By knowing PLS and the number of seeds planted per square foot, it is now possible to replicate experiments from year to year and to compare results from different years or locations with more precision. Therefore, it is anticipated that all future seeding rates for trials will be reported using this standard.

APPENDIX 4-4. SPECIES EVALUATED FOR GERMINATION FOR THE SUITABILITY TRIAL

Table 4-35. Species evaluated for germination for the Suitability trial.

Species	Used at Tranquillity Site[1]	Life history[2]	Form[3]	Active growth period[4]	Precip. range (inches)	Fine soil adapted[1]	Salinity tolerance[5]	Shade tolerance[5]	Fire tolerance[5]	Drought tolerance[5]	Mycorrhizal status[6]	Growth rate[7]	Mature height (feet)	Legal weed[1]	Supplier[8]	Seed pre-treatment[9]	On plant lists[10]
Achillea millefolium		P	FH	SP	8-60	N	No	No	H	M		M	3	Y	D	NG	d
Amsinckia menziesii	Y	A	He											Y			a,c,d,e
Aristida ternipes var. *hamulosa*		P	He												C	NG	d,e
Asclepias fascicularis	Y	P	He											Y	C,D	N	a,b,d,e
Baccharis pilularis		P	Su	SP,SU	12-30	N	H	No	M	H	FM	M	10			N	
Baccharis viminea		P	Sh	SU	10-18	Y	H	No	M	LH		R	10			NG	
Bromus carinatus	Y	A	Gr	F,W,SP	14-20	N	M	No	No	L	NB	R	2.5		A,B,C	NG	a,c,d,e
Calandrinia ciliata		A	He											Y	C		a,d,e
Ceanothus cuneatus		P	Sh	SP,SU	16-36	Y	M	No	H	H		M	11		B,C	Y	d
Crassula connata		A	He											Y			a,d,e
Cressa truxillensis		P	Su				H						<114	Y	C		a,d,e,g
Elymus elymoides		P	Gr	SP	5-16	Y	L	No	M	H		M	1.5		B,C		d,e
Elymus glaucus		P	Gr	SP	16-60	Y	M	No	H	H		R	3.3		A,B,C,D	N	d,e
Elymus multisetus		P	Gr										314	Y	B,C	NG	d,e
Elymus trachycaulus		P	Gr	SP	8-25	Y	H	No	H	H		R	3		C	NG	d
Encelia californica		P	Sh		12-26	Y		No			NB					N	
Eremocarpus setigerus	Y	A	FH				M						<114	Y	C		a,b,c,d,e
Eriogonum fasciculatum		P	Sh	SP,SU	8-20	N	M	No	H	H	FM	M	3		B,C	N	a,d,e,f
Eriogonum giganteum		P	Su			Y	H	Int					54		C	N	
Eriophyllum confertiflorum		P	Su				M				NB		34		B,C	Y	d,e
Eschscholzia californica		A	FH	SP,SU,F	8-18	Y	No	Int	L	M		M	1.2	Y	A,B,D	N	b,d,e
Festuca californica		P	Gr	F,W,SP	12-20	Y	L	No	H	H		M	4			N	
Festuca idahoensis		P	Gr	SP	12-20	Y	No	Int	M	L		M	2		D	N	e
Festuca rubra		P	Gr	SP,F	30-60	Y	L	Int	H	M		M				N	d,e

Species	Used at Tranquillity Site[1]	Life history[2]	Form[3]	Active growth period[4]	Precip. range (inches)	Fine soil adapted[1]	Salinity tolerance[5]	Shade tolerance[5]	Fire tolerance[5]	Drought tolerance[5]	Mycorrhizal status[6]	Growth rate[7]	Mature height (feet)	Legal weed[1]	Supplier[8]	Seed pre-treatment[9]	On plant lists[10]
Helianthus annuus	Y	A	FH	SU	12-60	Y	L	No	No	M		R	9	Y	C	NG	a,d,e
Hemizonia fasciculata		A	He								NB		3.3		C	NG	e
Hordeum brachyantherum		P	Gr	SP,SU	14-24	Y	M	No	H	M		M	1.6		A,B,D	N	b,d,e
Hordeum californicum		P	Gr	SP	6-8.5	Y	No	No	H	M		S	2		B	N	d,e
Isocoma menziesii		P	Sh				H				NB				C		d
Larrea tridentata		P	Sh				MH							Y	C	Y	d,f
Lasthenia chrysostoma		A	FH														d,g
Layia platyglossa		A	FH				M								A,B,C		d,e
Leymus triticoides	Y	P	Gr	SP,SU,F	7-24	Y	H	No	H	H		R	3	Y	A,B,C,D		a,c,d,e
Lupinus bicolor		A	FH			Y								Y	A,B,C,D	Y	a,b,d,e
Melica californica		P	Gr	SP,SU	14-24	N	No	Int	H	M		M	4		D	N	d
Melica imperfecta		P	Gr	SP	9-16	N	L	No	H	H		M	3.2		A,B,C	N	d,f
Muhlenbergia rigens		P	Gr	SP,SU	10-18	N	L	Int	H	H		M	4.5	Y	B,C,D	N	d,e
Nassella cernua		P	Gr	SP	12-18	Y	No	No	H	M	OM	R	2.6	Y	A,B,C,D		d
Nassella lepida		P	Gr	SP	12-18	Y	No	No	H	M	OM	R	3		B,C,D		d
Nassella pulchra		P	Gr	SP,SU	14-40	Y	L		H	M	FM	R	3		A,B,C,D		b,d
Phacelia distans	Y	A	He												C	VG	a,b,d,e
Poa secunda	Y	P	Gr	SP	8-16	Y	L	No	M	H		M	4		C,D	N	a,d,e
Spergularia macrotheca	Y	P	FH													N	a,g
Trichostema lanceolatum	Y	A	FH											Y		VG	b,c,d
Triphysaria eriantha		A	FH														d,e

[1] N = No, Y = Yes
[2] A = Annual, P = Perennial
[3] FH = Forb/Herb, Gr = Graminoid, He = Herb, Sh = Shrub, Su = Subshrub
[4] SP = Spring, SU = Summer, F = Fall, W = Winter
[5] L = Low, M = Medium, H = High, LH = Low-High, MH = Medium-High, Int = Intermediate, No = None
[6] FM = Facultative mycotroph, NB = Net builder
[7] M = Moderate, R = Rapid, S = Slow
[8] A = Elkhorn Native Plant Nursery, B = Pacific Coast Seed, C = S&S Seed, D = Hedgerow Farms
[9] N = None, NG = None for genus, VG = Varies for species in genus, Y = Yes
[10] a = Plants of Alkali Sink Ecological reserve, b = Species in Fresno/Kings County by John Stebbins, c = Target Plant Species for LRDP document, d = CalFlora Fresno County, e = CalFlora Valley Grassland, f = CalFlora Creosote Bush, g = CalFlora Alkali Sink

APPENDIX 4-5. COLLECTION SITES, SPECIES, AND DATES OF 2002 NATIVE SEED COLLECTIONS

Alkali Sink Ecological Reserve

Allenrolfea occidentalis	11/20/2002
Frankenia salina	11/20/2002
Grindelia camporum	9/4/2002
Hemizonia pungens	5/30/2002; 6/6/2002; 6/11/2002; 6/12/2002; 6/13/2002; 7/2/2002
Isocoma acradenia	9/24/2002
Kochia californica	10/24/2002
Lasthenia californica	4/30/2002
Spergularia atrosperma	7/2/2002
Sporobolus airoides	9/4/2002
Trichostema ovatum	11/20/2002; 11/25/2002

Fresno West Golf Course

Amsinckia menziesii	4/8/2002; 4/9/2002
Castilleja exserta	4/17/2002
Hemizonia pungens	5/9/2002; 5/15/2002; 5/21/2002; 6/5/2002
Lasthenia chrysantha	3/13/2002; 3/20/2002; 4/9/2002; 5/8/2002
Lepidium dictyotum	3/20/2002
Spergularia macrotheca	7/2/2002

Highway 180, San Mateo Avenue

Sambucus mexicana	6/6/2002

Highway 33, Firebaugh Area

Allenrolfea occidentalis	12/2/2002
Frankenia salina	12/2/2002
Grindelia camporum	9/11/2002; 12/2/2002

Highway 33, south of Dos Palos

Epilobium brachycarpum	9/11/2002
Grindelia camporum	9/11/2002
Helianthus annuus	9/11/2002

James Avenue, Site A

Cressa truxillensis	6/23/2002

Jensen Avenue Evaporation Ponds

Sesuvium verrucosum	6/27/2002; 7/2/2002; 9/4/2002; 9/26/2002

Kerman Ecological Reserve, North	
Atriplex fruticulosa	10/25/2002
Atriplex polycarpa	11/21/2002
Gilia tricolor	4/12/2002
Hemizonia pungens	5/15/2002; 5/22/2002
Lasthenia chrysantha	4/11/2002; 4/12/2002
Sesuvium verrucosum	8/6/2002
Trichostema lanceolatum	10/21/2002
Trichostema ovatum	10/14/2002
Wislizenia refracta	10/24/2002; 11/21/2002
Lanfranco Property	
Amsinckia menziesii	5/24/2002; 6/25/2002
Hemizonia pungens	5/24/2002; 6/25/2002
Sesuvium verrucosum	6/25/2002
Lateral 7 Inlet Canal	
Phacelia ciliata	6/11/2002; 7/2/2002
Little Panoche Road, Site A	
Atriplex polycarpa	11/29/2002
Isocoma acradenia	11/29/2002
Isomeris arborea	5/19/2002
Little Panoche Road, Site B	
Allenrolfea occidentalis	11/29/2002
Atriplex polycarpa	11/29/2002
Heliotropium curassavicum	7/10/2002
Hemizonia fitchii	7/10/2002; 9/11/2002; 9/12/2002; 10/1/2002; 10/22/2002; 11/29/2002
Holocarpha obconica	7/10/2002; 9/11/2002
Isocoma acradenia	10/22/2002
Isomeris arborea	7/10/2002
Main Canal at Firebaugh	
Amsinckia menziesii	5/22/2002
Mendota Wildlife Area	
Asclepias fascicularis	8/13/2002
Cressa truxillensis	8/13/2002; 9/13/2002
Grindelia camporum	9/17/2002
Helianthus annuus	8/13/2002; 9/13/2002
Old Friant Road, Site B	
Castilleja exserta	5/11/2002
Castilleja sp.	5/11/2002
San Joaquin River, San Mateo Road	
Sambucus mexicana	8/14/2002
San Luis Drain, Jefferson Avenue	
Sesuvium verrucosum	6/18/2002

San Luis Drain, south of turkey farm

Atriplex spinifera	8/5/2002
Monolopia stricta	3/13/2002; 3/15/2002; 3/20/2002; 4/2/2002; 4/3/2002; 4/5/2002

Tranquillity Site, Auxiliary Site 1

Phacelia ciliata	5/22/2002; 5/24/2002; 5/29/2002

Tranquillity Site, HRS

Phacelia ciliata	4/30/2002

Tranquillity Site, Native Plant Nursery

Hemizonia pungens	7/22/2002; 7/23/2002; 9/12/2002; 9/13/2002; 9/20/2002; 9/26/2002
Isocoma acradenia	10/21/2002
Lasthenia chrysantha	4/23/2002
Phacelia ciliata	4/19/2002; 4/22/2002; 4/23/2002; 4/24/2002; 4/30/2002

Tranquillity Site, North Avenue Parcel

Amsinckia menziesii	5/29/2002; 6/27/2002; 8/14/2002
Phacelia ciliata	5/29/2002
Sesuvium verrucosum	8/5/2002

Tranquillity Site, Section 10

Asclepias fascicularis	7/10/2002
Helianthus annuus	8/6/2002; 8/7/2002
Malacothrix coulteri	4/5/2002
Phacelia ciliata	4/5/2002

Yuba Avenue Habitat

Hemizonia pungens	6/14/2002

APPENDIX 4-6. TRANQUILLITY WIND ANALYSIS

- Adrian Howard

One problem on the Tranquillity site involves unwanted tumbleweeds that blow through the property. These tumbleweeds disperse their seed and then the seedlings require eradication. Some tumbling species include *Atriplex argentea* and *Salsola tragus*. To reduce the need for seedling eradication in the Habitat Restoration Study blocks (section 4.1) and native plant nursery (section 4.3), barriers around some areas of the property where planned to reduce the number of tumbleweeds entering research blocks and the nursery.

Before the installation of hedgerows and fencing, we examined wind direction. Both experience and yearly average wind direction data indicated that the wind predominantly blows from the northwest. Based upon this supposition, a hedgerow was established on the north and west sides of blocks 2 and 4, the west sides of blocks 3 and 5 and a fence was installed on the north and west sides of the native plant nursery.

However, during the month of December it was noted that the fence was catching the tumbleweeds on both sides, as they were blowing in from the southeast. This first appeared to be an anomaly, but a greater number of tumbleweeds on the inside of the fence than outside of the fence over time suggested otherwise.

We obtained wind direction data for the 2002 calendar year from the California Irrigation Management Information System (CIMIS) weather station # 105, which is located 1.5 miles west of the demonstration project site at the Westlands Water District (WWD) Tranquillity Field Office. The 2002 yearly wind direction data indicated that the wind blew out of the northwest 60% of the time, and the southeast 11% of the time. However, monthly wind direction data for 2002 showed wind direction shifting equally into the southeast during winter months, when tumbleweeds disperse and establish.

To compare 2002 wind direction with previous years, we analyzed 10 years of data beginning 1 January 1993 and ending 31 December 2002 (Table 4-36). Ten-year wind-direction data indicated that the wind blew from the northwest 57% of the time, and from the southeast 14% of the time. Wind direction data by month indicated that during the 8 months from March through October, wind originates from the northwest 68% of the time and the southeast 9.5%. However, during the months critical for the dispersal and establishment of tumbleweeds (November through February), the wind is split from the northwest (35%) and the southeast (30%).

Table 4-36. Ten-Year (1993-2002) wind direction probabilities by month

Month	NNE	ENE	ESE	SSE	SSW	WSW	WNW	NNW
January	0.06	0.10	0.27	0.12	0.05	0.11	0.18	0.12
February	0.06	0.09	0.19	0.11	0.05	0.13	0.22	0.14
March	0.09	0.07	0.10	0.05	0.04	0.14	0.30	0.21
April	0.07	0.04	0.05	0.03	0.02	0.13	0.40	0.25
May	0.06	0.03	0.03	0.02	0.02	0.12	0.41	0.32
June	0.05	0.02	0.01	0.01	0.01	0.10	0.46	0.34
July	0.04	0.01	0.01	0.01	0.02	0.12	0.48	0.32
August	0.03	0.02	0.01	0.01	0.02	0.15	0.46	0.29
September	0.06	0.03	0.03	0.02	0.04	0.17	0.39	0.27
October	0.07	0.05	0.05	0.03	0.06	0.19	0.32	0.22
November	0.07	0.08	0.13	0.08	0.07	0.16	0.25	0.16

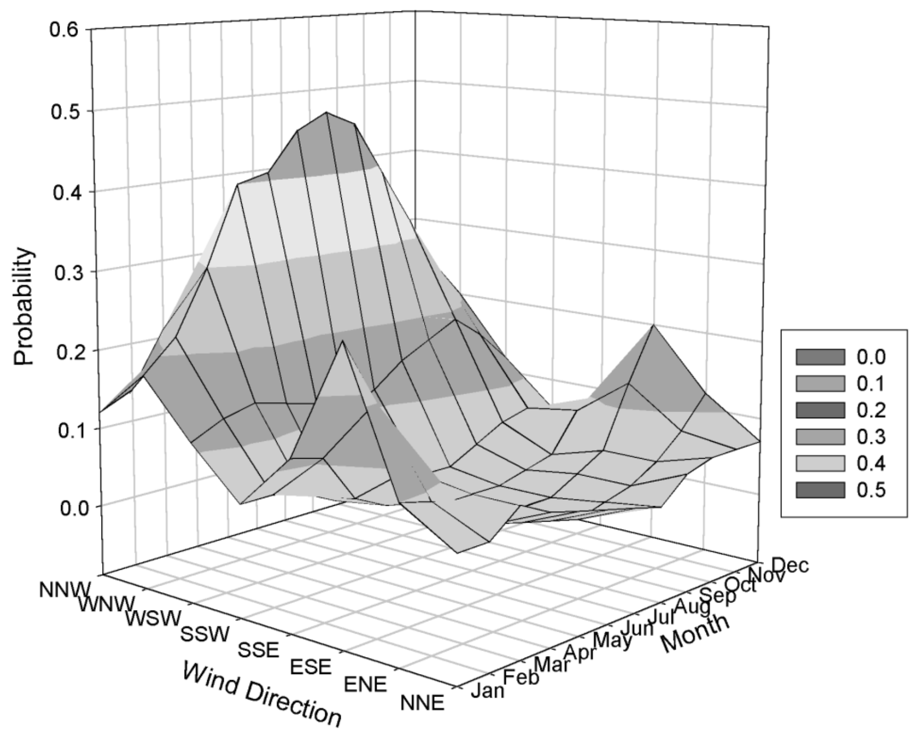

Figure 4-54. Probability graph for wind direction from 1993-2002. Note that while the annual average has the wind coming from the NW, during the winter months it is equally probable from the northwest as the southeast.

However, the direction of travel of tumbleweeds is not determined by wind direction alone. There needs to be sufficient wind speed to move tumbleweeds. The wind speed required to move tumbleweeds was unknown, so a value of 7.66 mph was used for analysis, which is the mean hourly wind speed for November through February 1993-2002, plus one standard deviation (4.47 + 3.19). Using this speed as a cut off point, all hourly averages greater than this value were recorded, along with the cardinal direction of wind. Due to the differences in the way this data was collected, the cardinal points are slightly different from those used to calculate the proportions above.

Since this did not show a difference between northwest and southeast, the data was reanalyzed using 10.85 mph as the cut off point, which is the hourly mean plus two standard deviations. This shows the same distribution as the wind speed plus one standard deviation.

The data indicate that winds at the Tranquillity site are as likely to blow from the northwest as the southeast during the winter (November through February). Furthermore, the wind speeds from these two directions are equally capable of dispersing tumbleweeds. In order to protect sites from tumbleweeds it will be necessary to fence all sides of the property.

Table 4-37. Frequency table of hourly average wind speeds that exceed 7.66 mph in November through February, arranged by year and cardinal direction.

Direction	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
North	2	1	1	4	14	29	17	21	29
Northeast	0	0	10	8	0	2	4	0	4
East	25	95	147	231	19	26	19	19	27
Southeast	72	162	53	44	87	118	195	140	163
South	1	5	0	1	8	13	23	13	6
Southwest	5	1	9	26	1	0	0	0	1
West	29	30	103	252	9	21	19	42	23
Northwest	174	113	56	85	91	199	124	191	160

Table 4-38. Frequency table of hourly average wind speeds that exceed 10.85 mph in November through February, arranged by year and cardinal direction.

Direction	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02
North	0	0	0	0	2	6	2	2	6
Northeast	0	0	3	0	0	0	0	0	0
East	3	21	65	113	3	8	10	2	10
Southeast	32	70	29	23	29	55	113	79	76
South	0	1	0	0	5	5	12	7	4
Southwest	3	0	0	2	0	0	0	0	0
West	6	8	42	132	3	6	3	13	4
Northwest	61	36	23	38	32	67	53	56	54

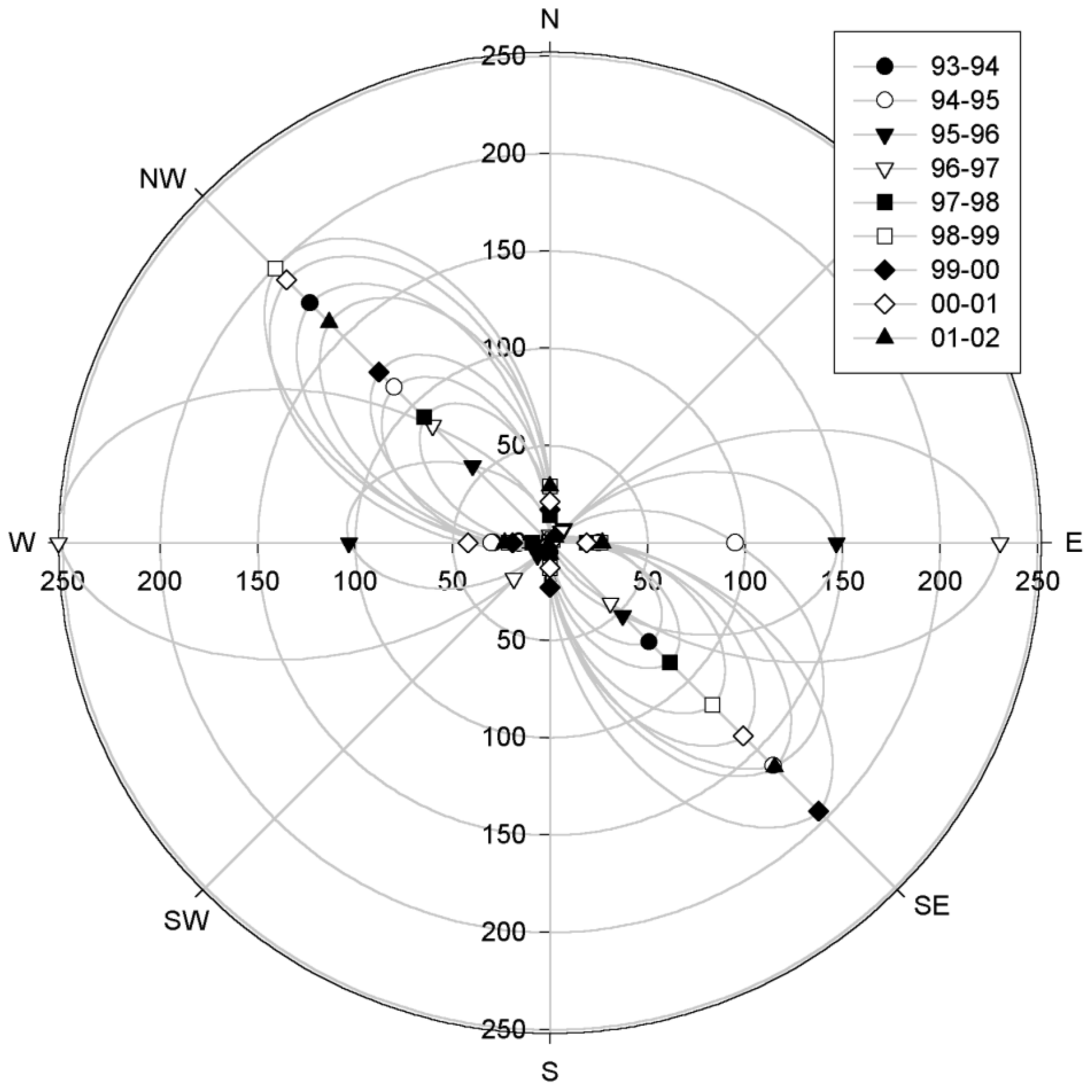

Figure 4-55. Frequency graph showing the hourly average wind speeds from November - February, 1993-2002 which exceeded 7.66 mph, along with their cardinal direction.

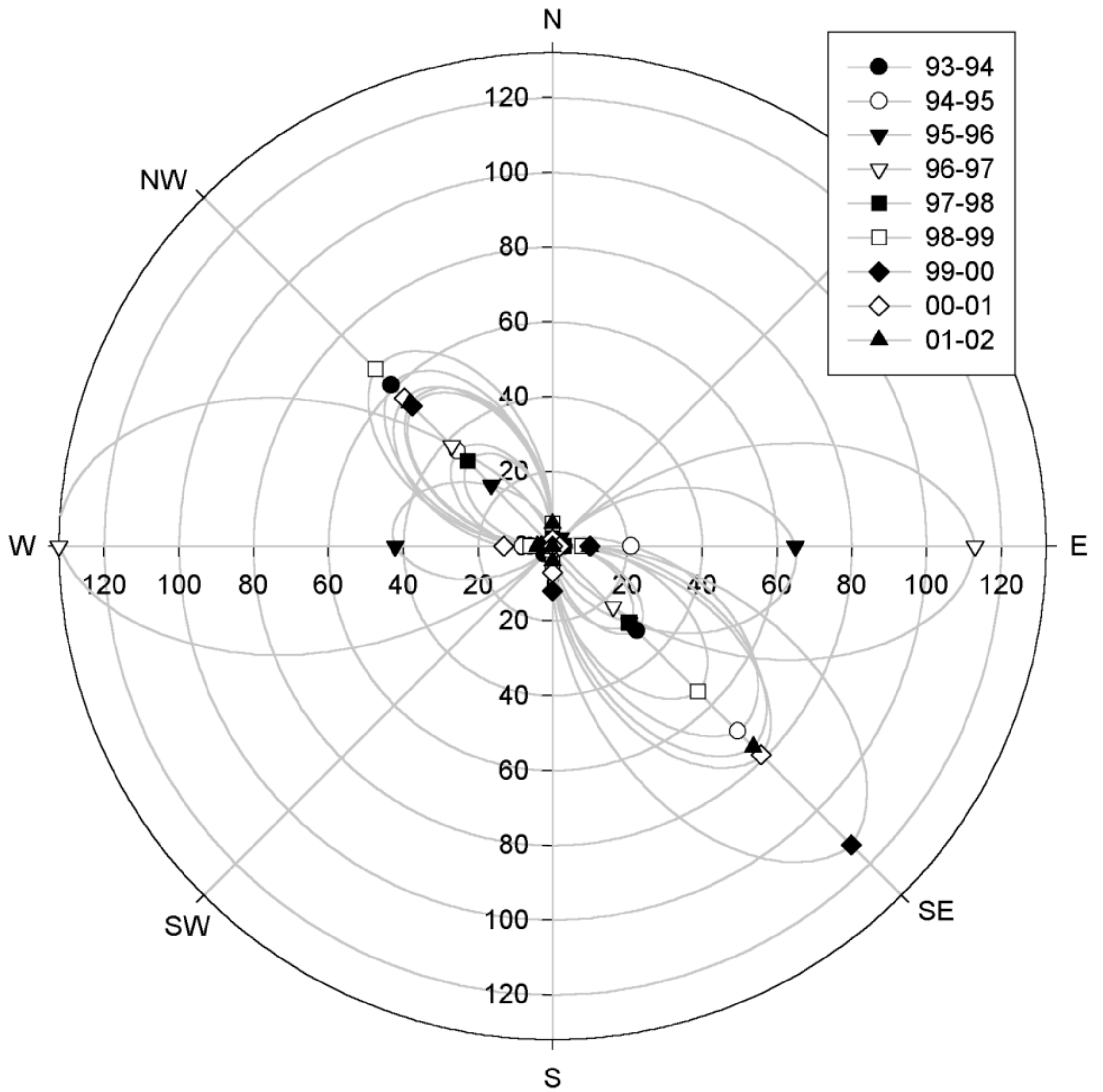

Figure 4-56. Frequency graph showing the hourly average wind speeds from November – February 1993-2002 which exceeded 10.85 mph, along with their cardinal direction.

APPENDIX 4-7. ADDITIONAL DATA ASSOCIATED WITH THE VEGETATION OF THE ATWELL ISLAND HRS

Table 4-39. The species encountered during spring monitoring at the Atwell Island HRS site. Species[1] are ordered first by origin and then alphabetically by species. Key to presence: +, occurred in the quadrats; *, did not occur in any quadrats but was noted elsewhere in the plot; –, not present. Key to species origins: N-I, Native - Imprinted; N, Native; N-U, Native - Undesirable; I-I, Imprinted and Introduced; B, Barley; I, Introduced; N.K., Not Known.

Species	Family	Common name	Origin	Study Area 1	Study Area 2	Study Area 3
Allenrolfea occidentalis	Chenopodiaceae	iodinebush	N-I	*	–	–
Amsinckia menziesii	Boraginaceae	Menzie's fiddleneck	N-I	–	+	+
Atriplex polycarpa	Chenopodiaceae	allscale saltbush	N-I	+	–	+
Frankenia salina	Frankeniaceae	alkali heath	N-I	–	+	–
Hemizonia pungens	Asteraceae	common spikeweed	N-I	+	+	+
Suaeda moquinii	Chenopodiaceae	bush seepweed	N-I	+	+	–
Atriplex serenana	Chenopodiaceae	bractscale	N	–	+	+
Cressa truxillensis	Convolvulaceae	alkali weed	N	–	–	+
Guillenia lasiophylla	Brassicaceae	California mustard	N	–	+	+
Hutchinsia procumbens	Brassicaceae	prostrate hutchinsia	N	–	+	–
Lepidium dictyotum	Brassicaceae	alkali pepperweed	N	–	–	+
Malacothrix coulteri	Asteraceae	snake's head	N	–	+	–
Monolepis nuttalliana	Chenopodiaceae	Nuttall's povertyweed	N	*	+	+
Phacelia ciliata	Boraginaceae	Great Valley Phacelia	N	–	–	*
Plagiobothrys sp.	Boraginaceae	popcornflower	N	–	–	+
Sesuvium verrucosum	Aizoaceae	western sea-purslane	N	+	–	–
Bromus spp.	Poaceae	brome	I-I	+	+	+
Vulpia spp.	Poaceae	fescue	I-I	+	+	+
Hordeum vulgare	Poaceae	barley	C	+	+	+
Atriplex argentea	Chenopodiaceae	silverscale saltbush	N-U	+	+	+
Avena spp.	Poaceae	oats	I	+	+	+
Bassia hyssopifolia	Chenopodiaceae	fivehook Bassia	I	+	+	+
Brassica nigra	Brassicaceae	black mustard	I	–	+	+
Brassica tournefortii	Brassicaceae	Asian mustard	I	–	–	–
Capsella bursa-pastoris	Brassicaceae	shepherd's purse	I	+	+	+
Carthamus tinctorius	Asteraceae	safflower	I	+	–	*
Chamomilla suaveolens	Asteraceae	pineapple weed	I	–	+	–
Cynodon dactylon	Poaceae	bermuda grass	I	+	–	–
Erodium cicutarium	Geraniaceae	redstem filaree	I	–	+	+
Hordeum murinum	Poaceae	foxtail barley	I	+	+	+

Species	Family	Common name	Origin	Study Area 1	Study Area 2	Study Area 3
Lactuca serriola	Asteraceae	prickly lettuce	I	+	+	+
Malva parviflora	Malvaceae	cheeseweed	I	*	1	–
Medicago polymorpha	Fabaceae	burclover	I	*	–	–
Melilotus indica	Fabaceae	sourclover	I	–	+	+
Phalaris minor	Poaceae	littleseed canarygrass	I	+	+	–
Polygonum arenastrum	Polygonaceae	dooryard knotweed	I	+	+	+
Senecio vulgaris	Asteraceae	old-man-in-the-Spring	I	*	+	+
Sisymbrium irio	Brassicaceae	London rocket	I	+	+	+
Sonchus spp.	Asteraceae	sowthistle	I	+	+	+
Spergularia bocconii	Caryophyllaceae	Boccone's sandspurry	I	+	+	–
Stellaria media	Caryophyllaceae	common chickweed	I	+	–	+
Chenopodium sp.	Chenopodiaceae	–	N.K.	+	+	–
Poa sp.	Poaceae	–	N.K.	+	–	–
Unknown Caryoph	Caryophyllaceae	–	N.K.	–	–	+
Unknown Grass	Poaceae	–	N.K.	–	–	+
Unknown	Not Known	–	N.K.	–	+	–

[1] The species list represents 52 species because of the contribution of the various multi-species "complexes": *Bromus* spp., 3 species; *Vulpia* spp., 2 species; *Avena* spp., 2 species; and, *Sonchus* spp., 2 species.

5. WILDLIFE DIVERSITY AND ABUNDANCE

This Chapter describes the results of monitoring wildlife on the Habitat Restoration Study (HRS) plots and computation of site-wide indices of wildlife richness (number of species or taxa) and abundance (number of individuals). At the Tranquillity site, we conducted monitoring over a 4-year period, 1999 (baseline conditions when the plots were planted in barley), 2000, 2001, and 2002. Restoration treatments were applied at the Tranquillity site starting in 2000. At the Atwell Island site, we conducted monitoring in 2001 (baseline conditions when the plots were planted in barley) and in 2002 (after restoration treatments had been applied). We monitored invertebrates, reptiles and amphibians, birds, and small mammals on the plots. We also determined avian nesting success on the study plots at Tranquillity in 2002. Site-wide species richness and abundance indices were generated from monitoring track stations, conducting windshield surveys, and spotlighting. In this chapter, we present information from the Tranquillity site. Although data were gathered from the Atwell Island site and entered into databases, analyses of the data are not complete. Accordingly, the results of the Atwell Island monitoring effort will be provided in a final report, which will be completed in 2004. The information obtained from these monitoring efforts will provide a basis for determining wildlife responses to the restoration treatments that were applied to the study plots. The results to date of the restoration treatments are presented in Section 4.2.

5.1. INVERTEBRATES

- Georgia Basso

5.1.1. Methods

The fourth annual LRDP invertebrate pitfall survey was conducted from 16-19 April 2002. Invertebrates were collected from the five pitfall-arrays established in April 1999 on each of the 20 study plots (Figure 5-1). Each array consisted of four 3-gallon buckets sunk into the ground, to the rim. The buckets were connected by 20 ft by 1 ft sections of galvanized steel flashing used to guide the invertebrates toward the bucket. During the four consecutive survey days, bucket lids were opened and supported approximately 1 inch above the rim by wooden stakes. Bucket lids were opened for approximately 24 hours between each survey day.

Richness and abundance values were calculated based on the invertebrates identified and counted in the pitfall traps. Indices of richness were based on identification to order and represent the number of orders occurring on each treatment or block. Identification to the ordinal level was used because consistent and accurate invertebrate field identification beyond that level has not been possible. Indices of richness based upon the family, genus, or species level would have more accurately measured fluctuations in richness over time and among treatments and blocks. Mean abundance values were used to determine invertebrate population trends. Mean abundance is the average number of invertebrates per plot, grouped by block or the average number of invertebrates per plot, grouped by treatment. High abundances and large population fluctuations of hemipterans and thysanopterans tended to mask fluctuations of other invertebrate orders. Accordingly, to facilitate a more complete interpretation of population trends, mean abundance data were analyzed and graphed, both including and excluding hemipterans and thysanopterans. Site wide abundance (number of invertebrates per day) was used to measure yearly trends and determine the relative prevalence of invertebrate pest species. Several invertebrate orders have been omitted from the site wide abundance calculations because their identifications have not been verified. Final values of site wide abundance for these orders will be included in the final report when identifications are completed. Data were analyzed using analysis of variance (ANOVA) tests computed on log transformed richness and abundance data. When applicable, Student's *t*-tests were preformed to determine significance between specific data sets. Significance was assumed at the 95% confidence level ($p \leq 0.05$).

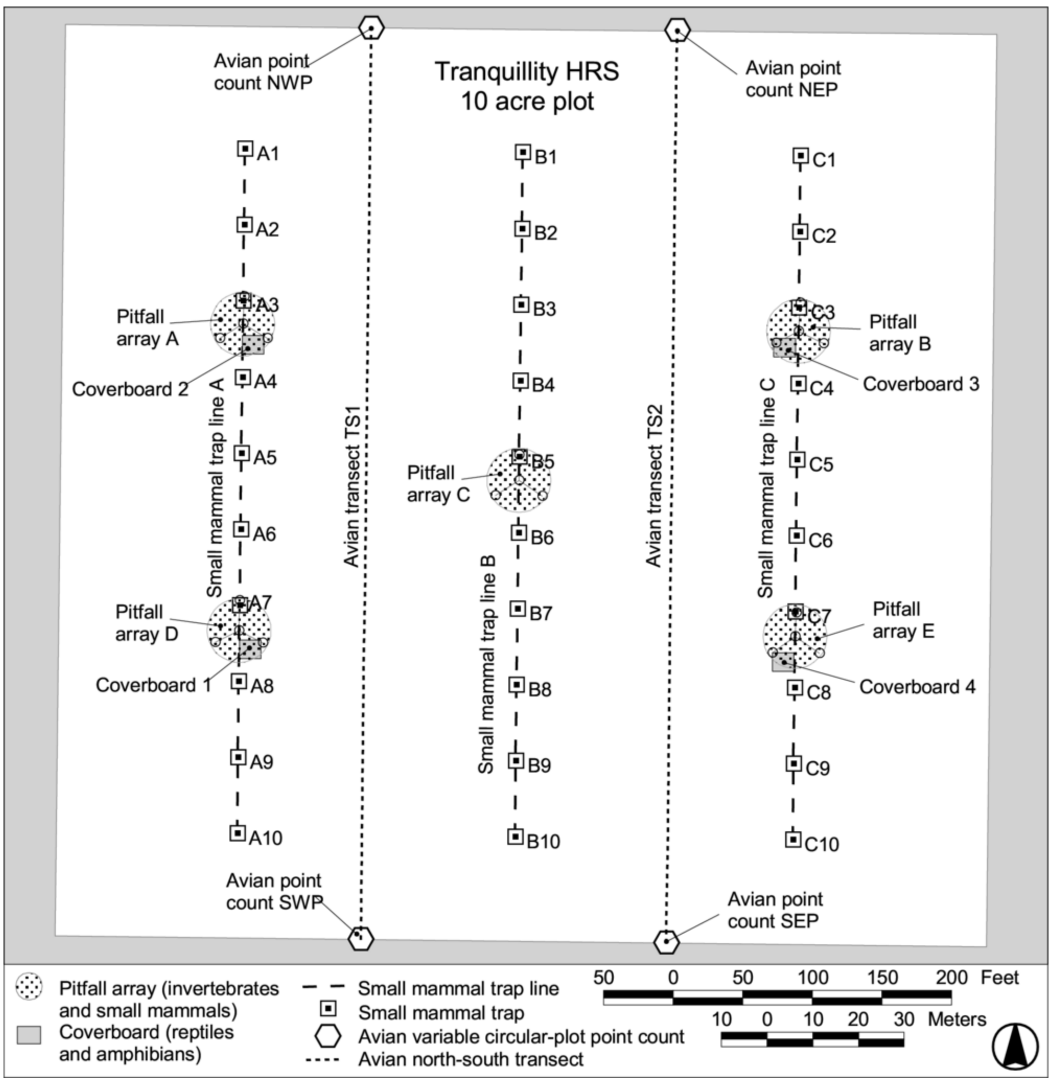

Figure 5-1. Locations of pitfall arrays, cover boards, avian transects, and small mammal trapping lines on a Tranquillity HRS plot.

5.1.2. Results

The number of orders (richness) among blocks ranged from 9 to 13 (Figure 5-2). There were significant differences in richness between blocks as well as between blocks within given years (Table 5-1). In 1999, 2000, and 2001 Block 1 had significantly higher richness than blocks 2, 3, 4, and 5. In 2002, richness was even across all blocks with 10 orders each. There were significant differences in richness between study years. Richness in 2000 was significantly lower than in 1999, 2001, and 2002 (Table 5-1). There was a trend toward increasing evenness from 2000 to 2002. Overall, the highest ordinal richness was observed in 1999 and the lowest in 2000 (Figure 5-2).

Between 9 and 11 orders were consistently found on plots of all treatments (Figure 5-3). There was no significant variation in richness over all treatments (p = 0.63, F = 0.57) or treatment within any given year (p = 0.20, F = 1.35). However, there are trends in richness between years that are discussed in the 2001 LRDP Annual Report (Uptain et al. 2002).

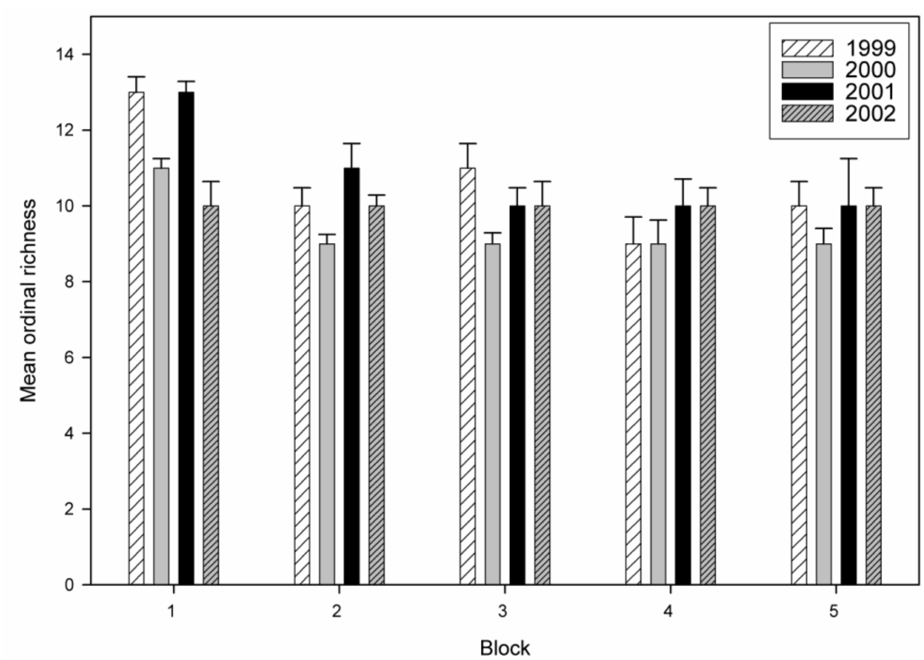

Figure 5-2. Richness of invertebrate orders by block at the Tranquillity HRS site, 1999 to 2002.

Table 5-1. Summary statistics for invertebrate richness data.

Statistical test	Factors	*p* value	F or *t*-value	Results
ANOVA	Difference between blocks	$p < 0.01$	F = 9.49	
ANOVA	Difference between blocks among years	$p < 0.01$	F = 4.77	
t-test	Block 1 vs. Block 2 in 1999	$p < 0.01$	$t = 3.96$	Block 1 > Block 2
t-test	Block 1 vs. Block 3 in 1999	$p < 0.01$	$t = 3.97$	Block 1 > Block 3
t-test	Block 1 vs. Block 4 in 1999	$p < 0.01$	$t = 5.27$	Block 1 > Block 4
t-test	Block 1 vs. Block 5 in 1999	$p < 0.01$	$t = 4.56$	Block 1 > Block 5
t-test	Block 1 vs. Block 2 in 2000	$p < 0.01$	$t = 9.81$	Block 1 > Block 2
t-test	Block 1 vs. Block 3 in 2000	$p < 0.01$	$t = 9.99$	Block 1 > Block 3
t-test	Block 1 vs. Block 4 in 2000	$p < 0.01$	$t = 4.89$	Block 1 > Block 4
t-test	Block 1 vs. Block 5 in 2000	$p < 0.01$	$t = 4.89$	Block 1 > Block 5
t-test	Block 1 vs. Block 2 in 2001	$p < 0.01$	$t = 4.69$	Block 1 > Block 2
t-test	Block 1 vs. Block 3 in 2001	$p < 0.01$	$t = 5.25$	Block 1 > Block 3
t-test	Block 1 vs. Block 4 in 2001	$p < 0.01$	$t = 5.25$	Block 1 > Block 4
t-test	Block 1 vs. Block 5 in 2001	$p = 0.05$	$t = 2.33$	Block 1 > Block 5
ANOVA	Difference between years	$p = 0.04$	F = 2.90	
t-test	1999 vs. 2000	$p = 0.05$	$t = 2.02$	1999 > 2000
t-test	2000 vs. 2001	$p = 0.01$	$t = -2.65$	2000 < 2001
t-test	2000 vs. 2002	$p = 0.02$	$t = -2.26$	2000 < 2002

Table 5-2. Site-wide abundance (number/day) and richness of invertebrate orders per year. The abundance values are calculated without the omitted orders but the richness values include those orders[1].

Order	1999	2000	2001	2002
Thysanoptera	8,362.25	7,752.75	308.00	197.75
Hemiptera	163.25	13,096.75	67.50	1,035.50
Orthoptera	366.50	3,377.75	3,166.00	813.25
Araneae	1,568.50	1,803.25	1,142.25	649.98
Coleoptera	1,515.75	604.25	545.75	657.00
Isopoda	115.25	1,933.25	637.00	186.25
Dermaptera	855.75	335.25	36.75	12.00
Hymenoptera	28.25	498.50	271.00	86.00
Thysanura	25.75	73.00	15.75	1.00
Scorpiones	20.25	20.25	5.00	0.00
Blattaria	3.25	29.50	4.50	0.25
Total	**13,024.75**	**29,524.50**	**6,199.50**	**3,638.98**
Richness (Ordinal)	**19**	**12**	**16**	**15**

[1]Omitted orders: Homoptera, Diptera, Collembola, Acari, Lepidoptera, Scolopendromorpha, Microcoryphia, Neuroptera, Opiliones, Mantodea.

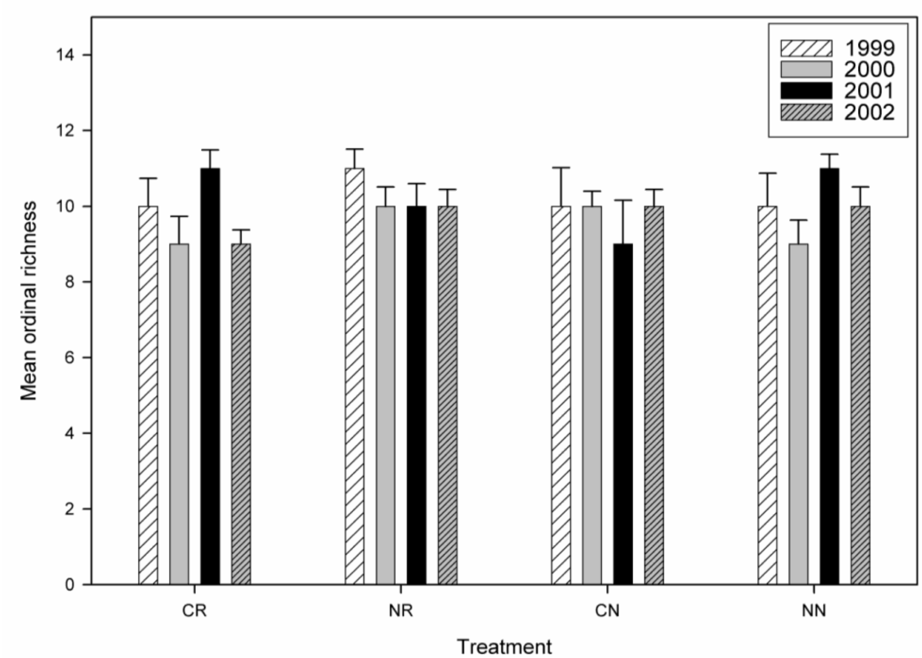

Figure 5-3. Richness of invertebrate orders by treatment at the Tranquillity HRS site, 1999 to 2002.

There are significant differences in mean abundance of invertebrates across blocks within specified study years when Hemiptera and Thysanoptera are included in the data (Table 5-3). In 1999, mean abundance was significantly higher on Blocks 2 and 5 than on Block 1. Blocks 2 and 5 had significantly higher mean abundances than Block 4. In 2000, Block 2 had significantly higher mean abundance than blocks 1 and 4. When comparing blocks 1 and 4, Block 4 had significantly higher mean abundance. In 2001, Block 3 had significantly higher mean abundance than blocks 1 and 5. Block 1 had significantly higher mean abundance than Block 5. In 2002, Block 1 had significantly lower mean abundance than all the other blocks and the lowest mean abundance value over the 4-year study period. Mean abundance differences between blocks 2 and 5 were also significant, with Block 5 having a higher mean abundance. There were significant mean abundance differences between years (Table 5-3); all years were significantly different from each other with the exception of 2001 and 2002.

Table 5-3. Summary statistics for invertebrate abundance data (including Hemiptera and Thysanoptera).

Statistical test	Factors	*p* value	F or *t*-value	Results
ANOVA	Difference between blocks among years	$p < 0.01$	F = 12.06	
t-test	Block 1 vs. Block 2 in 1999	$p = 0.02$	$t = -2.93$	Block 1 < Block 2
t-test	Block 1 vs. Block 5 in 1999	$p = 0.05$	$t = -2.40$	Block 1 < Block 5
t-test	Block 2 vs. Block 4 in 1999	$p < 0.01$	$t = 4.16$	Block 2 > Block 4
t-test	Block 4 vs. Block 5 in 1999	$p < 0.01$	$t = -3.97$	Block 4 < Block 5
t-test	Block 1 vs. Block 2 in 2000	$p < 0.01$	$t = -19.48$	Block 1 < Block 2
t-test	Block 2 vs. Block 4 in 2000	$p < 0.01$	$t = 5.72$	Block 2 > Block 4
t-test	Block 1 vs. Block 4 in 2000	$p = 0.02$	$t = -3.07$	Block 1 < Block 4
t-test	Block 3 vs. Block 5 in 2001	$p = 0.02$	$t = 2.85$	Block 1 < Block 3
t-test	Block 1 vs. Block 3 in 2001	$p = 0.05$	$t = -2.37$	Block 1 > Block 5
t-test	Block 1 vs. Block 5 in 2001	$p = 0.05$	$t = 2.37$	Block 3 > Block 5
t-test	Block 1 vs. Block 2 in 2002	$p < 0.01$	$t = -7.86$	Block 1 < Block 2
t-test	Block 1 vs. Block 3 in 2002	$p < 0.01$	$t = -4.21$	Block 1 < Block 3
t-test	Block 1 vs. Block 4 in 2002	$p < 0.01$	$t = -8.37$	Block 1 < Block 4
t-test	Block 1 vs. Block 5 in 2002	$p < 0.01$	$t = -5.57$	Block 1 < Block 5
t-test	Block 2 vs. Block 5 in 2002	$p = 0.04$	$t = -2.46$	Block 2 < Block 5
ANOVA	Difference between years	$p < 0.01$	F = 31.89	
t-test	1999 vs. 2000	$p < 0.01$	$t = -3.86$	1999 < 2000
t-test	1999 vs. 2001	$p < 0.01$	$t = 3.80$	1999 > 2001
t-test	1999 vs. 2002	$p < 0.01$	$t = 6.35$	1999 > 2002
t-test	2000 vs. 2001	$p < 0.01$	$t = 6.61$	2000 > 2001
t-test	2000 vs. 2002	$p < 0.01$	$t = 9.50$	2000 > 2002

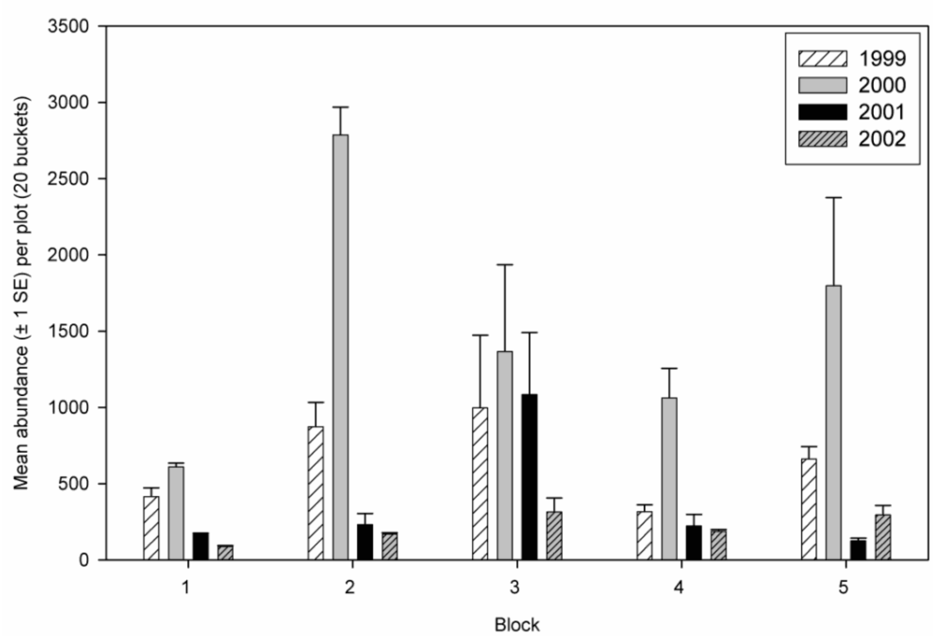

Figure 5-4. Mean abundance of invertebrates by block at the Tranquillity study site, 1999 to 2002.

There were significant differences in invertebrate mean abundance across blocks within specified study years when Hemiptera and Thysanoptera were excluded from the data (Table 5-4). In 1999, Block 1 had significantly higher mean abundance than blocks 2, 4, and 5. Block 3 had significantly higher mean abundance than Block 5. In 2000, Block 1 had significantly lower mean abundance than blocks 2, 4, and 5. Similarly, Block 3 had significantly lower mean abundance than blocks 2, 4, and 5. In 2001, Block 3 had significantly higher mean abundance than blocks 1 and 5. In 2002, Block 1 had significantly lower mean abundance than all other blocks. Block 3 had higher mean abundance than blocks 2 and 4. There were significant differences in invertebrate mean abundance between years (Table 5-4). Those differences were between 1999 and 2000, 1999 and 2002, 2000 and 2001, as well as 2000 and 2002.

Table 5-4. Summary statistics for invertebrate abundance data (excluding Hemiptera and Thysanoptera).

Statistical test	**Factors**	***p*-value**	**F or *t*-value**	**Results**
ANOVA	Difference between blocks among years	$p < 0.01$	F = 8.70	
t-test	Block 1 vs. Block 2 in 1999	$p = 0.01$	$t = 3.32$	Block 1 > Block 2
t-test	Block 1 vs. Block 4 in 1999	$p = 0.02$	$t = 2.99$	Block 1 > Block 4
t-test	Block 1 vs. Block 5 in 1999	$p < 0.01$	$t = 4.84$	Block 1 > Block 5
t-test	Block 3 vs. Block 5 in 1999	$p = 0.02$	$t = 2.95$	Block 3 > Block 5
t-test	Block 1 vs. Block 2 in 2000	$p < 0.01$	$t = -4.55$	Block 1 < Block 2
t-test	Block 1 vs. Block 4 in 2000	$p < 0.01$	$t = -6.78$	Block 1 < Block 4
t-test	Block 1 vs. Block 5 in 2000	$p < 0.01$	$t = -4.10$	Block 1 < Block 5
t-test	Block 2 vs. Block 3 in 2000	$p < 0.01$	$t = 3.76$	Block 2 > Block 3
t-test	Block 3 vs. Block 4 in 2000	$p < 0.01$	$t = -4.87$	Block 3 < Block 4
t-test	Block 3 vs. Block 5 in 2000	$p = 0.04$	$t = -2.48$	Block 3 < Block 5
t-test	Block 1 vs. Block 3 in 2001	$p = 0.04$	$t = -2.51$	Block 1 < Block 3
t-test	Block 3 vs. Block 5 in 2001	$p = 0.02$	$t = 2.88$	Block 3 > Block 5
t-test	Block 1 vs. Block 2 in 2002	$p < 0.01$	$t = -6.68$	Block 1 < Block 2
t-test	Block 1 vs. Block 3 in 2002	$p < 0.01$	$t = -8.52$	Block 1 < Block 3
t-test	Block 1 vs. Block 4 in 2002	$p < 0.01$	$t = -5.77$	Block 1 < Block 4
t-test	Block 1 vs. Block 5 in 2002	$p < 0.01$	$t = -7.75$	Block 1 < Block 5
t-test	Block 2 vs. Block 3 in 2002	$p = 0.01$	$t = -3.23$	Block 2 < Block 3
t-test	Block 3 vs. Block 4 in 2002	$p = 0.04$	$t = 2.51$	Block 3 > Block 4
ANOVA	Difference between years	$p < 0.01$	F = 13.49	
t-test	1999 vs. 2000	$p < 0.01$	$t = -5.22$	1999 < 2000
t-test	1999 vs. 2002	$p = 0.01$	$t = 2.58$	1999 > 2002
t-test	2000 vs. 2001	$p < 0.01$	$t = 3.24$	2000 > 2001
t-test	2000 vs. 2002	$p < 0.01$	$t = 9.03$	2000 > 2002

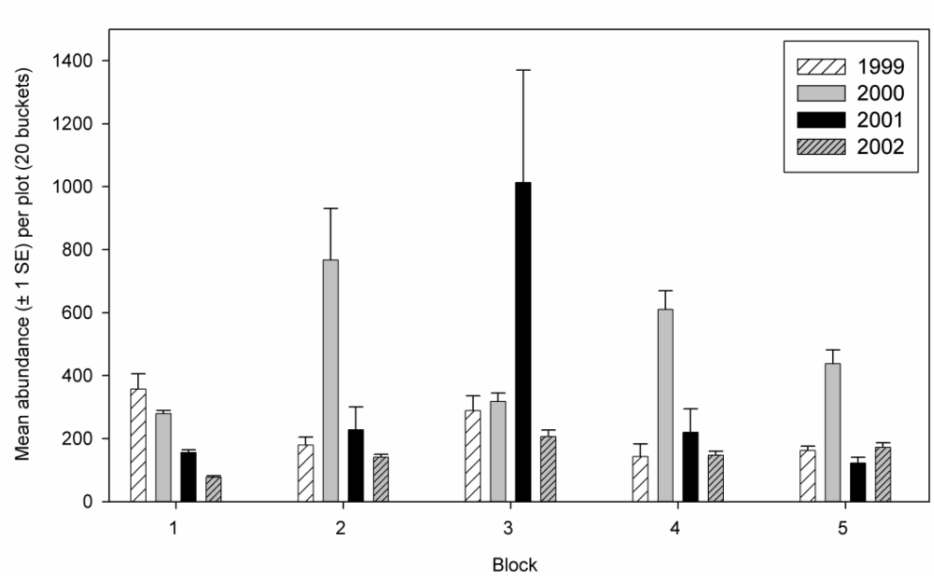

Figure 5-5. Mean abundance of invertebrates by block, excluding hemipterans and thysanopterans, at the Tranquillity study site, 1999 to 2002.

The greatest mean abundances occurred in 2000 on Block 2 and in 2001 on Block 3 (Figure 5-4, Figure 5-5). The invertebrate orders dominating these blocks, listed in descending order of abundance, are: 2000 Block 2; Hemiptera, Thysanoptera, Orthoptera and 2001 Block 3; Orthoptera, Thysanoptera, Hemiptera. Over the 4-year study period Thysanoptera abundance consistently decreased, Hemiptera abundance displayed cyclic population fluctuation, and Orthoptera abundance was lowest in 1999 followed by 2002 and highest in 2000 and 2001 (Table 5-5). The 4-year distribution of these orders shows highest mean abundance on block 3 and 2, respectively (Table 5-5).

Table 5-5. Block dominance of the three prominent pest orders at the Tranquillity study site, 1999 to 2002.

Year	Thysanoptera	Hemiptera	Orthoptera
1999	Block 3	Block 3	Block 4
2000	Block 2	Block 2	Block 2
2001	Block 3	Block 3	Block 3
2002	Block 2	Block 5	Block 3

There were no significant differences in mean abundance of invertebrates between treatments, both including hemipterans and thysanopterans ($p = 0.97$, $F = 0.07$; Figure 5-6) and excluding hemipterans and thysanopterans ($p = 0.70$, $F = 0.46$; Figure 5-6, Figure 5-7). Mean abundance by treatment varied significantly among years, both including and excluding hemipterans and thysanopterans ($p < 0.01$, $F= 6.22$ and $p < 0.01$, $F = 2.90$, respectively), yet no specific year was significantly different from any other year (Student's *t*-test).

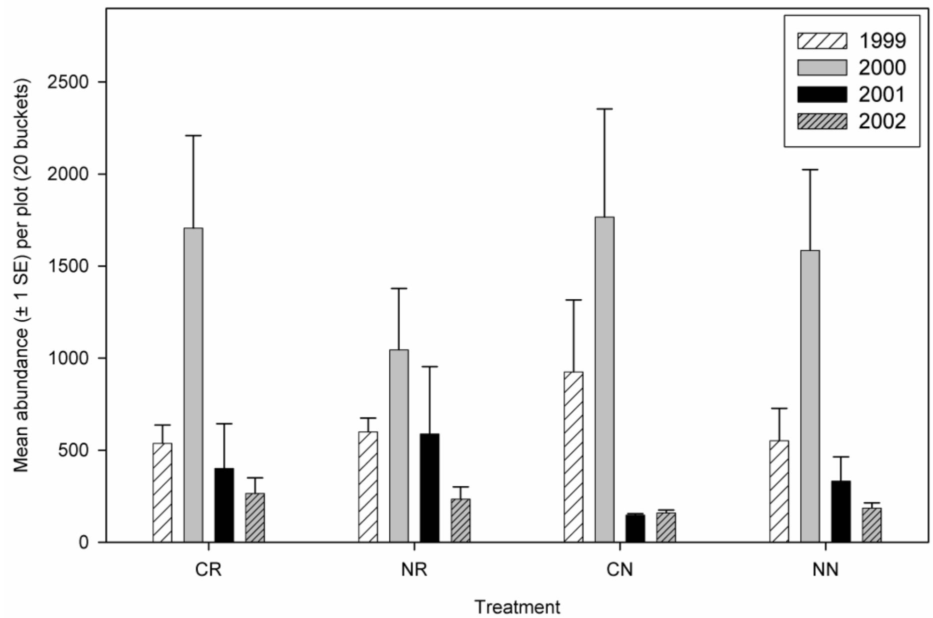

Figure 5-6. Mean abundance of invertebrates by treatment at the Tranquillity study site, 1999 to 2002.

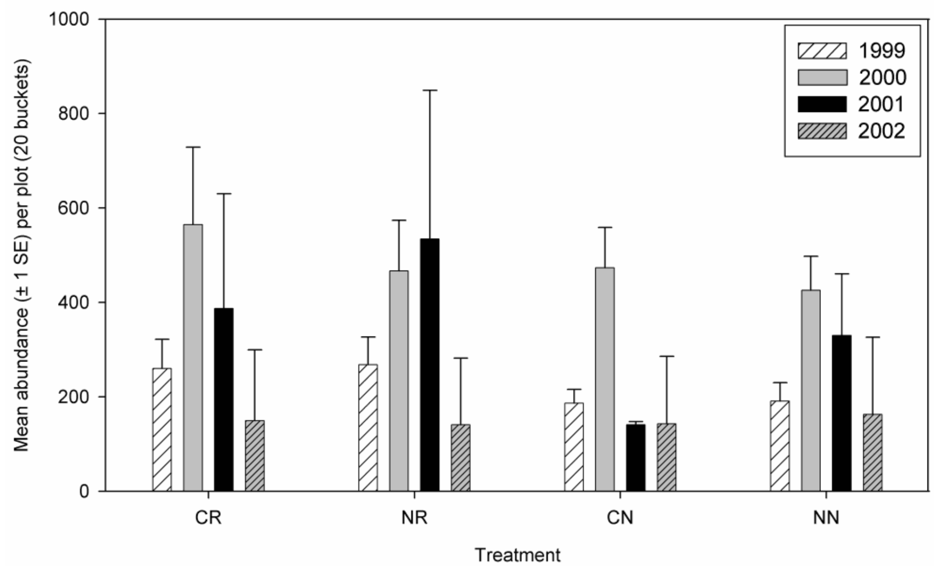

Figure 5-7. Mean abundance of invertebrates by treatment, excluding hemipterans and thysanopterans, at the Tranquillity study site, 1999 to 2002.

The mean abundance of invertebrates was more variable across blocks than across treatments during all years, regardless of whether hemipterans and thysanopterans were included or excluded (Figure 5-4, Figure 5-5, Figure 5-6, Figure 5-7). Mean abundance across blocks was most similar in 1999 and 2002 and blocking effect was most prominent in 2000 and 2001 (Figure 5-4, Figure 5-5). Generally, the highest mean invertebrate abundance occurred on blocks 3 and 2 (Figure 5-4, Figure 5-5). Block 1 generally had the lowest mean abundance hen hemipterans and thysanopterans were omitted. It is the only block to show a consistent decrease in yearly mean abundance (Figure 5-5).

5.1.3. Discussion and Conclusions

In the final report that will be prepared in 2004, we plan to be able to evaluate invertebrate richness at the family level. Although the current evaluation of richness is conducted at an ordinal level, trends are still evident. In 2002, all blocks were evenly rich, unlike previous years. This observed uniformity might be an indication of increased similarity across the blocks over time, particularity due to vegetative similarities (see section 4.1). The highest richness values were from Block 1, which is distinctly different from other blocks in isolation, long-term fallowing, fallowing practices of neighboring farmlands, location to water, soil structure, and vegetative composition (see section 4.1). These differences may all contribute to unique trends observed on that block. The decrease in richness between 1999 and 2000 was not as pronounced as the numbers appear to indicate (Figure 5-2) because the orders not recorded in 2000 had very low abundance in 1999. Representatives of these orders also were scarce or absent on all of the Tranquillity blocks in 2001 and 2002. In 2001, significant populations of Acari and Homoptera were noted for the first time during the study. The other orders contributing to an increase in richness from 2000 to 2002 were noted in very low abundance (see omitted orders (Figure 5-2). From a management perspective, the fluctuations in observed richness of invertebrate orders may be significant. The orders showing the greatest fluctuations are typically considered to be agriculturally beneficial (Borror et al. 1992, Deal S. 2003, Elzinga R.J. 1997, Univ. CA IMP Online Resource) and include Lepidoptera, Neuroptera, Mantodea, Scolopendromorpha, and Opiliones. Species in these orders that were found on the Tranquillity plots have been confirmed to be generally beneficial. The species identified in the orders Homoptera and Acari are considered pests. Representative species collected in the remaining three orders either fall under both pest and beneficial status or have an unknown economic status.

By omitting hemipterans and thysanopterans, Block 1 generally had lower abundance than the other blocks for all years with the exception of 1999. Overall, abundance of invertebrates declined since the initiation of the study in 1999. This trend may be attributed to decreasing amounts of barley on the blocks since planting in 1999 and the increasing vegetative similarity of the blocks since installation of the restoration treatments in 2000 (see section 4.1). While the original monoculture of barley now includes other floral species, the effects of treatment on richness and abundance of invertebrates have not been as influential as originally hoped. Due to poor land condition and the persistence of invasive weed species, the effects of treatments have been masked and effect of blocking continues to be more prominent.

The majority of species in the orders Thysanoptera, Hemiptera, and Orthoptera are considered agricultural pests (Borror et al. 1992, Deal S.W. 2003, Elzinga R. J. 1997, UC Davis IMP Online Resource). The highest overall invertebrate abundance as well as the greatest contribution of these orders, and hence the greatest pest load, occurred in 2000. In 2001 the highest pest load was observed on Block 3, and in 2002 in Block 2. In the upcoming year we will look more closely at abiotic and biotic components of these two blocks as well as that of the neighboring land. The final report will include a summary of our findings specific to pest distribution observed at the Tranquillity study site.

The relationship between abundance and ordinal richness seems to indicate that the two are inversely proportional. This relationship is apparent in two particular instances.

First, Block 1 typically had the greatest richness values and the lowest abundance. Second, abundance was higher in 2000 than in any other year, while richness was at the lowest level over the 4-year study period.

5.2. REPTILES AND AMPHIBIANS

- Darren Newman

5.2.1. Methods

Reptile and amphibian surveys were conducted concurrently with avian surveys on 8-10 June, 29 April and 2-3 May, and 9-11 July 2002. Transect surveys were conducted along the small mammal trapping lines, and four 4-ft by 4-ft coverboards per plot (Figure 5-1) were inspected for presence of amphibian and reptile species. In addition, pitfall traps were opened for the survey conducted 8-10 January 2002. Data also were compiled from incidental sightings.

5.2.2. Results

No reptiles or amphibians were observed during focused surveys. However, western toads were observed during spotlighting and avian surveys and California king snakes were observed during vegetation surveys. Western fence lizards were observed on the plots during the course of other surveys and tasks.

5.2.3. Discussion

The number and variety of amphibian and reptile species on the study plots have remained at relatively low levels, but there have been increases each year in the number of encounters since 1999. This is likely the result of colonization from adjacent lands. Pacific rattlesnake, western fence lizard, western whiptailed lizard, and coast horned lizard have been observed on, or are known to have inhabited adjacent lands in the recent past. As vegetation becomes established and plant communities develop, it is likely that the rate of colonization by reptiles and amphibians will increase.

5.3. AVIAN

- Krista Garcia

Avian richness, abundance, and species composition were evaluated on the Habitat Restoration Study plots. Nest surveys also were conducted on the plots to determine nesting activity and nesting success (section 5.3.2). Results of winter raptor surveys also are included in this avian section (section 5.4.1).

5.3.1. Quarterly Monitoring

5.3.1.1. Methods

Seasonal avian richness, abundance, and composition were monitored quarterly on the study plots. Surveys in 2002 were conducted on 16-18 January, 2-4 April, 22-24 July, and 8-10 October. Data for 2002, in conjunction with data collected in previous years, provided detailed comparisons of avian trends in areas of retired farmland in the Tranquillity area.

Four point counts on variable circular plots (Verner 1985) and two parallel north-south transects were used on each study plot (Figure 5-1). Surveys began within 30 minutes of sunrise (Ralph et al. 1993). All blocks were concurrently sampled by synchronizing starting times between blocks to within 5 minutes of each other. Each circular-plot was censused for 5 minutes and each transect was censused for 5 minutes, resulting in 30 minutes of observations per plot. Direction of the survey route was alternated on each subsequent survey day. All species recorded on experimental plots were included in data analyses; fly-over and species not on experimental plots were incidentally noted but excluded from analyses. Avian species observed on experimental plots were identified to species and all detected birds were documented as either a visual or a vocal account. Location, activity, and distances from observer also were recorded.

Total and mean species richness was determined for all seasons and years. Site-wide and mean abundance was determined for all plots, blocks, and treatments. Species composition and ecological classification also was determined. Statistical tests were preformed in Statistica (StatSoft, Inc) utilizing analysis of variance (ANOVA) and Student's *t*-tests to determine statistical significance. Significance was assumed at the 95% confidence level ($p \leq 0.05$).

Species richness was calculated in two ways. Total richness was determined for all seasons to provide an indication of seasonal trends, and mean species richness was calculated for each plot and combined to determine mean species richness for all seasons. Site-wide avian abundance (number of birds/day) for plots, blocks, and treatments across seasons and years was determined. Similarly, mean abundance (number of birds/plot/day) for blocks and treatments within seasons and years was determined.

For all statistical analyses, the category “blackbirds,” which is typically representative of mixed flocks of blackbirds including brewer’s blackbirds (*Euphagus cyanocephalus*) and red-winged blackbirds (*Agelaius phoeniceus*), was eliminated due to high numbers of flocking birds recorded. These high numbers tended to skew results and were representative of outlying data. Additionally, in the determination of mean richness the general categories “sparrow”, “finch”, and “duck” were eliminated if a specific sparrow, finch, or duck species was identified on the plot. The category “unidentified species” was eliminated from analyses if a sufficient number of species were represented for that plot (usually greater than three) due to the probability that the unidentified species was likely one of the identified species. The elimination of each category of data was decided on a case-by-case basis.

Fluctuations in species composition between seasons and years were examined by determining the relative contribution of each species to the total bird population. Species also were grouped according to ecological role to provide insight into particular niches that avian species may fill on retired agricultural land.

5.3.1.2. Results

Total species richness remained relatively constant across seasons and years, except in summer 2001 and 2002 when richness was lowest (Figure 5-8; Appendix 5-1). Mean species richness for 2002 ranged from 1.25 to 6.55 (Figure 5-9) and varied significantly by year and season (Table 5-6). Mean richness was significantly greater in 1999 than in all other years. Similarly, mean richness in 2001 was significantly greater than in 2002. Winter, spring, and fall (all years combined) had significantly higher richness than summer. Richness between seasons among individual years varied significantly. In 1999, mean richness was significantly lower in summer than in fall. In 2000, spring and fall had a greater mean richness than winter. Spring and fall also had significantly higher mean richness than summer. In 2001, mean richness in both the winter and spring was significantly higher than in summer and fall. In 2002, all seasons had a greater mean richness than summer and, winter had a greater mean richness than fall. No other mean richness comparisons were significant.

The site-wide number of birds (birds/day) excluding blackbirds varied annually (Figure 5-10). Site-wide bird abundance was highest in 2001 compared to all other years (Appendix 5-1). However, summer of 2001 had the lowest site-wide abundance of birds among all years at 13.3. The largest number of site-wide bird abundance was on plot 10 in 2001 and the lowest number of site-wide bird abundance was on plot 9 in 1999.

Mean abundance of birds (birds/plot/day) varied significantly among years and among seasons (Table 5-7). The mean abundance of birds was significantly less in 1999 than in all other years. Mean avian abundance in 2001 was significantly greater than in 2000 and 2002. The mean abundance for all plots combined was determined for all seasons (Figure 5-11). Mean abundance of birds per season (birds/plot/day/season), all years combined, was significantly greater in the winter, spring, and fall than in summer. Mean seasonal abundance within years varied. In 1999, mean bird abundance was greater in fall than spring and summer. In 2000, mean avian abundance was greater in spring than winter and summer, while fall abundance was greater than winter, spring, and summer. In 2001, summer had significantly fewer birds than all other seasons and significantly, more birds were present in the spring than in the fall. In 2002, the mean abundance of birds was significantly lower in the summer than in all other seasons and there were significantly greater abundances of birds in winter and spring than in fall. No other comparisons were significant.

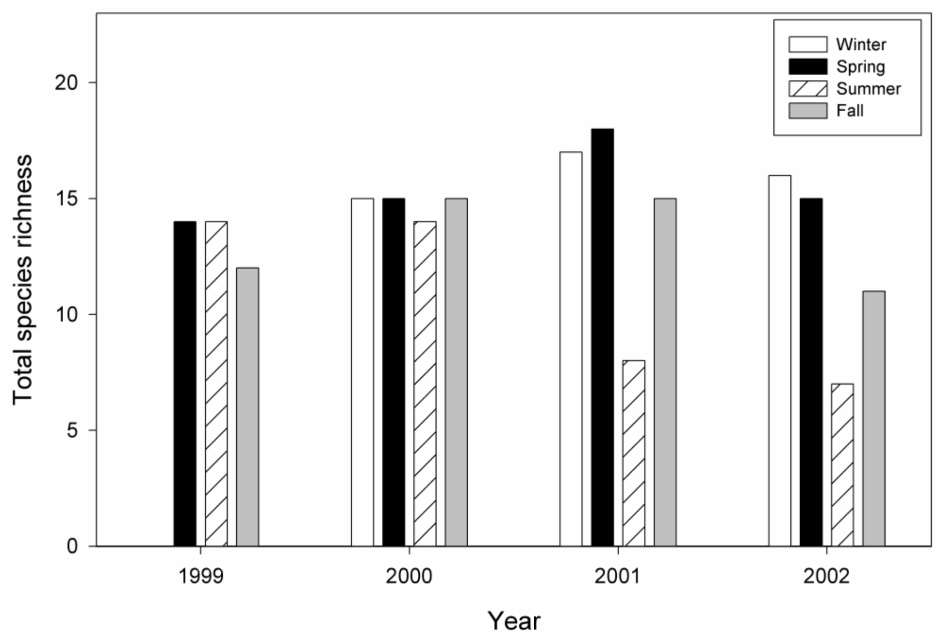

Figure 5-8. Total avian richness at the Tranquillity site, 1999 to 2002.

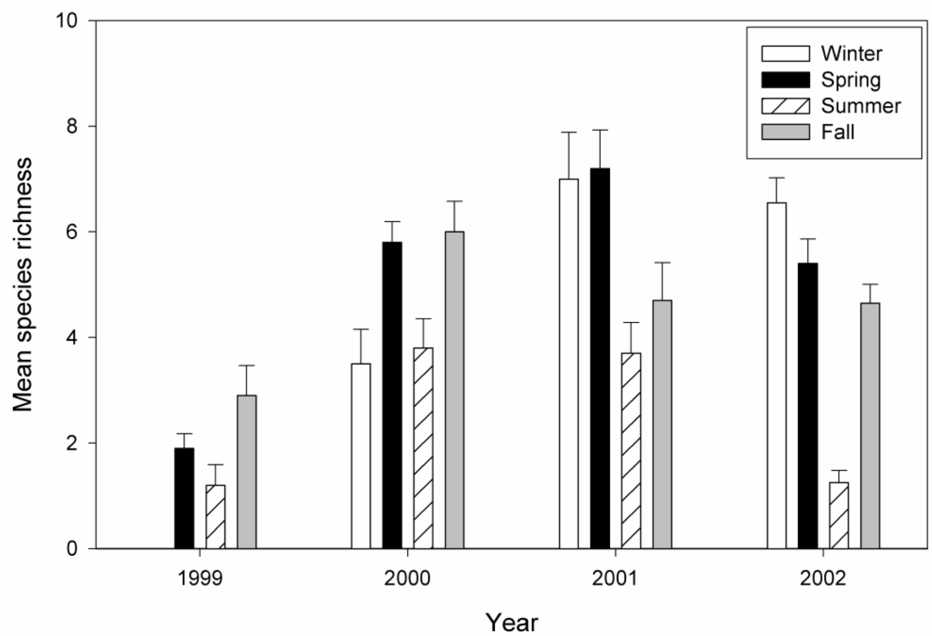

Figure 5-9. Mean avian species richness (± 1 standard error) per plot at the Tranquillity HRS site, 1999 to 2002

Table 5-6. Summary statistics for avian mean species richness data.

Statistical test	Factors	*p* value	F or *t*-value	Results
ANOVA	Richness difference between years	p < 0.01	F = 52.41	
t-test	1999 vs. 2000	p < 0.01	t = -7.98	1999 < 2000
t-test	1999 vs. 2001	p < 0.01	t = -9.47	1999 < 2001
t-test	1999 vs. 2002	p < 0.01	t = -6.39	1999 < 2002
t-test	2001 vs. 2002	p = 0.01	t = 2.43	2001 > 2002
ANOVA	Richness difference between seasons (all years combined)	p < 0.01	F = 21.32	
t-test	Winter vs. Summer	p < 0.01	t = 4.37	Winter > Summer
t-test	Spring vs. Summer	p < 0.01	t = 6.22	Spring > Summer
t-test	Fall vs. Summer	p < 0.01	t = 6.16	Fall > Summer
ANOVA	Richness difference between seasons among years	p < 0.01	F = 10.03	
t-test	Fall vs. Summer in 1999	p = 0.04	t = 2.10	Fall > Summer
t-test	Winter vs. Spring in 2000	p < 0.01	t = -3.18	Winter < Spring
t-test	Winter vs. Fall in 2000	p < 0.01	t = -2.98	Winter < Fall
t-test	Spring vs. Summer in 2000	p = 0.01	t = 2.70	Spring > Summer
t-test	Fall vs. Summer in 2000	p = 0.02	t = 2.54	Fall > Summer
t-test	Winter vs. Summer in 2001	p < 0.01	t = 3.11	Winter > Summer
t-test	Winter vs. Fall in 2001	p = 0.05	t = 2.01	Winter > Fall
t-test	Spring vs. Summer in 2001	p < 0.01	t = 3.93	Spring > Summer
t-test	Spring vs. Fall in 2001	p = 0.01	t = 2.75	Spring > Fall
t-test	Winter vs. Summer in 2002	p < 0.01	t = 12.45	Winter > Summer
t-test	Winter vs. Fall in 2002	p < 0.01	t = 2.89	Winter > Fall
t-test	Spring vs. Summer in 2002	p < 0.01	t = 8.53	Spring > Summer
t-test	Fall vs. Summer in 2002	p < 0.01	t = 8.36	Fall > Summer

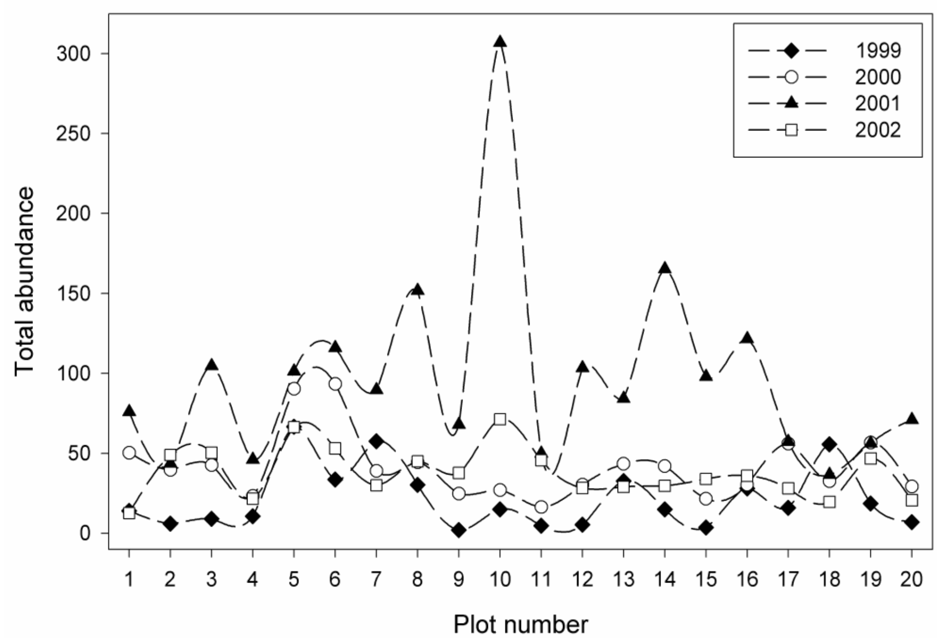

Figure 5-10. Site-wide avian abundance at the Tranquillity site, 1999 to 2002.

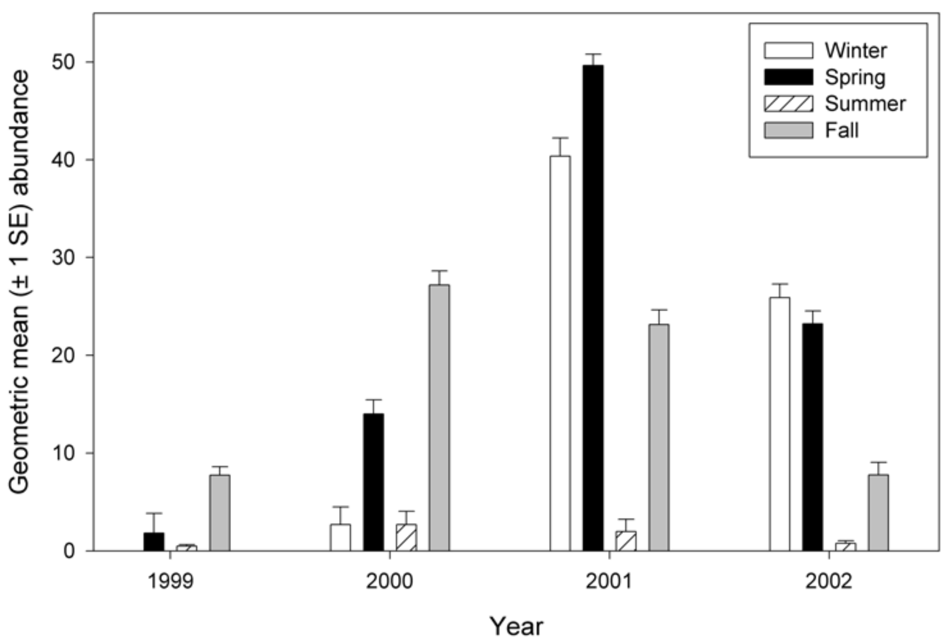

Figure 5-11. Mean avian abundance at the Tranquillity project site, 1999 to 2002.

Table 5-7. Summary statistics for avian mean seasonal abundance data.

Statistical test	Factors	*p* value	F or *t*-value	Results
ANOVA	Abundance difference between years	p < 0.01	F = 44.72	
t-test	1999 vs. 2000	p < 0.01	t = -4.63	1999 < 2000
t-test	1999 vs. 2001	p < 0.01	t = -7.01	1999 < 2001
t-test	1999 vs. 2002	p < 0.01	t = -5.18	1999 < 2002
t-test	2000 vs. 2001	p < 0.01	t = -2.72	2000 < 2001
t-test	2001 vs. 2002	p = 0.01	t = 2.46	2001 > 2002
ANOVA	Abundance difference between seasons (all years combined)	p < 0.01	t = 64.30	
t-test	Winter vs. Summer	p < 0.01	t = 7.04	Winter > Summer
t-test	Spring vs. Summer	p < 0.01	t = 10.37	Spring > Summer
t-test	Fall vs. Summer	p < 0.01	t = 12.31	Fall > Summer
ANOVA	Abundance difference between seasons among years	p < 0.01	t = 13.50	
t-test	Fall vs. Spring in 1999	p = 0.02	t = 2.39	Fall > Spring
t-test	Fall vs. Summer in 1999	p < 0.01	t = 5.18	Fall > Summer
t-test	Winter vs. Spring in 2000	p < 0.01	t = -3.92	Winter < Spring
t-test	Winter vs. Fall in 2000	p < 0.01	t = -5.02	Winter < Fall
t-test	Spring vs. Summer in 2000	p < 0.01	t = 5.91	Spring > Summer
t-test	Spring vs. Fall in 2000	p = 0.04	t = -2.21	Spring < Fall
t-test	Fall vs. Summer in 2000	p < 0.01	t = 6.87	Fall > Summer
t-test	Winter vs. Summer in 2001	p < 0.01	t = 5.95	Winter > Summer
t-test	Spring vs. Summer in 2001	p < 0.01	t = 17.20	Spring > Summer
t-test	Spring vs. Fall in 2001	p < 0.01	t = 3.55	Spring > Fall
t-test	Fall vs. Summer in 2001	p < 0.01	t = 9.53	Fall > Summer
t-test	Winter vs. Summer in 2002	p < 0.01	t = 13.48	Winter > Summer
t-test	Winter vs. Fall in 2002	p < 0.01	t = 4.45	Winter > Fall
t-test	Spring vs. Summer in 2002	p < 0.01	t = 11.71	Spring > Summer
t-test	Spring vs. Fall in 2002	p < 0.01	t = 3.71	Spring > Fall
t-test	Fall vs. Summer in 2002	p < 0.01	t = 8.71	Fall > Summer

The site-wide abundance of birds per block (birds/day/block) in 2001 was greater than all other years (Figure 5-12). There were significant differences in the mean abundance of birds between blocks and between years (Table 5-8). Block 2 had a significantly greater mean number of birds (birds/plot/day/block) than all other blocks in all years with all seasons combined (Figure 5-13). Mean abundance of birds (birds/plot/day/block/year), all seasons combined, between blocks among years varied annually. In 1999, Block 2 had a greater mean abundance of birds than Blocks 1 and 3. In 2000, Block 2 and Block 5 had a significantly greater mean abundance of birds than Block 3. In 2001, Block 2 had a greater mean abundance of birds than Blocks 1 and Block 5, and Block 4 had a significantly greater mean abundance of birds than Block 5. In 2002, no block had significantly different numbers of birds than any other block.

Table 5-8. Summary statistics for avian mean abundance by block data.

Statistical test	Factors	*p*-value	F or *t*-value	Results
ANOVA	Abundance difference between blocks (all years combined)	$p < 0.01$	$F = 6.67$	
t-test	Block 1 vs. Block 2	$p < 0.01$	$t = -3.21$	Block 1 < Block 2
t-test	Block 2 vs. Block 3	$p = 0.02$	$t = 2.42$	Block 2 > Block 3
t-test	Block 2 vs. Block 4	$p = 0.05$	$t = 2.02$	Block 2 > Block 4
t-test	Block 2 vs. Block 5	$p < 0.01$	$t = 3.17$	Block 2 > Block 5
ANOVA	Abundance difference between blocks among years	$p < 0.01$	$F = 2.58$	
t-test	Block 1 vs. Block 2 in 1999	$p < 0.01$	$t = -5.87$	Block 1 < Block 2
t-test	Block 2 vs. Block 3 in 1999	$p < 0.01$	$t = 4.68$	Block 2 > Block 3
t-test	Block 2 vs. Block 3 in 2000	$p = 0.01$	$t = 3.55$	Block 2 > Block 3
t-test	Block 3 vs. Block 5 in 2000	$p = 0.04$	$t = -2.52$	Block 3 < Block 5
t-test	Block 1 vs. Block 2 in 2001	$p = 0.05$	$t = -2.42$	Block 1 < Block 2
t-test	Block 2 vs. Block 5 in 2001	$p < 0.01$	$t = 4.12$	Block 2 > Block 5
t-test	Block 4 vs. Block 5 in 2001	$p = 0.01$	$t = 3.70$	Block 4 > Block 5

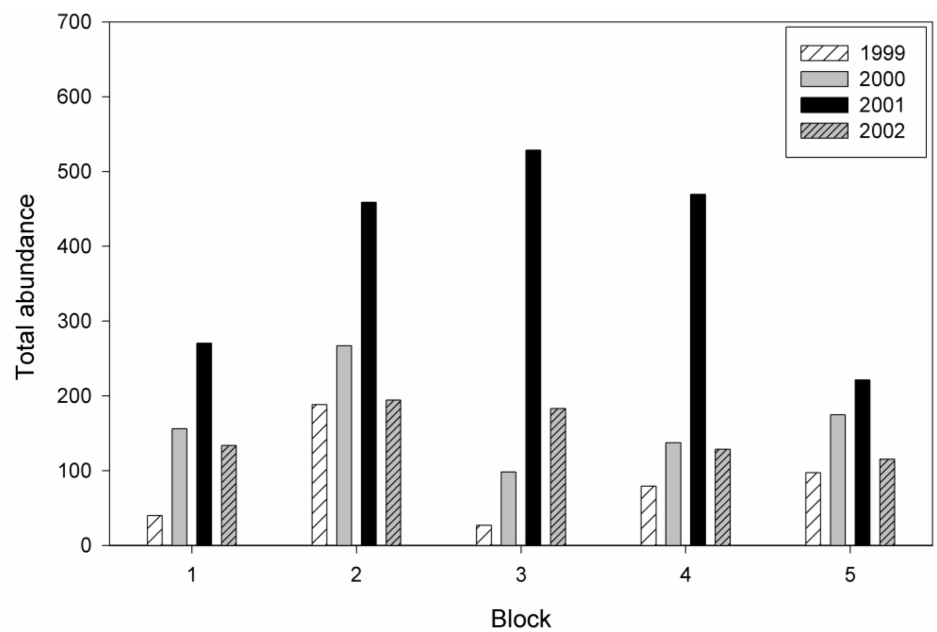

Figure 5-12. Site-wide avian abundance on all study blocks (birds/day/block) at the Tranquillity site, 1999 to 2002.

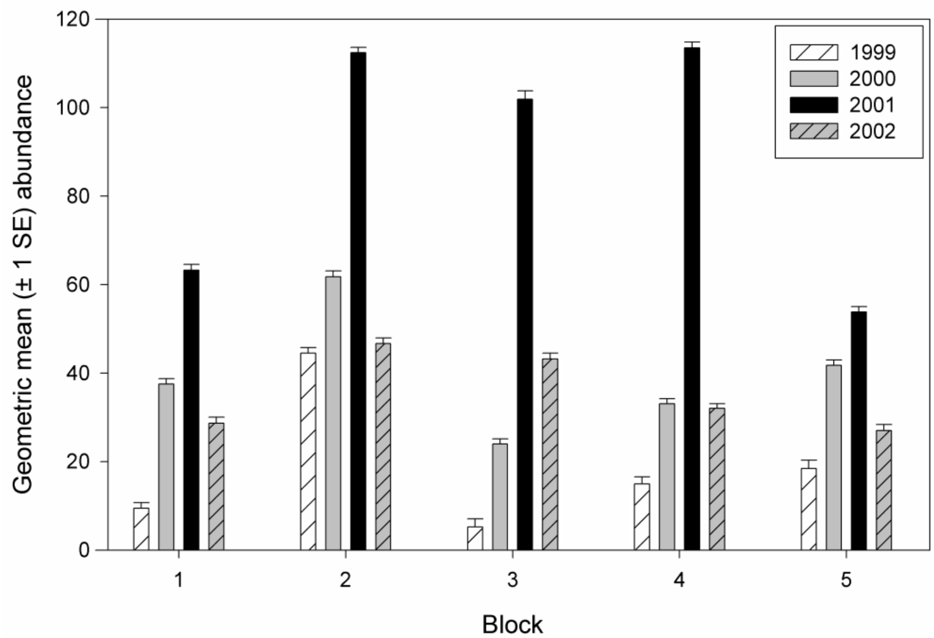

Figure 5-13. Mean avian abundance for all study blocks (birds/plot/day/block) with all seasons combined at the Tranquillity site, 1999 to 2002.

The site-wide avian abundance for treatment (mean/day/treatment) ranged from 93 to 690.6. The greatest site-wide abundance was in 2001 (Figure 5-14). Mean abundance differences for all years combined varied significantly as with other mean comparisons. However, mean avian abundance on experimental treatments consisting of native plant reintroduction (NR),microtopographic contouring (CN), microtopographic contouring with native plant reintroduction (CR) and control (NN) were not significantly different with all years combined (mean abundance of birds/plot/day/treatment) or within each year (mean abundance of birds/plot/day/treatment/year; Figure 5-15).

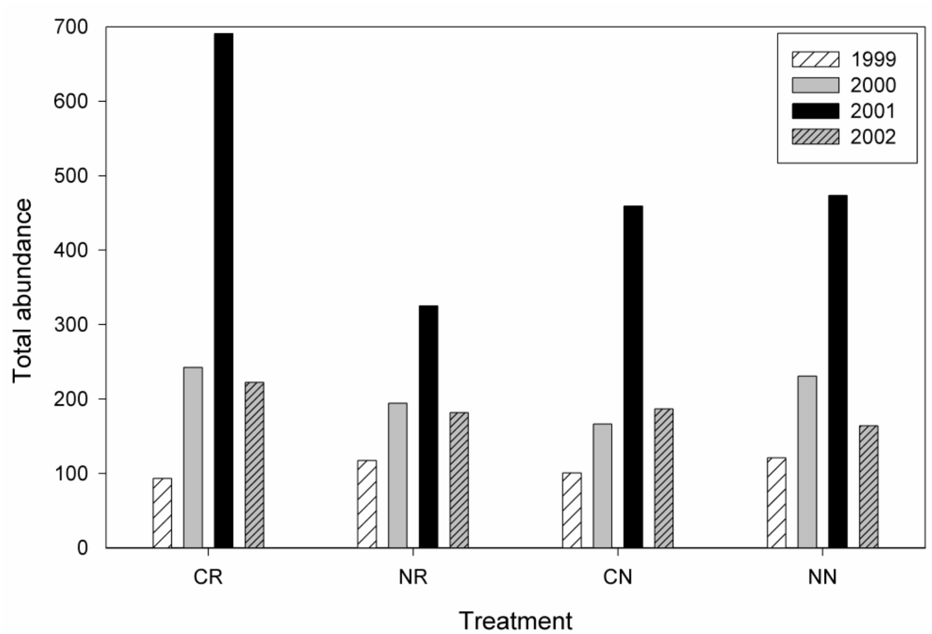

Figure 5-14. Site-wide avian abundance on restoration treatments (birds/day/treatment) at the Tranquillity site, 1999 to 2002.

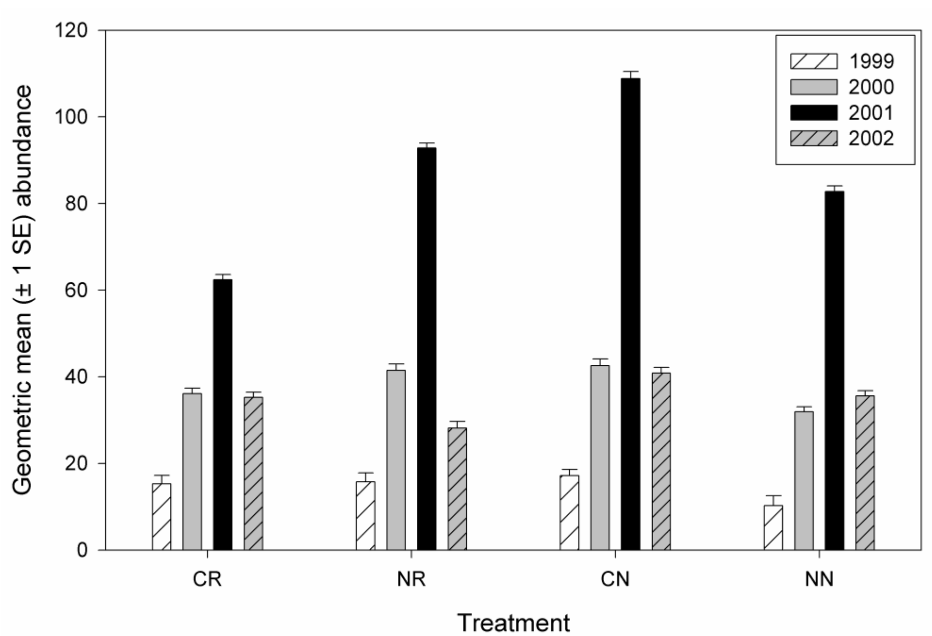

Figure 5-15. Mean avian abundance on restoration treatments (birds/plot/day/treatment) at the Tranquillity site, 1999 to 2002.

Species composition varied seasonally as residents, migrants, and wintering birds used the plots. Five bird species that are either species of special concern in California (CSC) or on the federal candidate list (FSC) were observed on study plots in 2002. Three of these species increased in abundance since 2001 while two others decreased. The loggerhead shrike (*Lanius ludovicianus;* FSC/CSC) and the burrowing owl (*Athene cunicularia;* FSC/CSC) were among the top five most abundant species in summer 2002.

The horned lark (*Eremophila alpestris;* CSC), loggerhead shrike, and the northern harrier (*Circus cyaneus*), which is federally proposed for threatened listing (FPT/CSC), ranked in the top five most abundant species in fall 2002 (Table 5-9).

Table 5-9. Seasonal relative abundance (RA) and ranked species composition (Rank) of birds at the Tranquillity site, 1999 to 2002. Species codes are defined in Appendix 5-2.

Winter 1999			**Winter 2000**			**Winter 2001**			**Winter 2002**		
Species	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**
			BRBL	50.80	1	SAVS	49.80	1	SAVS	45.87	1
			SAVS	9.63	2	BRBL	19.65	2	HOFI	11.94	2
N/A			MOPL	8.02	3	WEME	17.41	3	BRBL	10.57	3
			LBCU	6.95	4	RWBL	3.62	4	WEME	10.35	4
			AMKE	5.88	5	WCSP	2.82	5	RWBL	9.83	5
Spring 1999			**Spring 2000**			**Spring 2001**			**Spring 2002**		
Species	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**
RWBL	54.58	1	RWBL	77.59	1	RWBL	77.34	1	SAVS	46.55	1
BRBL	18.33	2	BRBL	10.82	2	SAVS	9.27	2	WEME	19.15	2
YHBL	8.33	3	WEME	6.73	3	WCSP	3.92	3	RWBL	12.84	3
WEME	6.67	4	MALL	0.99	4	SOSP	3.59	4	TRSW	4.58	4
MALL	3.33	5	CLSW	0.66	5	WEME	2.06	5	BRBL	3.66	5
			NOHA	0.66	5						
			RNPH	0.66	5						
			SAVS	0.66	5						
Summer 1999			**Summer 2000**			**Summer 2001**			**Summer 2002**		
Species	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**
AMKE	21.74	1	WEME	57.94	1	WEME	25.64	1	WEME	56.81	1
WHIM	17.39	2	RWBL	19.63	2	BARS	17.95	2	LOSH	22.72	2
WEME	15.22	3	WTKI	3.74	3	NOHA	17.95	2	BARS	6.81	3
CORA	8.7	4	AMKE	2.8	4	WTKI	15.38	3	RNPH	6.81	3
NOHA	8.7	4	BAOW	2.8	4	LOSH	7.69	4	BUOW	2.27	4
LOSH	6.52	5	BARS	2.8	4	SEOW	7.69	4	TRSW	2.27	4
			WEKI	2.8	4	WEKI	5.13	5	WEKI	2.27	4
			CORA	1.87	5						
			SOSP	1.87	5						
Fall 1999			**Fall 2000**			**Fall 2001**			**Fall 2002**		
Species	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**	**Species**	**RA**	**Rank**
AMPI	24.71	1	SAVS	64.68	1	SAVS	46.01	1	WEME	45.52	1
WEME	22.46	2	WEME	21.11	2	WEME	42.02	2	SAVS	36.81	2
SAVS	19.25	3	RWBL	3.13	3	SOSP	2.66	3	HOLA	9.95	3
BRBL	13.37	4	WTKI	2.51	4	HOLA	1.6	4	LOSH	2.23	4
HOLA	11.33	5	BRBL	2.3	5	WCSP	1.6	4	NOHA	1.49	5
						BRBL	1.33	5			

5.3.1.3. Discussion

Richness of bird species varied in all years with summer having the lowest values. Species richness in 2002 was greatest in winter, and lowest in summer compared to all other years. The tree swallow (*Tachycineta bicolor*) ranked in the top five most abundant species for spring 2002 and was recorded during the summer census for 2002, but had not been recorded on the plots in previous years. Winter richness in 2002 was greater than in the spring by one species, but the species composition differed substantially.

An avian census was not conducted for winter in 1999 therefor comparisons which would have included this information are absent. Mean abundance values for 1999 in all seasons generally obtained lower observations when compared to other years. Reasons for this may include the lack of development and establishment of vegetative species during the first year after the installation of treatments. No differences were apparent between Blocks 1 or 5 and the other blocks. These 2 blocks are located closer to neighboring lands that contain agricultural species, fallow lands, game pens and dirt roads, and differ in vegetation characteristics from other blocks (see section 4.1).

Most (59%) of the avian species documented on the study plots are considered grassland specialists (Appendix 5-2), which are categorized in two groups: obligate grassland specialists and facultative grassland specialist groups. Obligate grassland specialists are exclusively adapted and entirely dependent on grassland habitats. Facultative grassland specialists are not solely dependent on grasslands but use them often (Vickery et al. 1999). Since 2001, 75% (n = 24) of the grassland specialists have declined in abundance, which is likely a response to changes in vegetation characteristics. Species such as barley (*Hordeum vulgare*) have declined in abundance yearly since 1999. Barley may have initially been used as a food source for some avian species, small mammals, and invertebrates, but the decline in barley may have contributed to the decline in avian grassland specialists.

5.3.2. Nest Surveys

5.3.2.1. Introduction

In 2002, we implemented a program evaluate avian nesting success on the HRS plots to provide another measure of avian responses to restoration treatments. We investigated the diversity of nesting bird species, estimated nesting success, and identified parameters for nest failure through both direct observation and the synthesis of results from other biological censuses.

5.3.2.2. Methods

Open terrain such as that found at the Tranquillity site, generally attracts a variety of ground-nesting birds. The standard method used to search for ground-nesting birds and their nests involves dragging a rope (Labisky 1957). This method requires a person at either end of a specified length of rope and usually a third person walking behind the rope lifting it over shrubs. As the rope is pulled through the vegetation, it flushes any nesting birds.

A 60-meter, 0.375 inch nylon rope was used. Each plot was divided into three sections and surveyed on successive weeks. Nest searching began the first week of March and continued through the second week of April 2002.

Precautions described by Ralph et al. (1993) were taken to minimize nest disturbance and risk of predation while locating and monitoring nests. Nest locations were recorded by a GPS unit. Each nest was marked with a colored-flag 5 m south of the nest and was checked at 3 to 4-day intervals until nesting ended. The presence or absence of adults, number of eggs or nestlings, and a brief nestling description were recorded each monitoring session. Nests were considered successful if at least one young fledged.

Vegetation was sampled at the nest site once nestlings fledged. Vegetation was sampled using 35 by 70-cm quadrats in the four cardinal directions around the nest. Estimates were recorded for percent total cover of individual species and percent total cover of total green vegetation, grass, shrub, forb, litter, and bare ground. Average height of each plant species within the quadrat was measured, and nest dimensions and orientation were documented to determine aspects of habitat (Ralph et al. 1993).

5.3.2.3. Results

There were 23 nests located during the 2002 season: 1 horned lark (*Eremophila alpestris*), 2 loggerhead shrike (*Lanius ludovicianus*), 3 western meadowlark (*Sturnella neglecta*), 3 short-eared owl (*Asio flammeus*), and 14 mallard (*Anas platyrhynchos*). We observed copulation by song sparrows (*Melospiza melodia*) on the study plots although no nest was located. Six of the 23 nests were found outside of the study plots, and were monitored in conjunction with the nests on study plots. Approximately 70% of the nests were located on plots that had contours installed as a treatment (Figure 5-16). Approximately 65% of the nests discovered on the study plots were located in Block 2.

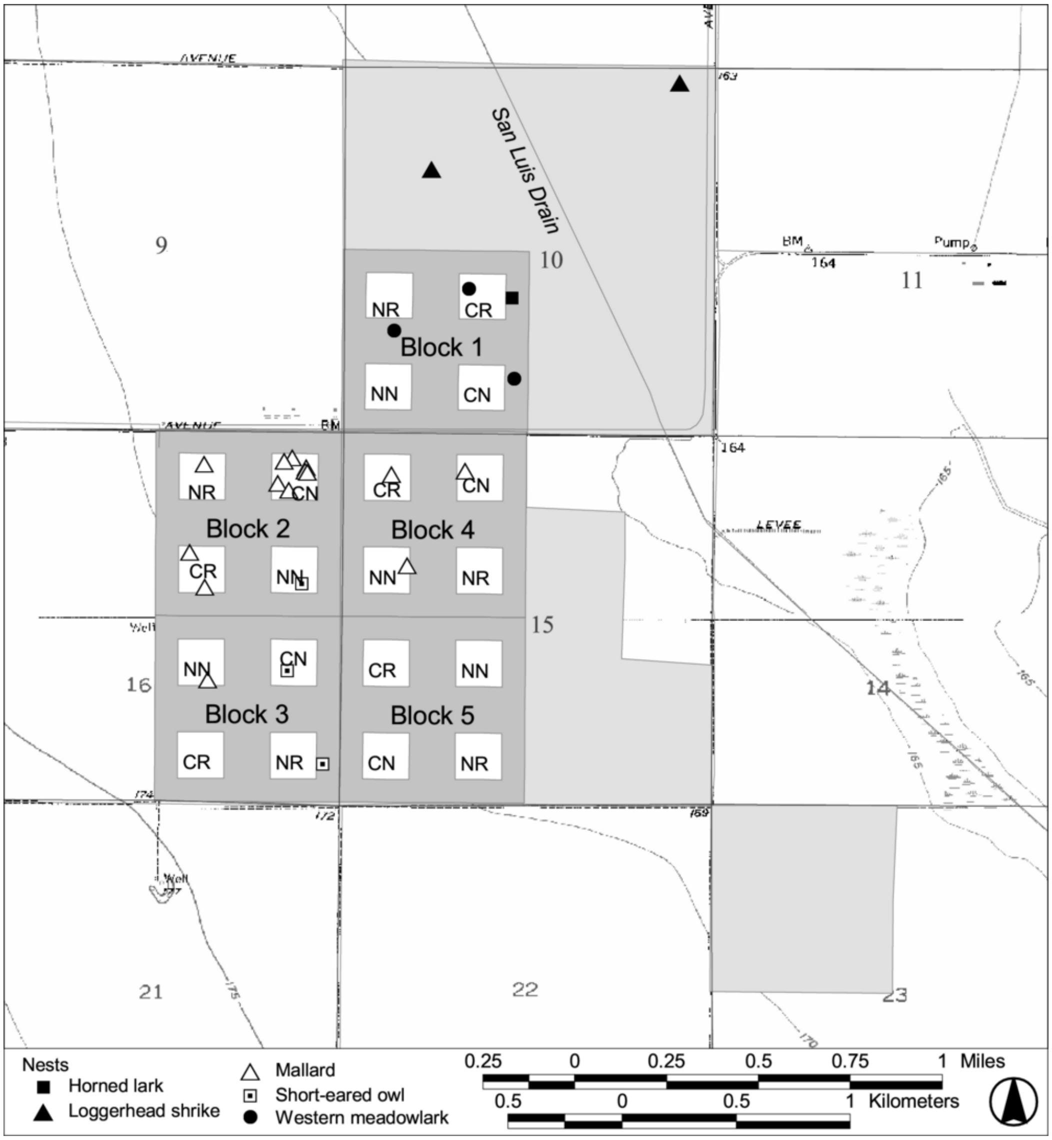

Figure 5-16. Nest locations at the Tranquillity site, spring 2002.

Mallard nests typically were constructed of dead barley (*Hordeum vulgare*) and silver scale (*Atriplex argentea*) stems, and had a down lining. Approximately 86% of the mallard nests monitored were partially or completely concealed by shrubs, primarily dead *A. argentea*. One nest was found underneath a live *A. polycarpa*. Most species initiated clutches in mid-March (Table 5-10).

Table 5-10. Avian nesting information for the Tranquillity site, spring 2002.

Species	Initiation date	Fledge date	Clutch size	Success rate	Sample size (n)
mallard (*Anas platyrhynchos*)	16-Mar	17-Apr	10.2	0.57	14
short-eared owl (*Asio flammeus*)	18-Mar	25-Apr	7.7	0.67	3
western meadowlark (*Sturnella neglecta*)	19-Mar	9-Apr	3.7	0.33	3
loggerhead shrike (*Lanius ludovicianus*)	28-Feb	6-Apr	5.5	1.00	2

There were 2 successful nesting efforts by short-eared owls. Both nests were oriented toward the north and they were approximately 50 by 50 cm in size. The nests consisted of a scrape on the ground sparsely lined with dead barley stems. The nests of western meadowlark were domed structures concealed by a canopy of fine grass with a small tunnel at the entrance of each nest.

Nests of loggerhead shrikes were located off the study plots in a quailbush (*Atriplex lentiformes*)-hedgerow in the northern section of the project site. Both nests were approximately 1.5 m above the ground. One nest was a cup of small twigs (presumably quailbush twigs) lined with fine grass. The second shrike nest was destroyed post-fledging by a fire; therefore no nest information was obtained.

Depredation appeared to be the leading cause of nest failure. Fragmented eggshells, nest disturbance, dead nestlings, or complete absence of eggs or shells constituted evidence of nest depredation. Two western meadowlark nests were depredated within days of the fledging date. Decapitated nestlings were found at both nest sites, suggesting depredation by an owl (Holt and Leasure 1993). In addition, a decapitated nestling western meadowlark was found cached at a nearby short-eared owl nest. Although efforts were made to deter avian predators (i.e. no dead end trails to the nests, and no nest checks when corvids were present), it still was possible that our actions unintentionally led predators to some nests.

Several mallard nests were found abandoned with a complete clutch. The reasons for abandonment were uncertain. One case probably resulted from our activities. This particular nest was located adjacent to an avian transect. The female was repeatedly flushed from the nest during the 3-day period of the spring avian census. After the completion of this census, the female was not seen on the nest again.

We observed communal nesting of female mallards on plot 6, which is representative of a study plot with higher shrub coverage, primarily dead *Atriplex argentea*. Martin (1993) presented two hypotheses for placing nests in dense vegetation: predation risk decreases with increases in total vegetation in the nest patch because greater foliage density inhibits transmission of visual, chemical, or auditory cues by prey (total-foliage hypothesis); and increases in the density of plants of the type used by prey reduces the probability of predation because it increases the number of potential prey sites that must be searched, increasing the probability that the predator gives up before finding the occupied site (potential-prey-site hypothesis).

It is not clear why mallards preferentially selected plot 6 for nesting. Other plots had structural heterogeneity similar to plot 6, which would seem to contradict both hypotheses. Other plots with higher shrub coverage should have shown similar numbers of nests. Approximately 57% of the nests on plot 6 were successful. Perhaps previous nest success has led to high nest site fidelity.

5.3.2.4. Discussion

The short-eared owl is listed as a rare species in Fresno and Madera counties according to the Fresno Audubon Society (2001) and is a species of special concern in California (CNDDB 2002). Eleven chicks of short-eared owls were successfully reared in plots 8 and 10. In general, the high density of deer mice (*Peromyscus maniculatus*; 5.3.3) and California voles (*Microtus californicus*) on the study plots probably provided an adequate prey base for this species. Carcasses of both rodent species and a few headless western meadowlark fledglings were found cached at the two successful nests. Short-eared owl chicks leave the nest approximately 12-18 days after hatching (Baicich and Harrison 1997). At this stage, chicks are still incapable of flight, and continue to be protected and fed by the parents. The duration of post-dispersal care is unknown (Holt and Leasure 1993). Pre-fledged dispersers were observed on several occasions on plot 8. In one instance, a chick was found to have taken up residence in an abandoned mallard nest. The mallard imposter seemed as startled to be discovered, as the researcher was surprised to discover it at this location.

5.3.3. Small mammals

- Steven Messer

5.3.3.1. Methods

Trapping for small mammals in 2002 was conducted on a quarterly basis. Trapping occurred on 29 January-1 February, 6-9 May, 15-18 July, and, 28-31 October. Thirty Sherman live-traps were used on each of the 20 study plots in three lines of 10 traps each, with an inter-trap spacing of 15m (Figure 5-1). There were 120 traps on each block totaling 600 traps on all five blocks. Traps were baited and set with a small handful of millet roughly an hour before sunset and checked starting 2 hr after dark. All five blocks are checked simultaneously with 1 biologist per block. Each night, the starting point was moved to the ending point of the previous night so that the traps were open for approximately the same amount of time over the survey period. All traps are checked, and then closed for the remainder of the night. Mammals trapped were identified, sexed, weighed, and reproductive status and trap location noted. Kangaroo rats (*Dipdomys heermanni*.) were marked with passive integrated transponders (PIT tags) and other species were marked by clipping a patch of fur from the rump or hindquarters.

Pitfall traps also were used to capture small mammals. Data from the pitfall traps were used to augment the assessment of species richness and some small mammals captured in the pitfalls were sacrificed for selenium analysis. The four-day pitfall survey was conducted annually and was concurrent with the invertebrate survey (see section 5.1.1). Pitfall traps were checked after sunrise for small mammals, and closed. The tip of the tail was amputated from trapped shrews (*Sorex ornatus*) and pocket mice (*Perognathus inornatus*) for genetic analyses. Once the small mammals were removed, a second inspection of the pitfall traps was made to count and remove invertebrates. In 2002, the Pitfall survey was conducted on 16-19 April.

5.3.3.2. Results

We captured 1,842 small mammals in 2002 during live-trapping efforts on the Tranquillity HRS plots. The majority (1,828 out of 1,842 captures) were deer mice (*Peromyscus maniculatus*). Other species captured included 12 Heermann's kangaroo rats (*D. heermanni*), one western harvest mouse (*Reithrodontomys megalotis*), and one house mouse (*Mus musculus*). There were no significant changes in the number of animals captured between 2001 and 2002, but there were some important seasonal differences in numbers of captures. For example, captures in spring and summer were relatively high (Figure 5-17). The abundance of small mammals during the fall sampling period increased on all blocks except on Block 1 from 1999 to 2001 (1999 to 2000 p = 0.02, t = -3.21 and 2000 to 2001 $p < 0.01$, t = -4.52, Figure 5-18). Small mammal abundance during the fall season then declined significantly between 2001 and 2002on blocks 2, 3, and 5 ($p < 0.01$ and t = 4.37, p = 0.03 and t = 2.85, and p = 0.01 and t = 2.50, respectively).

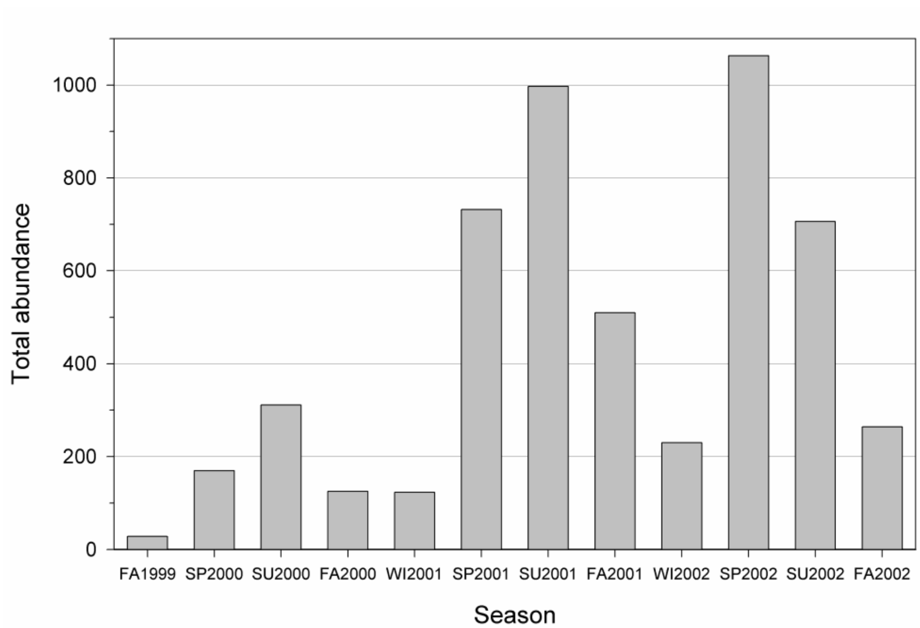

Figure 5-17. Abundance of small mammals by season at the Tranquillity site, 1999 to 2002.

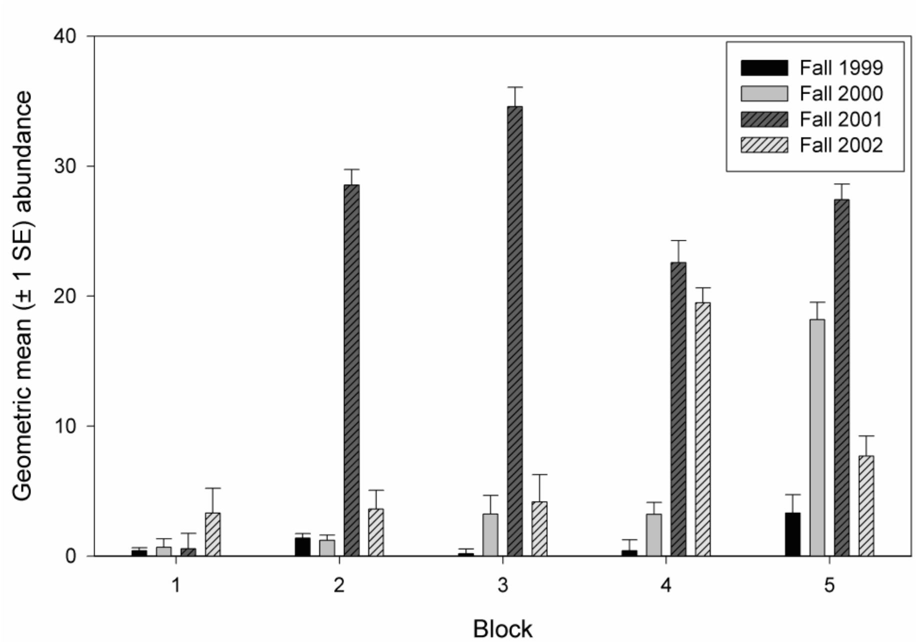

Figure 5-18. Abundance of small mammals during the fall sampling period by block at the Tranquillity site, 1999 to 2002.

All shrews, voles (*Microtus californicus*), and pocket gophers (*Thomomys bottae*) were captured in pitfall traps. We captured 20 shrews, 2 voles, and 2 pocket gophers in 2002 (Table 5-11). Most of the shrews (70%) captured in 2002 were on plots seeded with native vegetation. This is similar to results found in 2000 and 2001, but not in 1999. Numbers of other species caught in the pitfall traps were not abundant enough to show trends in treatments or time.

Table 5-11. Mammals caught in pitfall traps on the Tranquillity site, 1999 to 2002.

Year	Species	Plot Treatment	Number captured
1999	ornate shrew (*Sorex ornatus*)	Contoured and imprinted	1
		Contoured, but not imprinted	10
		Imprinted, but not contoured	2
		Not imprinted or contoured	1
	California vole (*Microtus californicus*)	Contoured and imprinted	1
		Contoured, but not imprinted	1
		Imprinted, but not contoured	1
		Not imprinted or contoured	0
2000	ornate shrew (*Sorex ornatus*)	Contoured and imprinted	7
		Contoured, but not imprinted	3
		Imprinted, but not contoured	5
		Not imprinted or contoured	3
	California vole (*Microtus californicus*)	Contoured and imprinted	0
		Contoured, but not imprinted	0
		Imprinted, but not contoured	0
		Not imprinted or contoured	0
2001	ornate shrew (*Sorex ornatus*)	Contoured and imprinted	11
		Contoured, but not imprinted	0
		Imprinted, but not contoured	11
		Not imprinted or contoured	3
	California vole (Microtus californicus)	Contoured and imprinted	4
		Contoured, but not imprinted	19
		Imprinted, but not contoured	10
		Not imprinted or contoured	4
2002	ornate shrew (*Sorex ornatus*)	Contoured and imprinted	6
		Contoured, but not imprinted	2
		Imprinted, but not contoured	8
		Not imprinted or contoured	4
	California vole (*Microtus californicus*)	Contoured and imprinted	1
		Contoured, but not imprinted	0
		Imprinted, but not contoured	1
		Not imprinted or contoured	0
	Botta's pocket gopher (*Thomomys botta*)	Contoured and imprinted	0
		Contoured, but not imprinted	1
		Imprinted, but not contoured	0
		Not imprinted or contoured	1

5.3.3.3. Discussion

In 2002, some species began to decline on the experimental plots. Deer mice numbers dropped significantly in the fall from 2001 to 2002 on blocks 2, 3, and 5 (Figure 5-17). A likely explanation is that the deer mouse population had exceeded carrying capacity (K) in 2001 and declined as a result in 2002. Yet, yearly abundances decreased significantly only on Block 5. House mice decreased from 46 captures in 2001 to 1 capture in 2002. This may be due partially to a decrease in cultivation and other disturbances. California voles also declined in numbers, from 38 captures in 2001 to 2 captures in 2002. This may be due to a decrease in available water, a result of cessation of irrigation of the buffer areas between study plots.

Additional species have colonized the HRS plots since retirement. Heermann's kangaroo rats were captured for the first time in 2002. The blocks where they were caught are next to a source population located on the east side of the buffer area adjacent to blocks 4 and 5. Pocket gophers also were captured on the plots and activity first observed in 2002. Three western harvest mice were captured in 2002—two were caught by hand during amphibian surveys in January. This would not have occurred in earlier years because this was the only time pitfalls were opened during amphibian and reptile surveys. The third was caught during the live-trapping survey. All western harvest mice were caught in January.

Small mammals, especially deer mice, were significantly fewer on Block 1 than on other blocks. This is probably due to the difference in soil type, low vegetative growth, preponderance of red brome, and historical land use. The soils in Block 1 are extremely motile and are not well suited to support burrows. Plants on Block 1 do not grow as tall as on the other blocks (probably due to less soil moisture) resulting in less structural heterogeneity. Furthermore, vegetation primarily consists of red brome. Block 1 was idle for a number of years, while the other experimental blocks were recently retired from agricultural production.

5.4. SITE-WIDE SURVEYS

5.4.1. Winter Raptor Surveys

Data generated from surveys for wintering raptors in conjunction with data generated from other surveys aided in assessing the effectiveness of restoration in providing habitat, and a prey base for raptors. Analyses of the data provided species composition and abundance information. This information applies, not only to the restored lands, but also to adjacent areas including natural, farmed, and fallow lands. The data generated also helped to determine increases in densities and/or diversity over time as restored areas matured.

5.4.1.1. Methods

The annual winter raptor survey for the Tranquillity project site was conducted 10-12 December 2002. Survey time generally occurred one hour after sunrise and was dependent on weather conditions.

A windshield survey was conducted along a predetermined survey route (Figure 5-19). Odometer readings were taken at the start and end of the route and route deviations necessitated by impassable roads were noted to calibrate odometer readings. Data recorded included locality, start location, sky, wind, moon phase, temperature, start, and end times. The survey route was driven slowly (approximately 5-10 mph) and two researchers used binoculars and a spotting scope to identify birds. All raptors observed were recorded by species, sex and age (if possible), and location (using odometer readings and a global positioning system). In addition to raptors, all loggerhead shrikes (*Lanius ludovicianus*), mountain plovers (*Chardrius montanus*) or other sensitive bird species observed along the route were recorded and reported to the California Natural Diversity Database (CNDDB).

5.4.1.2. Results

Five species of raptors were recorded during the 2002 survey: red-tailed hawk (*Buteo jamaicensis*), northern harrier (*Circus cyaneus*), white-tailed kite (*Elanus leucurus*), American kestrel (*Falco sparverius*), and peregrine falcon (*Falco peregrinus*). Two additional species were observed at the site, but not during the survey: ferruginous hawk (*Buteo regalis*) and prairie falcon (*Falco mexicanus*). Species richness of wintering raptors has declined slightly between 1999 and 2002 but abundance of raptors has steadily increased (Table 5-12).

Table 5-12. Richness and abundance of wintering raptors at the Tranquillity site, 1999 to 2002.

Species	1999	2000	2001	2002
American kestrel (*Falco sparverius*)	34	31	33	36
ferruginous hawk (*Buteo regalis*)	0	0	3	0
northern harrier (*Circus cyaneus*)	24	32	37	13
peregrine falcon (*Falco peregrinus*)	0	0	1	2
prairie falcon (*Falco mexicanus*)	1	2	0	0
rough-legged hawk (*Buteo lagupus*)	3	1	0	0
red-tailed hawk (*Buteo jamaicensis*)	21	22	24	30
white-tailed kite (*Elanus leucurus*)	6	14	7	1
Total raptor richness	**6**	**6**	**7**	**5**
Additional wintering raptors				
loggerhead shrike (*Lanius ludovicianus*)	N/A	11	14	22
mountain plover (*Charadrius montanus*)	N/A	0	6	40
buteo sp.	4	0	1	0
unknown	1	0	0	0
Total abundance	**94**	**113**	**126**	**144**

American kestrel was the most commonly observed species during the survey (frequency = 100%, rate = 1.08; Table 5-13) and female kestrels were encountered more frequently than males (female = 18, male =3, undetermined = 15, n = 36).

Table 5-13. Frequency and rate of bird species encountered at the Tranquillity site, 1999 to 2002 during winter raptor surveys.

Species code[1]	1999			2000			2001			2002		
	Total	Freq.[2]	Rate[3]	Total	Freq.[2]	Rate[3]	Total	Freq.[2]	Rate[3]	Total	Freq.[2]	Rate[3]
AMKE	34	100%	1.021	31	100%	0.931	33	100%	0.991	36	100%	1.081
Buteo sp.	4	67%	0.120	0	0%	0.000	1	33%	0.030	0	0%	0.000
FEHA	0	0%	0.000	0	0%	0.000	3	100%	0.090	0	0%	0.000
LOSH	0	0%	0.000	11	100%	0.330	14	100%	0.420	22	100%	0.661
MOPL	0	0%	0.000	0	0%	0.000	6	33%	0.180	40	33%	1.201
NOHA	24	100%	0.721	32	100%	0.961	37	100%	1.110	13	100%	0.390
PEFA	0	0%	0.000	0	0%	0.000	1	33%	0.030	2	67%	0.060
PRFA	1	33%	0.030	2	67%	0.060	0	0%	0.000	0	0%	0.000
RLHA	3	100%	0.090	1	33%	0.030	1	33%	0.030	0	0%	0.000
RTHA	21	100%	0.631	22	100%	0.661	24	100%	0.721	30	100%	0.901
WTKI	6	67%	0.180	14	100%	0.420	7	100%	0.210	1	33%	0.030
Unknown	1	33%	0.030	0	0%	0.000	0	0%	0.000	0	0%	0.000

[1] Species codes key (common name): AMKE- American Kestrel, FEHA-Ferruginous Hawk, LOSH-Loggerhead Shrike, MOPL-Mountain Plover, NOHA-Northern Harrier, PEFA-Peregrine Falcon, PRFA-Prairie Falcon, RLHA-Rough-legged Hawk, RTHA-Red-tailed Hawk, and WTKI-White-tailed Kite.

[2] Frequency: Percent of survey with positive observations.

[3] Rate: Mean number observed per mile of survey.

5.4.1.3. Discussion

The Peregrine falcon, a California-listed endangered species, was recorded two of the three days during the winter raptor survey in 2002. A peregrine falcon was first recorded in 2001. Although numbers of red-tailed hawks and American kestrels slightly increased, northern harriers, prairie falcon, rough-legged hawks, and white-tailed kites have declined in abundance.

Sightings of loggerhead shrikes in 2002 were greater than previous years. Similarly, sightings of mountain plovers, which is federally proposed for listing as threatened, increased in abundance in 2002. A flock of 40 mountain plovers was observed in 2002.

5.4.2. Spotlighting Surveys

5.4.2.1. Methods

Spotlighting surveys at the Tranquillity site were conducted on 4-5 and 11-12 March, 24-26 June, 9-11 September and 9-11 December 2002 following methods that have been previously presented (Uptain et al. 2001). Survey routes for biological monitoring encompassed the Tranquillity project site and included perimeters of various restorations study areas (Figure 5-19).

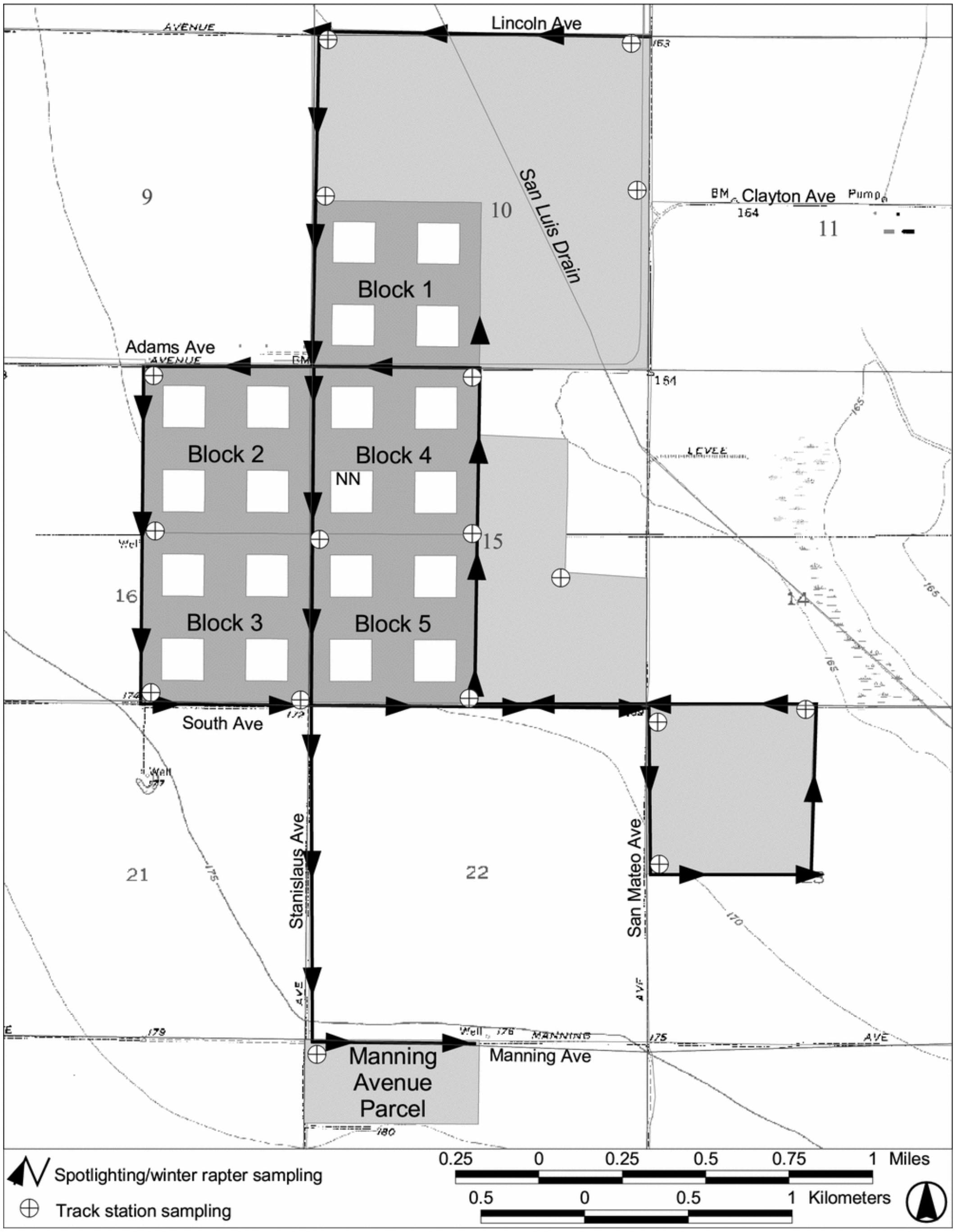

Figure 5-19. Spotlighting survey route, winter raptor survey route and track stations at the Tranquillity site.

5.4.2.2. Results

The highest rates of observations of animals sighted during spotlighting efforts were in summer 2002, summer 2000, and fall 2001 when there were 2.29, 2.14, and 1.93 observations per mile, respectively (Table 5-14). The lowest rate of observation was in winter of 2001 when only 0.68 animals per mile were seen. The highest rates of observation (excluding unknown and unidentified species) were in fall of 2001 (12 species) spring 2002 (12 species) and winter 2002 (11 species, Figure 5-20). The fewest number of species was observed in winter 1999 and winter 2001. Barn owls (*Tyto alba*), desert cottontails (*Sylvilagus auduboni*), and black-tailed hares (*Lepus californicus*) were seen during 12 of the 13 census periods (Table 5-14). Western toads (*Bufo boreus*) and red-tailed hawks (*Buteo jamaicensis*) also were present during most census periods.

Table 5-14. Rate (mean number of observations per mile of survey) of species occurrence during spotlighting surveys at the Tranquillity site, 1999 to 2002.

Common Name	1999		2000				2001			2002				Total
	Fall	Win	Spr	Sum	Fall	Win	Sum	Fall	Win	Spr	Sum	Fall	Win	
Western toad	0.06	0	0.15	0.64	0.02	0	0.15	0.13	0	0.13	0.04	0.09	0.02	**1.43**
Common king snake	0	0	0	0.02	0	0	0	0.02	0	0	0	0	0	**0.04**
Black-crowned night heron	0	0	0	0	0	0	0.49	0	0	0	0.06	0	0.02	**0.58**
Burrowing owl	0.06	0.06	0.26	0.11	0	0	0	0	0	0	0.19	0.04	0.04	**0.77**
Barn owl	0.90	0.30	0	0.62	0.34	0.17	0.09	0.49	0.24	0.06	0.64	0.36	0.17	**4.39**
Short-eared owl	0.02	0	0.09	0.02	0.02	0.02	0.02	0.02	0	0	0	0	0.02	**0.24**
Unknown owl	0	0	0	0	0	0	0.02	0	0	0.02	0	0	0	**0.04**
Unknown duck	0	0	0	0	0	0	0.02	0	0	0	0	0	0	**0.02**
Unknown egret	0	0	0	0	0	0	0.02	0	0	0	0	0	0	**0.02**
Killdeer	0	0	0.06	0.02	0.04	0.30	0	0	0.04	0.14	0	0	0	**0.62**
Lesser nighthawk	0	0	0	0	0	0	0	0.02	0	0	0	0	0	**0.02**
Northern harrier	0	0	0	0	0	0	0	0	0	0	0	0	0.02	**0.02**
Red-tailed hawk	0	0.43	0	0	0.19	0.30	0.02	0.21	0.24	0.02	0	0	0.41	**1.81**
American kestrel	0	0	0	0	0	0	0	0	0	0.02	0	0	0	**0.02**
Unknown raptor	0	0	0	0	0	0	0	0	0	0	0	0	0.02	**0.02**
Western meadowlark	0	0	0	0	0	0	0	0.06	0	0	0	0	0	**0.06**
Savannah sparrow	0	0	0	0	0	0	0	0	0	0.05	0	0	0	**0.05**
Unknown bird	0	0	0	0	0	0	0	0	0	0.03	0	0	0	**0.03**
Unknown bat	0.02	0	0	0	0	0	0	0.02	0	0.14	0	0	0	**0.19**
Black-tailed hare	0.09	0.15	0.17	0.24	0.09	0.02	0.13	0.19	0	0.02	0.21	0.15	0.11	**1.56**
Desert cottontail	0.06	0	0.28	0.17	0.04	0.06	0.09	0.26	0.17	0.27	0.94	0.56	0.28	**3.18**
Unknown leporid	0.02	0.04	0	0	0	0.02	0	0	0	0	0	0	0.02	**0.11**
Coyote	0	0	0.04	0	0	0.06	0.04	0	0	0	0	0	0.02	**0.17**
Domestic dog	0	0	0	0	0	0.02	0	0	0	0	0	0.06	0.02	**0.11**
Unknown canid	0	0.02	0	0	0	0	0.02	0	0	0.02	0	0	0	**0.06**
Domestic cat	0	0	0	0	0	0	0	0	0	0.02	0	0	0	**0.02**
Kangaroo rat	0	0	0.02	0.17	0	0	0	0.13	0	0.05	0.06	0.06	0	**0.50**
Deer mouse	0	0	0	0	0.02	0	0.21	0.15	0	0.02	0.11	0.02	0	**0.53**
Unknown rodent	0	0.02	0.02	0.02	0	0	0.04	0.02	0	0.02	0	0.02	0	**0.16**
California ground squirrel	0	0	0	0	0	0.02	0	0	0	0	0	0	0	**0.02**
Pocket gopher	0	0	0	0	0	0	0	0	0	0.02	0	0	0	**0.02**
California vole	0.02	0	0	0	0	0	0.04	0.04	0	0	0.02	0	0	**0.13**
Unidentified	0.13	0.11	0.26	0.11	0.15	0.06	0.13	0.15	0	0	0	0	0	**1.09**
Total	**1.39**	**1.13**	**1.35**	**2.14**	**0.92**	**1.07**	**1.54**	**1.93**	**0.68**	**1.03**	**2.29**	**1.37**	**1.18**	**18.01**

The three owl species present on the Tranquillity site exhibited great fluctuations in rate of observation (Figure 5-21). There were generally a greater number of observations of barn owls in summer and fall, whereas observations tended to be lowest in winter and spring. Western burrowing owls were absent from fall 2000 to spring of 2002. Short-eared owls (*Asio flammeus*) were not observed from winter 2001 to winter 2002 and they were infrequently observed during all other survey periods. Leporids and small mammals tended to be most abundant in the spring and summer and least abundant in the winter (Figure 5-22). The abundance of leporids was uncommonly high in summer of 2002.

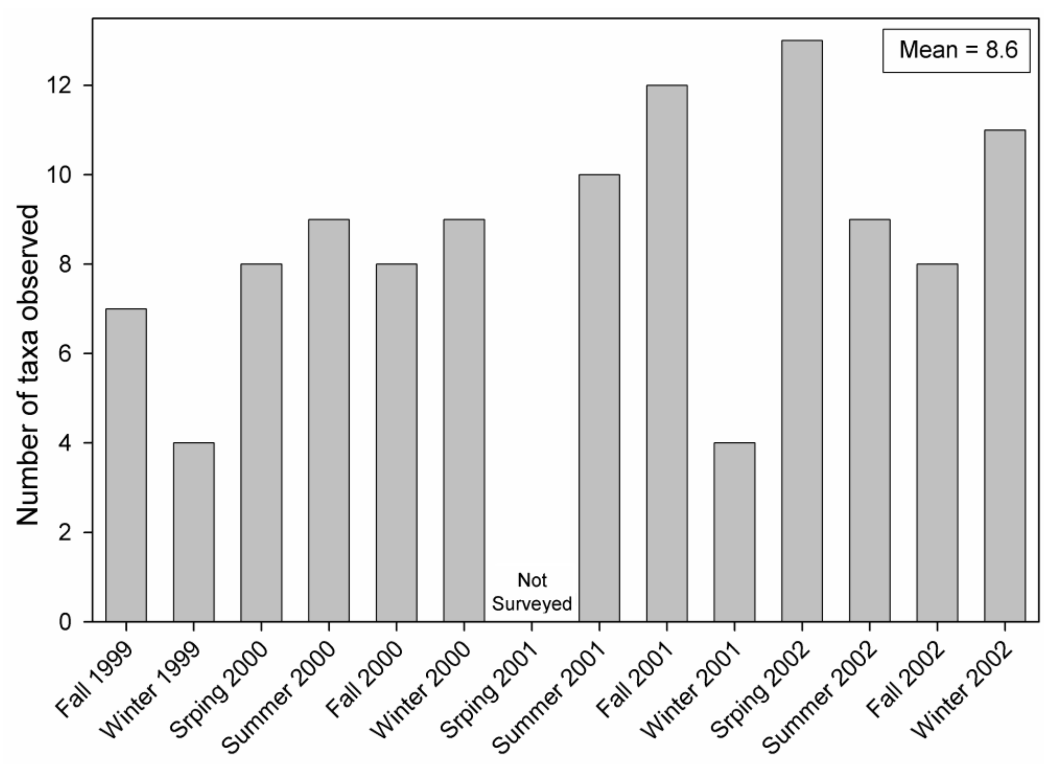

Figure 5-20. Number of species observed (excluding unknown or unidentified species) during spotlighting surveys at the Tranquillity site, 1999 to 2002.

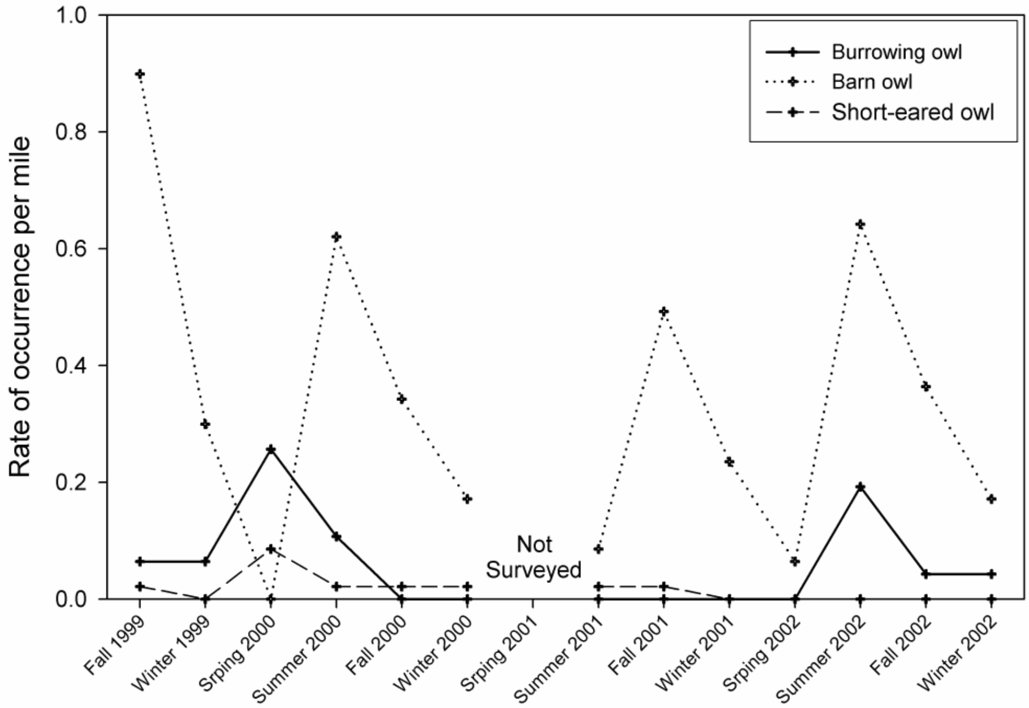

Figure 5-21. Rate of observation of three owl species during spotlighting surveys at the Tranquillity site, 1999 to 2000.

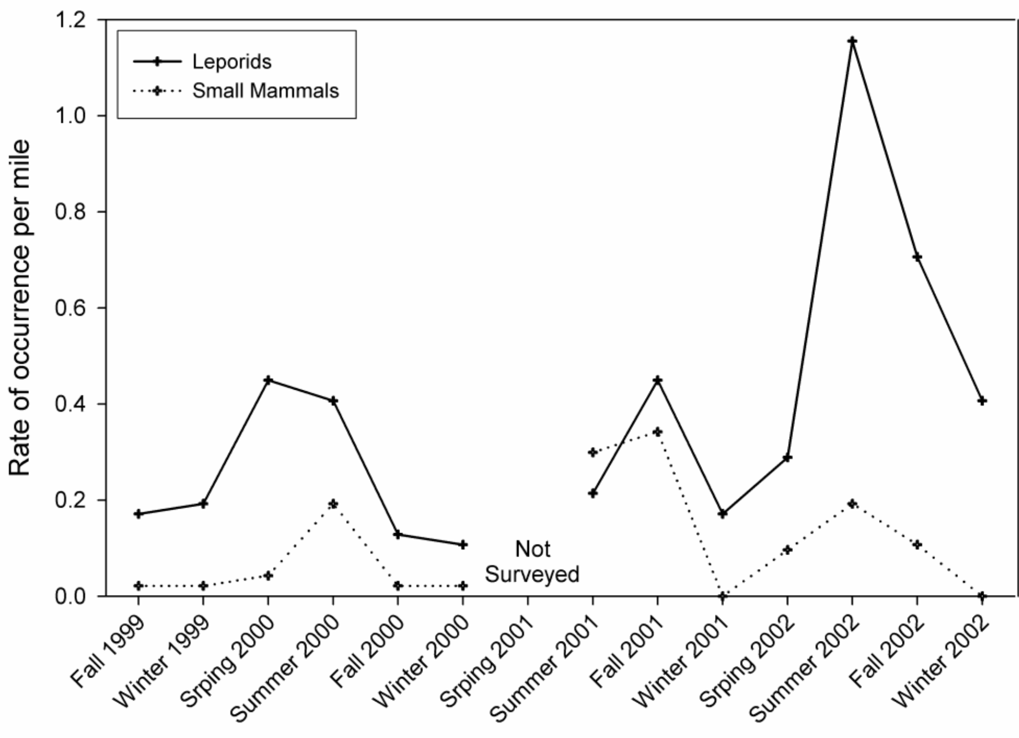

Figure 5-22. Rate of observation of leporids and small mammals during spotlighting surveys at the Tranquillity site, 1999 to 2002.

5.4.2.3. Discussion

Fluctuations in the abundance of owls on the Tranquillity site may be the result of seasonal migrations out of the region, seasonal movements to lands adjacent to the site that may contain greater abundances of prey species, or decreased activity during winter resulting in fewer observations. It is likely that barn owls migrate south during the winter. Although burrowing owls are known to migrate south in the winter, some populations also are known to winter in the Central Valley. We suspect that a portion of the population of burrowing owls that occur on and near the Tranquillity site is migratory, resulting in fewer observations during the winter. The absence of burrowing owls from fall 2000 to spring 2002 is difficult to explain. Short-eared owls are present on the Tranquillity site, but in numbers low enough to result in few to no sightings during spotlighting efforts. Short-eared owls successfully fledged on the site in April 2002 (see section 5.3.2) and abundant prey (California voles, *Microtis californicus*) were present during 2001 (see section 5.3.3). Seasonal fluctuations in abundance of small mammals and leporids are not unusual and are likely the result of breeding. The high abundance of leporids in summer of 2002 may indicate favorable local or regional conditions.

5.4.3. Track Station Surveys

5.4.3.1. Methods

Track station surveys were conducted at the Tranquillity site concurrent with the spotlighting surveys on 5, 12-13 March, 25-27 June, 11-13 September and 10-12 December 2002 utilizing methodology previously presented (Uptain et al. 2001).

5.4.3.2. Results

The number of visits to track plates by small mammals and invertebrates was greater than birds, reptiles, and amphibians during each survey period (Table 5-15). The mean number of visits of all taxa was significantly variable across years ($p < 0.01$, F = 8.39, Figure 5-23). Visits by birds were significantly lower in 1999 than in 2000 ($p = 0.04$, $t = 2.94$), visits by mammals were significantly lower in 1999 than in 2000, 2001, and 2002 ($p = 0.04$ and $t = 2.95$, $p = 0.01$ and $t = 4.42$, and $p = 0.04$ and $t = 2.99$, respectively). Additionally, small mammal visits were significantly lower in 2000 than in 2001 and 2002 ($p = 0.01$ and $t = 3.69$, and $p = 0.04$ and $t = 2.46$, respectively).

Tracks of mammals were present each survey period, unlike other taxa (Table 5-15). Similarly, tracks of mammals and invertebrates were present each year, while tracks of other taxonomic groups were not (Figure 5-23). The mean number of tracks of each taxa differs from each other taxa, when data from all years are combined ($p < 0.01$, F = 28.81).

Table 5-15. Frequency and rate of wildlife tracks at the Tranquillity site, 1999 to 2002.

Year	Season	Invertebrates		Amphibians		Reptiles		Birds		Mammals	
		Freq.	**Rate**	**Freq.**	**Rate**	**Freq.**	**Rate**	**Freq.**	**Rate**	**Freq.**	**Rate**
1999	Fall	100.00	0.53	0	0	0	0	0	0	100.00	0.41
	Winter	0	0	0	0	0	0	0	0	100.00	0.35
2000	Spring	33.33	0.24	0	0	0	0	33.33	0.18	66.67	0.53
	Summer	100.00	0.88	100.00	0.29	0	0	100.00	0.35	100.00	0.65
	Fall	100.00	0.65	100.00	0.18	0	0	66.67	0.12	100.00	0.47
	Winter	66.67	0.76	33.33	0.06	0	0	100.00	0.24	100.00	0.59
2001	Spring	100.00	0.35	66.67	0.12	0	0	100.00	0.41	100.00	0.94
	Summer	66.67	0.18	33.33	0.06	0	0	33.33	0.12	100.00	0.88
	Fall	66.67	0.47	66.67	0.12	66.67	0.06	100.00	0.18	100.00	0.94
	Winter	33.33	0.06	0	0	0	0	33.33	0.06	100.00	0.65
2002	Spring	100.00	0.76	0	0	0	0	66.67	0.12	100.00	0.88
	Summer	100.00	0.94	100.00	0.12	0	0	100.00	0.24	100.00	0.88
	Fall	0	0	66.67	0.06	0	0	66.67	0.12	100.00	0.94
	Winter	0	0	0	0	0	0	33.33	0.06	100.00	0.53

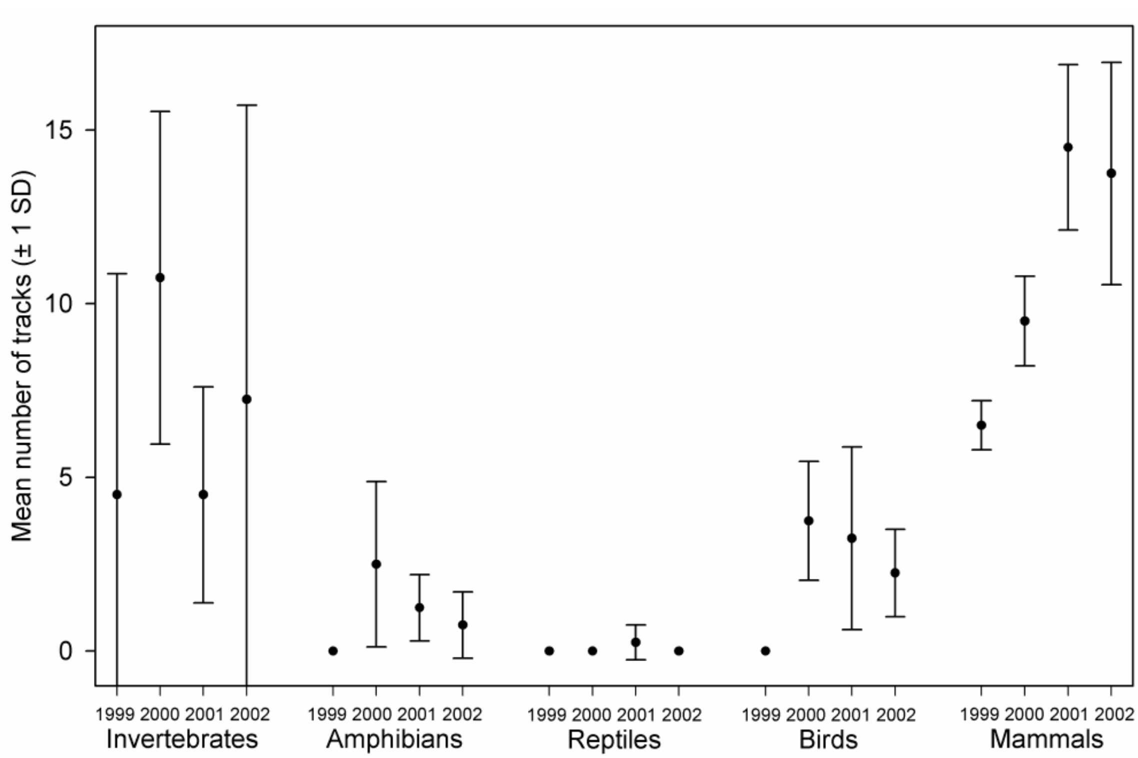

Figure 5-23. Rate of visitation at track stations each year from 1999 to 2002 at the Tranquillity site.

5.4.3.3. Discussion

Invertebrate visitation to the track stations fluctuated seasonally from 1999 to 2002. Most of the tracks observed were of beetles, which may be present in relatively high numbers or they may have been attracted to the bait (cat food) to a greater degree than other invertebrates. Amphibians (western toads) were first detected during the summer of 2000, but visits to the track stations declined from 2000 to 2002. We would not expect a high number of tracks of western toads on the track plates because they are not typically drawn to the bait. Tracks left by reptiles were only noted during fall 2001. We would not expect high numbers of tracks of lizards or snakes because they would not typically be attracted by the bait. Tracks of birds were first noted in 2000 and the number of visits of birds to the track stations declined through 2002. Most tracks were made by corvids (ravens and crows) that were likely attracted to and were feeding on the bait. Mammal tracks mostly consisted of mice and other small mammals, but some canid tracks also were present. Most of the canid tracks were of domestic dogs, although some of the tracks were from coyotes. The increase in numbers of small mammals in the area will likely result in an increase in the abundance of canids and a concomitant increase in the number of canid tracks at the track stations.

5.5. LITERATURE CITED

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APPENDIX 5-1. AVIAN SPECIES RICHNESS AND ABUNDANCE BY SEASON AT THE TRANQUILLITY SITE, 1999 TO 2002

Table 5-16. Avian species richness and abundance by season at the Tranquillity site, 1999 to 2002. Species codes, status, and habit are presented in Appendix 5-2.

Taxon code	1999			2000				2001				2002				Total
	Spring	Sum	Fall	Winter	Spring	Sum.	Fall	Winter	Spring	Sum.	Fall	Winter	Spring	Sum.	Fall	
AMCR	0.33	0.00	0.00	0.00	0.00	0.33	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
AMKE	0.00	3.33	1.33	7.33	0.00	1.00	0.00	0.67	0.00	0.00	0.00	0.33	0.00	0.00	0.67	14.67
AMPI	0.00	0.00	77.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	78.33
BAOW	0.00	0.00	0.00	0.00	0.00	1.00	1.67	11.67	0.00	0.00	0.33	0.00	0.00	0.00	0.00	14.67
BARS	0.33	0.33	0.00	0.00	0.67	1.00	0.00	0.00	1.67	2.33	0.00	0.00	4.00	1.00	0.00	11.33
BEWR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	0.00	0.00	1.00
BHCO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
BNST	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
BRBL	14.67	0.00	41.67	63.33	32.67	0.00	7.33	213.33	3.33	0.00	1.67	33.33	10.67	0.00	0.00	422.00
BUOW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	1.00	0.00	0.33	0.67	2.67
CLSW	0.00	0.67	0.00	0.00	2.00	0.33	0.00	0.00	0.67	0.33	0.00	0.00	4.00	0.00	0.00	8.00
CORA	0.00	1.33	0.00	0.00	1.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
HOFI	0.67	0.33	0.00	0.00	0.00	0.33	1.00	14.00	0.00	0.00	1.00	37.67	0.00	0.00	1.33	56.33
HOLA	2.33	0.33	36.33	2.00	0.33	0.00	2.33	0.00	2.33	0.00	2.00	1.00	5.00	0.00	13.33	67.33
KILL	1.33	0.33	0.33	0.33	0.67	0.33	0.33	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.33
LASP	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
LBCU	0.33	0.00	0.00	8.67	0.00	0.00	0.33	0.33	0.67	0.00	0.33	0.00	0.00	0.00	0.00	10.67
LOSH	0.00	1.00	0.00	0.33	0.00	0.00	0.00	0.33	0.00	1.00	0.33	0.67	0.00	3.33	3.00	10.00
MALL	2.67	0.00	0.00	0.00	3.00	0.00	0.00	0.00	6.67	0.00	0.00	0.00	1.00	0.00	0.00	13.33
MOPL	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
NOHA	0.00	1.33	1.33	2.00	2.00	0.00	6.00	9.33	4.33	2.33	1.33	9.67	0.67	0.00	2.00	42.33
NOMO	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.67
PRFA	0.00	0.00	0.00	1.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.33

Taxon code	1999			2000				2001				2002				Total
	Spring	Sum	Fall	Winter	Spring	Sum.	Fall	Winter	Spring	Sum.	Fall	Winter	Spring	Sum.	Fall	
RNPH	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.00	1.00	0.33	4.00
RTHA	0.00	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
RWBL	44.00	0.00	20.33	0.00	234.33	7.00	10.00	39.33	539.33	0.00	0.33	31.00	37.33	0.00	0.00	963.00
SAPH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33
SAVS	0.00	0.00	60.00	12.00	2.00	0.00	206.33	540.67	64.67	0.00	57.67	144.67	135.33	0.00	49.33	1,272.67
SEOW	0.00	0.00	0.00	0.33	0.33	0.00	0.67	23.00	1.33	1.00	0.00	8.00	2.00	0.00	0.00	36.67
SOSP	0.00	0.00	0.00	6.67	0.00	0.67	7.00	2.00	25.00	0.00	3.33	3.00	8.33	0.00	0.00	56.00
TRSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.33	0.33	0.00	13.67
WCSP	0.00	0.00	1.00	5.00	0.00	0.00	0.00	30.67	27.33	0.00	2.00	2.00	4.00	0.00	0.33	72.33
WEKI	0.67	0.33	0.00	0.00	0.33	1.00	0.33	0.00	3.33	0.67	0.00	0.00	0.00	0.33	0.00	7.00
WEME	5.33	2.33	70.00	6.33	20.33	20.67	67.33	189.00	14.33	3.33	52.67	32.67	55.67	8.33	61.00	609.33
WESA	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67
WHIM	0.00	2.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67
WREN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.67
WTKI	0.00	0.33	1.67	0.33	0.00	1.33	8.00	8.00	0.00	2.00	1.33	3.67	0.33	0.00	1.00	28.00
YHBL	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.67
YRWA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.67
Species richness	**14**	**14**	**12**	**15**	**15**	**14**	**15**	**17**	**18**	**8**	**16**	**16**	**15**	**7**	**12**	**40**
Additional birds not identified to species																
Ducks	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Finches	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
Sparrows	0.67	0.00	23.33	0.33	3.67	0.00	31.00	4.00	1.00	0.00	12.33	5.67	8.67	0.00	0.67	91.33
Swallows	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33
Unknown	0.00	0.00	0.00	0.67	0.33	0.00	14.33	4.67	3.67	0.33	0.00	0.00	0.00	0.00	0.00	24.00
Total abundance	**81.00**	**15.67**	**335.00**	**126.67**	**306.33**	**36.00**	**364.33**	**1,094.33**	**702.00**	**13.33**	**138.33**	**315.33**	**290.67**	**14.67**	**134.00**	**3,967.66**

APPENDIX 5-2. AVIAN SPECIES CODES, COMMON AND SCIENTIFIC NAMES, STATUS, AND OCCURRENCE

Table 5-17. Avian codes, common and scientific names, status, and occurrence.

Species code	Common name[1]	Scientific name	Status[2]	1999	2000	2001	2002
AMCR	American Crow	*Corvus brachyrhynchos*		+	+	+	-
MAKE	American Kestrel*	*Falco sparverius*		+	+	+	+
AMPI	American Pipit**	*Anthus rubescens*		+	-	+	+
BAOW	Barn Owl*	*Tyto alba*		-	+	+	-
BARS	Barn Swallow	*Hirundo rustica*		+	+	+	+
BHCO	Brown-headed Cowbird*	*Molothrus ater*		-	-	+	-
BNST	Black-necked Stilt	*Himantopus mexicanus*		+	-	-	-
BRBL	Brewer's Blackbird	*Euphagus cyanocephalus*		+	+	+	+
BUOW	Burrowing Owl**	*Athene cunicularia*	FSC/CSC	-	-	+	+
CLSW	Cliff Swallow	*Petrochelidon pyrrhonota*		+	+	+	+
CORA	Common Raven	*Corvus corax*		+	+	-	-
FEHA	Ferruginous Hawk**	*Buteo regalis*	FSC/CSC	-	-	+	-
HOFI	House Finch	*Carpodacus mexicanus*		+	+	+	+
HOLA	Horned Lark**	*Eremophila alpestris*	CSC	+	+	+	+
KILL	Killdeer*	*Charadrius vociferus*		+	+	+	-
LASP	Lark Sparrow*	*Chondestes grammacus*		+	-	-	-
LBCU	Long-billed Curlew**	*Numenius americanus*	CSC	+	+	+	-
LOSH	Loggerhead Shrike*	*Lanius ludovicianus*	FSC/CSC	+	+	+	+
MALL	Mallard*	*Anas platyrhynchos*		+	+	+	+
MOPL	Mountain Plover**	*Charadrius montanus*	FPT/CSC	-	+	-	-
NOHA	Northern Harrier**	*Circus cyaneus*	FPT/CSC	+	+	+	+
NOMO	Northern Mockingbird	*Mimus polyglottos*		+	-	+	+
PEFA	Peregrine Falcon*	*Falco peregrinus*	FD/CE	-	-	+	+
PRFA	Prairie Falcon*	*Falco mexicanus*	CSC	-	+	-	-
RLHA	Rough-legged Hawk**	*Buteo lagupus*		+	+	-	-
RNPH	Ring-necked Pheasant*	*Phasianus colchicus*		-	+	+	+
RTHA	Red-tailed Hawk	*Buteo jamaicensis*		-	+	-	-
RWBL	Red-winged Blackbird*	*Agelaius phoeniceus*		+	+	+	+
SAPH	Say's Phoebe*	*Sayornis saya*		-	-	+	-
SAVS	Savannah Sparrow**	*Passerculus sandwichensis*		+	+	+	+
SEOW	Short-eared Owl**	*Asio flammeus*	CSC	-	+	+	+
SOSP	Song Sparrow	*Melospiza melodia*		-	+	+	+
TRSW	Tree Swallow	*Tachycineta bicolor*		-	-	-	+
WCSP	White-crowned	*Zonotrichia leucophrys*		+	+	+	+

Species code	Common name[1]	Scientific name	Status[2]	1999	2000	2001	2002
	Sparrow						
WEKI	Western Kingbird*	*Tyrannus verticalis*		+	+	+	+
WEME	Western Meadowlark**	*Sturnella neglecta*		+	+	+	+
WESA	Western Sandpiper	*Calidris mauri*		+	-	-	-
WHIM	Whimbrel	*Numenius phaeopus*		+	-	-	-
WTKI	White-tailed Kite	*Elanus leucurus*		+	+	+	+
YHBL	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*		+	-	-	-
YRWA	Yellow-rumped Warbler	*Dedrocia coronata*		-	-	+	-

[1] * = Facultative grassland specialist, ** = Obligate grassland specialist

[2] Key to status: FSC: Federal Special Concern; CE: CA Endangered; CSC: CA Special Concern; FPT: Federally proposed for listing as threatened; FD: Federally Delisted

6. OTHER TASKS ACCOMPLISHED

- Krista Garcia, Kimberly E. Kreitinger, and Nur Ritter

6.1. NORTH AVENUE PARCEL SURVEY

6.1.1. Overview

The United States Bureau of Reclamation (USBR) augmented the amount of land dedicated to the Land Retirement Program at the Tranquillity site with the acquisition of a parcel known as the North Avenue Parcel. This property was purchased in May of 2002 and is located across from the western boundary of the Mendota Wildlife Management Area; cultivated fields border the other three sides of this property (Figure 1-2) The North Avenue Parcel consists of 440 acres of recently fallowed land. A baseline inventory consisting of spotlighting, small mammal trapping, avian surveys, track stations, invertebrate sweeps (Figure 6-1), and a broad-scale vegetation survey (Figure 6-2) was preformed to assess habitat quality and to document presence of all plant, invertebrate, herpetological, avian, and mammalian species.

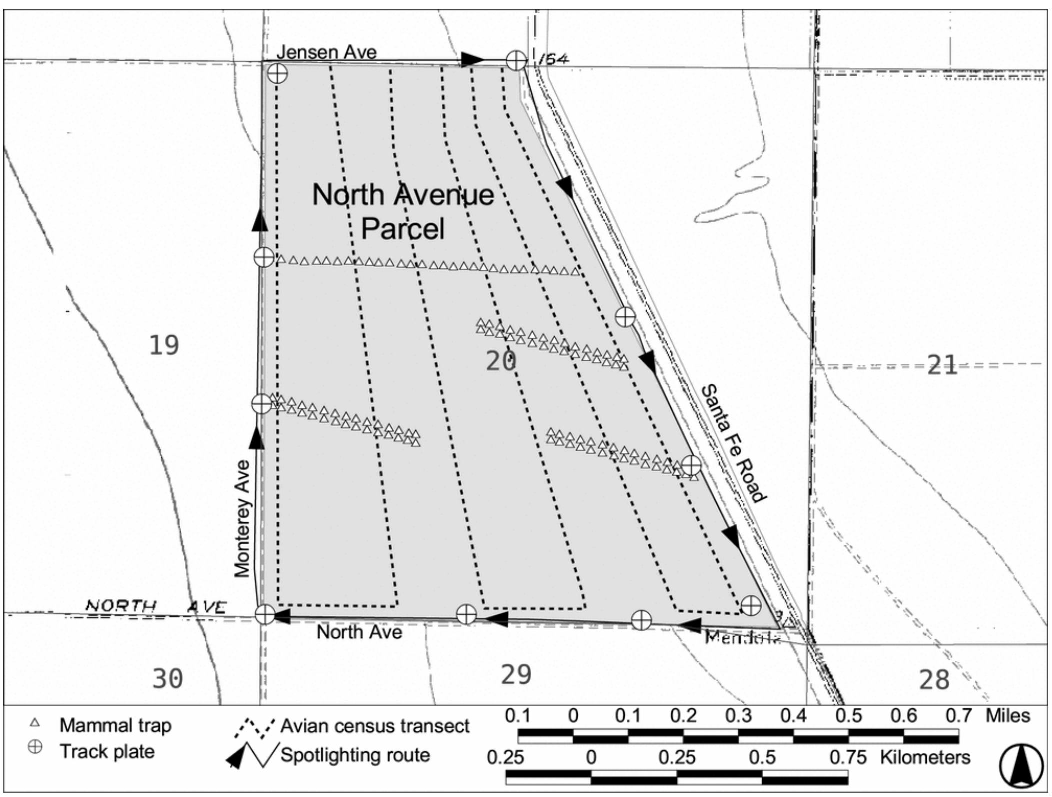

Figure 6-1. Survey transects and locations on the North Avenue Parcel.

6.1.2. Survey Methods and Results

6.1.2.1. Spotlighting

The spotlighting survey was preformed on 28-30 May 2002. The spotlighting route followed roads bordering the property and were driven at speeds of 10-15 mph. The survey began approximately 30 minutes after sunset. Two 1,000,000-candle power spotlights were used to detect eyeshine of any animals along the route. Animal sightings were recorded on standardized data sheets and the observer locations were recorded using a global positioning system receiver. The most common species encountered was the barn owl (*Tyto alba*), although desert cottontails (*Sylvilagus audubonii*) were also numerous (Table 6-1).

Table 6-1. List of species encountered during spotlighting at the North Avenue Parcel.

Species	28-May	29-May	30-May	Frequency[1]
barn owl (*Tyto alba*)	5	0	5	0.67
black-tailed hare (*Lepus californicus*)	2	0	1	0.67
deer mouse (*Peromyscus maniculatus*)	0	0	1	0.33
desert cottontail (*Sylvilagus audubonii*)	4	4	1	1.00
kangaroo rat (*Dipodomys* sp.)	0	1	0	0.33
killdeer (*Charadrius vociferus*)	1	0	0	0.33
mallard (*Anas platyrhynchos*)	0	6	0	0.33
western toad (*Bufo boreas*)	0	1	0	0.33

[1] Frequency: rate of species occurrence for the census period.

6.1.2.2. Small mammal survey

The small mammal census was conducted on 28-30 May 2002. One hundred and twenty Sherman live-traps were systematically placed near active burrows or areas on the property with small mammal sign. All traps were baited with millet several hr before sunset and checked approximately two hours after sunset. Gender, reproductive status, age, and weight were recorded for each small mammal captured. Each individual captured was marked with a pen to aid in distinguishing recaptured mammals.

Three species of small mammals were documented during this trapping effort (Table 6-2). The most commonly trapped species was the deer mouse (*Peromyscus maniculatus*). Sign of other small mammal species included California ground squirrel (*Spermophilus beecheyi*) burrows and pocket gopher (*Thomomys bottae*) mounds.

Table 6-2. List of species trapped during the small mammal census at the North Avenue Parcel.

Species	28-May	29-May	30-May	Frequency
deer mouse (*Peromyscus maniculatus*)	4	5	5	1.00
Heerman's kangaroo rat (*Dipodomys heermanii*)	0	2	1	0.67
house mouse (*Mus musculus*)	1	0	1	0.67

6.1.2.3. Avian survey

An avian survey for the North Avenue Parcel was preformed on 29-31 May 2002. The avian census began approximately one hour after sunrise and consisted of two transects. One-third of the property was censused each day. Avian species observed during the survey were recorded as visual or as vocal accounts and numbers of individuals were recorded. Birds observed flying over the property or observed outside the property boundaries were also noted.

The most common species recorded included: mallard (*Anas platyrhynchos*), red-winged blackbird (*Agelaius phoeniceus*), and horned lark (*Eremophila alpestris*; Table 6-3). A total of 26 species were observed during the 3-day census.

Table 6-3. List of avian species recorded during the North Avenue Parcel survey

Species	29 May	30 May	31 May	Frequency
American Crow (*Corvus brachyrhynchos*)	1	2	1	1.00
barn swallow (*Hirundo rustica*)	0	2	0	0.33
black phoebe (*Sayornis nigricans*)	0	1	0	0.33
black-crowned night-heron (*Nycticorax nycticorax*)*	2	1	0	0.67
cattle egret (*Bubulcus ibis*)	0	15	0	0.33
cliff swallow (*Petrochelidon pyrrhonota*)	3	5	4	1.00
common raven (*Corvus corax*)	4	0	5	0.67
double-crested cormorant (*Phalacrocorax auritus*)*	2	0	0	0.33
great blue heron (*Ardea herodias*)*	1	0	0	0.33
great egret (*Ardea alba*)*	2	0	0	0.33
horned lark (*Eremophila alpestris*)	12	11	11	1.00
house finch (*Carpodacus mexicanus*)*	0	0	3	0.33
killdeer (*Charadrius vociferus*)*	1	1	3	1.00
loggerhead shrike (*Lanius ludovicianus*)	1	1	1	1.00
long-billed curlew (*Numenius americanus*)	0	0	15	0.33
mallard (*Anas platyrhynchos*)	210	179	253	1.00
mourning dove (*Zenaida macrouna*)	15	5	1	1.00
northern harrier (*Circus cyaneus*)	2	0	1	0.67
northern mockingbird (*Mimus polyglottos*)	1	2	1	1.00
red-tailed hawk (*Buteo jamaicensis*)*	0	0	1	0.33
red-winged blackbird (*Agelaius phoeniceus*)	71	11	23	1.00
ring-necked pheasant (*Phasianus colchicus*)	1	0	0	0.33
tree swallow (*Tachycineta bicolor*)	0	0	1	0.33
western kingbird (*Tyrannus verticalis*)	1	0	1	0.67
western meadowlark (*Sturnella neglecta*)	7	4	3	1.00
white-tailed kite (*Elanus leucurus*)	2	2	0	0.67
* Observed as incidental or flyovers.				

6.1.2.4. Track station survey

The track station survey was conducted on 29-31 May 2002. Ten track stations were established along the tertiary roads surrounding the property. Each square-meter track plate was dusted with Dolomite fire clay and baited with one can of cat food. All tracks present on the plates were identified to species when possible.

The tracks of twelve animal species were documented on the track plates (Table 6-4). Desert cottontail (*Sylvilagus audubonii*), mice tracks (presumably *Peromyscus maniculatus*), and beetle species (Order Coleoptera) were prevalent throughout the 3-day effort.

Table 6-4. Track station survey results.

Animal	Classification	Visits to track plates			Frequency
		29 May	30 May	31 May	
Beetle	Order Coleoptera	4	4	4	1.00
Unknown bird.	Class Aves	2	1	3	1.00
Black-tailed hare	*Lepus californicus*	0	0	2	0.33
Centipede	Class Chilopoda	0	3	3	0.67
Cricket	Order Orthoptera	1	0	2	0.67
Desert cottontail	*Sylvilagus audubonii*	3	2	1	1.00
False chinch bug	Family Lygaeidae	1	1	2	1.00
Kangaroo rat	*Dipodomys* sp.	1	2	1	1.00
Millipede	Class Diplopoda	0	0	1	0.33
Unknown mouse	Class Mammalia	3	4	4	1.00
Striped skunk	*Mephitis mephitis*	1	2	2	1.00
Western toad	*Bufo boreas*	0	0	1	0.33

6.1.2.5. Vegetation monitoring

Vegetation monitoring on the North Avenue Parcel took place on 13 and 29May, 27 June, and 2 July 2002. Sampling incorporated a walking census of the property along with point sampling (non-random). No fixed transects were walked; rather, distinctive looking areas were continually sought out; as the route from "area" to "area" was walked, a running list of all species was compiled.

Periodically, areas were identified as being "representative" of the characteristic vegetation type (e.g., red brome dominated habitat), and were selected for more "comprehensive" sampling. Sampling was conducted within a circular area with a radius of 15 ft (66.67 m^2; ~ 1/60th of an acre). All species within this "plot" were noted. Species were ranked in decreasing order of abundance (estimated visually); however, no attempt was made to assign actual cover values. In all, 33 such quadrats were sampled (Figure 6-2).

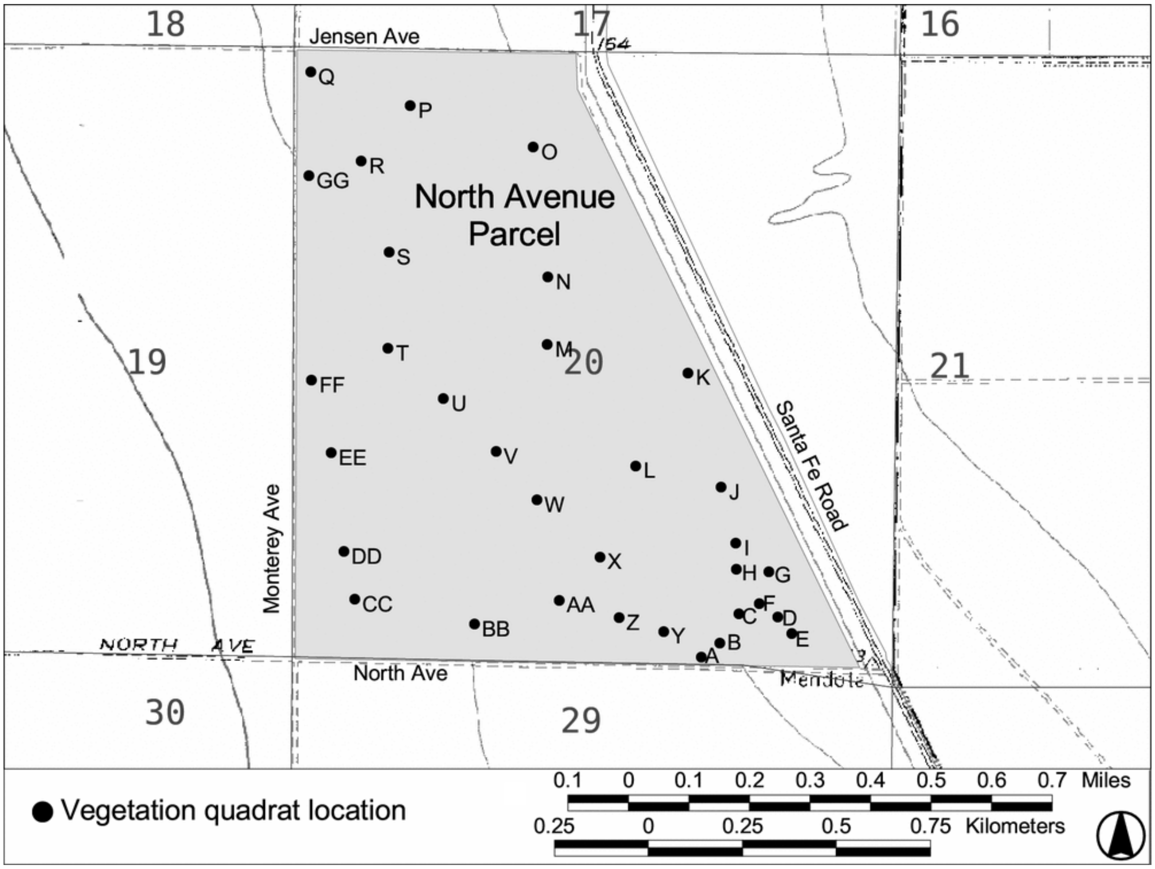

Figure 6-2. Location of vegetation sampling quadrats; the North Avenue Parcel.

Thirty-two species in fourteen families were noted during the vegetation survey (Table 6-5); all but six of these occurred in the quadrats. All species were herbaceous, although the above-ground vegetation of *Acroptilon repens* (Russian knapweed) had a decidedly shrubby aspect.

Generally, the flora was typical for fallowed lands in the western side of the San Joaquin Valley. About 21.8% of the flora (7 spp.) corresponded to "desirable" native species; of these, only *Amsinckia menziesii* (Menzie's fiddleneck) was encountered with any great frequency. Nevertheless, later in the season, two perennial native herbs, *Heliotropium curassavicum* (seaside heliotrope) and *Sesuvium verrucosum* (western sea purslane) were observed in abundance along one portion of the eastern edge of the property. *Phacelia ciliata* (Great Valley phacelia), a valuable native species was fairly abundant in the southeastern section of the property.

Species richness was fairly low and was extremely variable, ranging from 2 to13 species (Figure 6-3). The poorest areas were those that were dominated by non-native grasses, some of which were formerly cultivated on the site.

Table 6-5. Species encountered during vegetation monitoring of the North Avenue Parcel, 2002. Key to life histories: AH, annul herb; PH, perennial herb. Key to species origins: I, Introduced; N, Native; N-U, Native - Undesirable.

Species	Family	Life history	Common name	Origin	Freq.[1]
Hordeum murinum	Poaceae	AH	foxtail barley	I	33
Hordeum vulgare	Poaceae	AH	barley	I	31
Amsinckia menziesii	Boraginaceae	AH	Menzie's fiddleneck	N	24
Capsella bursa-pastoris	Brassicaceae	AH	shepherd's purse	I	24
Sisymbrium irio	Brassicaceae	AH	London rocket	I	23
Brassica nigra	Brassicaceae	AH	black mustard	I	20
Senecio vulgaris	Asteraceae	AH	old-man-in-the-Spring	I	20
Erodium cicutarium	Geraniaceae	AH	redstem filaree	I	12
Malva parviflora	Malvaceae	AH	cheeseweed	I	10
Avena sp.	Poaceae	AH	oats	I	9
Bromus madritensis	Poaceae	AH	red brome	I	8
Phalaris minor	Poaceae	AH	littleseed canarygrass	I	8
Heliotropium curassavicum	Boraginaceae	AH	seaside heliotrope	N	7
Atriplex argentea	Chenopodiaceae	AH	silverscale saltbush	N-U	5
Convolvulus arvensis	Convolvulaceae	AH	bindweed	I	5
Phacelia ciliata	Hydrophyllaceae	AH	common phacelia	N	5
Lactuca serriola	Asteraceae	AH	prickly lettuce	I	3
Malvella leprosa	Malvaceae	AH	alkali mallow	N	3
Melilotus indica	Fabaceae	AH	sourclover	I	3
Beta vulgaris	Chenopodiaceae	AH	beet	I	2
Bromus diandrus	Poaceae	AH	ripgut brome	I	2
Amaranthus albus	Amaranthaceae	AH	pigweed amaranth	I	1
Asclepias fascicularis	Asclepiadaceae	AH	narrow-leafed milkweed	N	1
Atriplex cf. *patula*	Chenopodiaceae	AH	spear orache	N	1
Chenopodium album	Chenopodiaceae	PH	lambsquarter	I	1
Hordeum depressum	Poaceae	PH	alkali barley	N	1
Acroptilon repens	Asteraceae	PH	Russian knapweed	I	0
Chamomilla suaveolens	Asteraceae	PH	pineapple weed	I	0
Rumex crispus	Polygonaceae	PH	curly dock	I	0
Salsola tragus	Chenopodiaceae	PH	Russian thistle	I	0
Sesuvium verrucosum	Aizoaceae	PH	western sea purslane	N	0
Vulpia myuros	Poaceae	PH	rattail fescue	I	0

1. Species with a frequency of "0" were those that were not noted in the quadrats but which were observed during the general census of the vegetation.

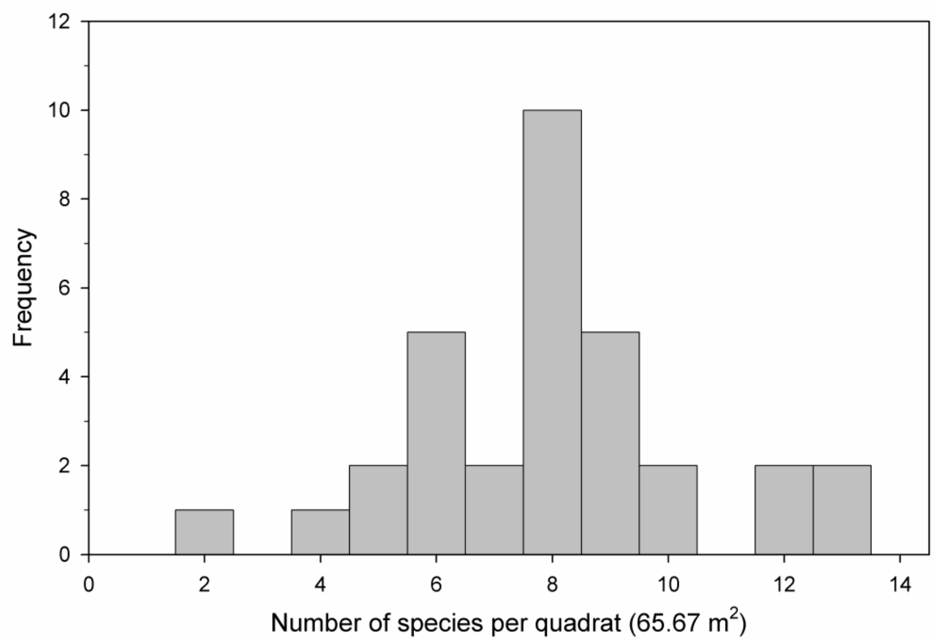

Figure 6-3. Overview of plant species richness on the North Avenue Parcel, 2002.

6.2. SITE MANAGEMENT

6.2.1. Fire Protection

Following consultation with the California Department of Forestry and Fire Protection (CDF), certain precautions have been taken to protect the property against arson. These precautions have become necessary because of the many fires that have occurred on, or next to the LRDP property. A brief overview of the measures taken to protect the land follows.

A pre-fire management plan has been completed to aid CDF in the event of a fire. The plan will be reviewed and resubmitted each year to the local fire chief to incorporate changes in land use at the site. All LRPD lands that border a roadway now have a tilled strip of soil parallel to the road. This strip is kept bare of vegetation to help prevent the spread of fires from adjacent properties, and to help avoid ignition from a lit cigarette tossed from a passing vehicle. Following CDF recommendations, vegetation is kept clear from the bases of telephone and power poles. This is to reduce the likelihood of downed power lines in the event of a fire.

6.2.2. Road Maintenance

Most of the roads surrounding the Tranquillity project site are unpaved and require maintenance, especially so after winter rains. In most cases, re-grading of the road is required each spring. Scraping, disking and rolling may be required in areas where the road was significantly damaged.

6.2.3. Grazing

No managed grazing occurred on the LRDP Tranquillity site in 2002. However, trespass sheep grazing did occur on the majority of the 440-acre North Avenue Parcel, thereby affecting the siting of the Mowing trial. Most trespass grazing was done on weekends and evenings when project personnel where not on site.

6.3. RECREATION

6.3.1. Game Bird Heritage Program Dove Hunt

The California Department of Fish and Game (CDFG) has annually planted approximately 60 acres of safflower in the northwest corner of Section 10 of the Tranquillity site (Figure 6-4). The safflower field is used for an annual dove hunt in September.

The hunting season for mourning dove (*Zenaida macroura*) is from 1-15 September. The CDFG hosted two hunts on the Tranquillity site 1 September 2002. Hunt G was from 0.5 hr before sunrise to 1200 and, Hunt H was from 1300 hr to sunset. Approximately 43 hunters attended and 128 dove were taken (average 3 per person). After opening day, this area was open to dove hunting for the remainder of the dove season and a permit was not required (CDFG 2002).

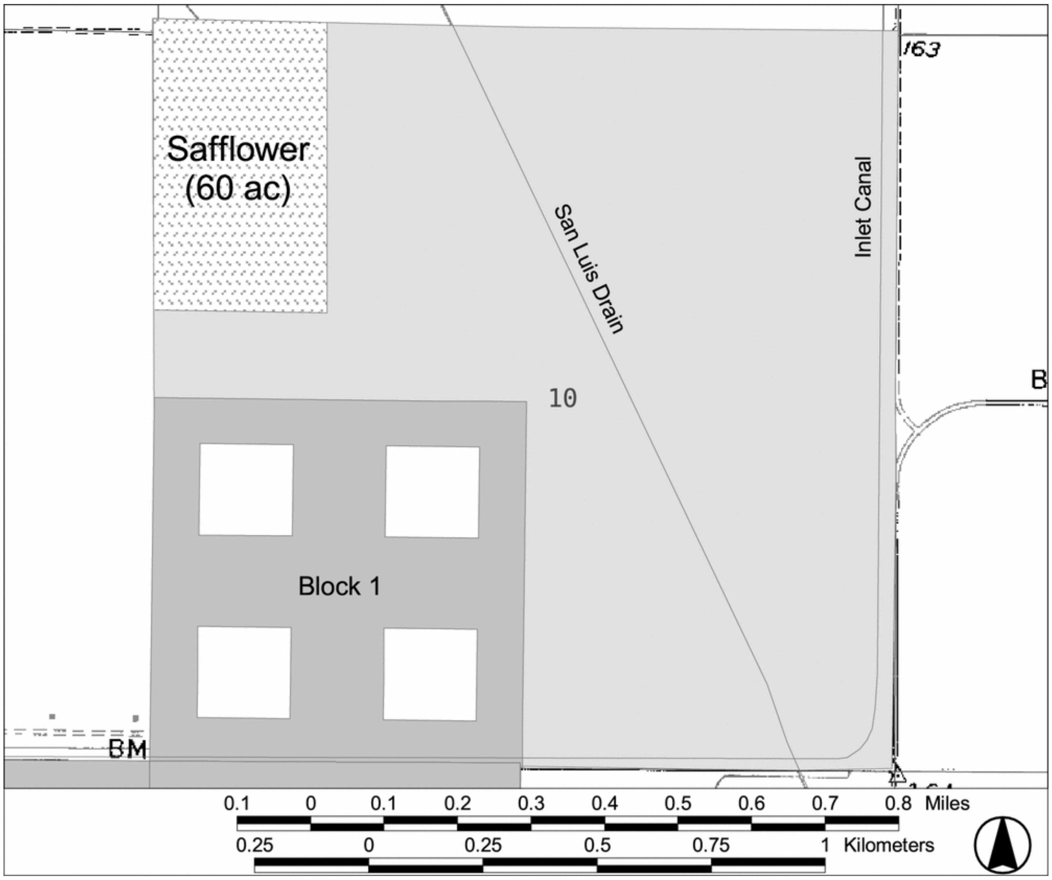

Figure 6-4. Safflower planting in the northwest corner of Section 10.

6.4. *Tours, Presentations, Conferences, and Workshops*

In May 2002, ESRP personnel and senior staff attended The Wildlife Society's Western Sections annual conference held in Visalia, CA. Senior staff presented information and progress regarding the LRDP project. Another report also was presented at this conference on ornate shrews that included information derived from the LRDP project. An ESRP staff member attended the Partners in Flight Conference held in March 2002 and presented information on avian responses to restoration in a poster. Two articles, which were featured in the Central Valley Bird Club Bulletin in summer and fall 2002, were written and submitted by an ESRP staff member. One article was an account of a nesting yellow-billed magpie in Fresno County and one was an account of a sighting of a black-chinned sparrow in the Central Valley. An ESRP GIS specialist attended the Annual Society for Conservation GIS (SCGIS) and the Annual ESRI International User conference in July 2002. In August 2002, two ESRP senior staff members presented papers on restoration of retired farmlands at a joint Ecological Society of America and Society for Ecological Restoration conference held in Tucson, AZ

6.5. LITERATURE CITED

California Department of Fish and Game. 2002. Wing Beats News Letter, July 2002.

7. MANAGEMENT AND RESTORATION AT THE ATWELL ISLAND SITE

- Stephen Laymon

7.1. RESULTS OF STUDY PLOT RESTORATION

In addition to the study plot restoration that was described in section 4.2, other restoration studies are being conducted at the Atwell Island site. In areas where restoration studies or active restoration efforts are not being conducted, farming is being used as a placeholder until the land can be restored. On the farmed areas, we are transitioning from water intensive crops such as alfalfa to crops with lower water needs such as oats.

7.1.1. Small Test Plots

During November 2001, BLM established a series of 456, 1/1000-acre (6.58 ft by 6.58 ft) test plots in the southwest quarter of Section 23 (Figure 7-1). Seed from 29 species of shrubs, forbs, and grasses were planted in the plots (Table 7-1). Four types of site preparation were used: scraping the surface, disking to 8 inches, harrowing to 4 inches, and no preparation. A standard seeding rate of 40 lbs/acre was used. Plots with other seeding rates (10 lbs/acre, 80 lbs/acre, and 160 lbs/acre) also were established on the scraped area. Within the disked area, plots with supplemental nutrients were established. Bone meal was used to increase soil phosphorus content and blood meal was used to increase soil nitrogen content. Rates of 500 and 1,000 lbs/acre effectively doubled and tripled the available soil phosphorus and nitrogen. An additional treatment of 500 lbs/acre of both blood and bone meal was used. There was no replication of plot treatments because the test plots are being used as a screening technique to look for broad effects and are the first step of a tiered study approach. These plots will be used to search for interesting trends and to help focus future, more in-depth, research.

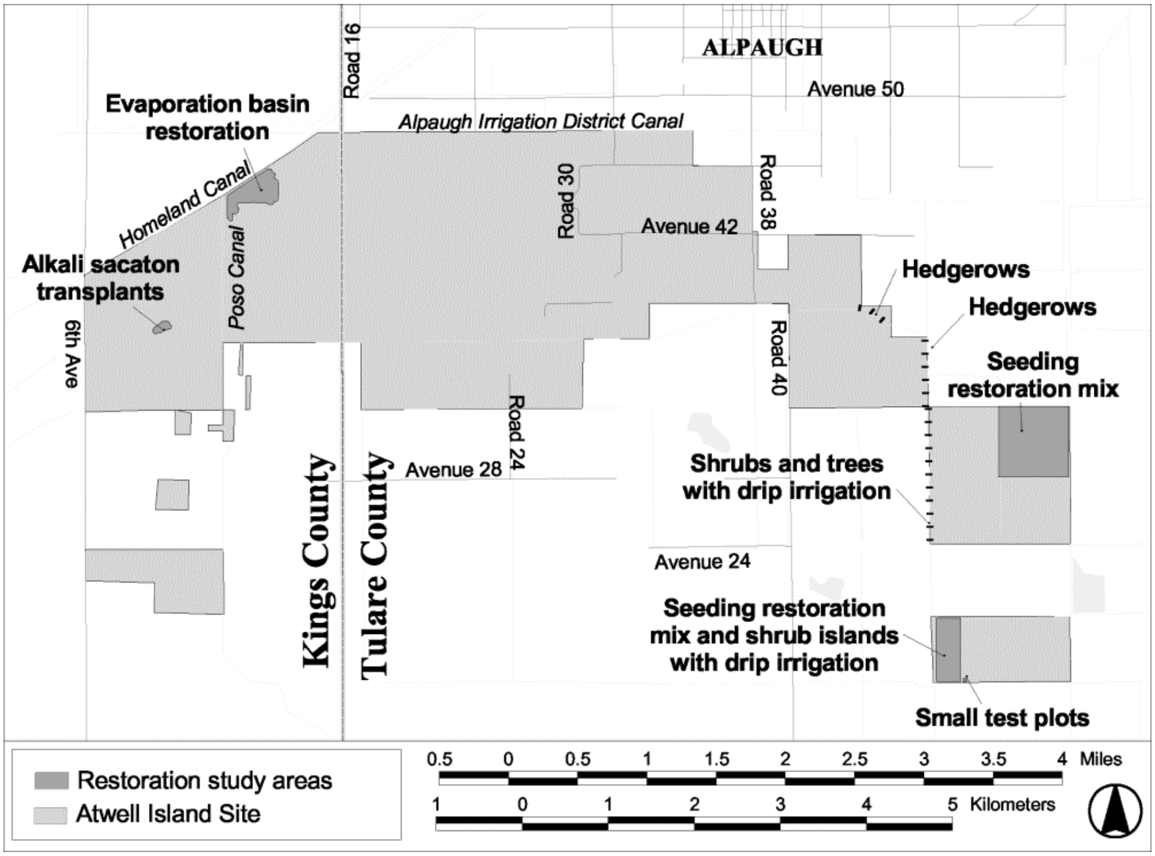

Figure 7-1. Management activities and restoration at the Atwell Island site

Table 7-1. Plants seeded on the small test plots, Atwell Island site, 2001.

Common name	Scientific name	Plant type	Seed source
bush seepweed	*Suaeda moquinii*	shrub	locally collected
spiny saltbush	*Atriplex spinifera*	shrub	locally collected
alkali heath	*Frankenia salina*	shrub	locally collected and purchased commercially
iodine bush	*Allenrolfea occindentalis*	shrub	purchased commercially
goldenbush	*Isocoma acradenia*	shrub	locally collected
quail bush	*Atriplex lentiformis*	shrub	purchased commercially
valley saltbush	*Atriplex polycarpa*	shrub	purchased commercially
alkali sacaton	*Sporabolus ariodes*	grass	local and commercial
few-flowered fescue	*Vulpia microstachys*	grass	locally collected and purchased commercially
slender-hair grass	*Descampsia danthanisides*	grass	locally collected
nodding needlegrass	*Nasella cernua*	grass	purchased commercially
creeping wildrye	*Leymus triticoides*	grass	purchased commercially
Arizona brome	*Bromus arizonicus*	grass	purchased commercially
Spikeweed	*Hemizonia pungens*	forb	locally collected
alkali mallow	*Malvella leprosa*	forb	locally collected
alkali heliotrope	*Heliotropium currassavicum*	forb	locally collected
Jipsom weed	*Datura wrightii*	forb	locally collected
Goldfield	*Lasthenia californica*	forb	locally collected and purchased commercially
purple owl's clover	*Castilleja exerta*	forb	purchased commercially
slender-leaf milkweed	*Asclepias fascicularis*	forb	locally collected
common sunflower	*Helianthus annus*	forb	locally collected
California poppy	*Eschscholizia californica*	forb	purchased commercially
Gumplant	*Grendilia camporum*	forb	purchased commercially
turkey mullen	*Eremocarpus setigerus*	forb	purchased commercially
telegraph weed	*Heterothica grandiflora*	forb	locally collected
mustang clover	*Lotus purshianus*	forb	purchased commercially
sky lupine	*Lupinus nanus*	forb	purchased commercially
caterpillar phacilia	*Phacelia tanacetifolia*	forb	purchased commercially
tomcat clover	*Trifolium tridentatum*	forb	purchased commercially

Rainfall in the project area during the winter of 2001-2002 was very low, with only 2.8 in falling between 13 November 2001 and 25 March 2002. The test plots were monitored on 7 January and 20 February 2002. No seedlings of the seven shrub species were found of any on either date. Of the six grass species, none were found on 7 January, but in February, a few seedlings of alkali sacaton, few-flowered fescue, and slender-hair grass were found. These were found primarily in the disked area. Of the 16 forb species, goldfield, purple owl's clover, California poppy, mustang clover, caterpillar phacilia, and tomcat clover were found during the 7 January check. Only goldfields and tomcat clover had more than 10% coverage. On the 20 February check, only 5 species of forbs were found. The goldfield and the caterpillar phacelia had the best coverage, with over 20%. Spikeweed and tomcat clover seedlings were also found. During this visit, the phacelia was beginning to die from lack of water and only the goldfields looked healthy. The locally collected goldfield seed did not germinate as well as the commercially purchased goldfield seed. The goldfield plants grown from commercially purchased seed died without blooming or setting seed, while plants from the locally collected seed was blooming and setting seed. Broad trends showed that higher seeding rates led to better germination and establishment. The 10 lbs/acre seeding had very few plants. The *phacelia* did best in the plowed areas, while the goldfield did best in the scraped areas. Very few plants of any species were found in the untreated control, indicating very poor germination and survival of native plants in areas with heavy competition. There were no obvious trends in the amended plots. These plots will be followed in subsequent years.

7.1.2. Hedgerows

During February 2002 BLM formed and planted 37 hedgerows in the southeast quarter of Section 10. Hedgerows were planted in 2 forms, single curved lines and groups of 4 or 5 straight lines. We planted rows 1-6 with commercial S&S hedgerow mixture consisting of 60% bran and 40% native seed. The seed contained 29% quail bush, 22% creeping wild rye, 14% few-flowered fescue, 14% ranchers' fireweed (*Amsinkia menziessii*), 7% common sunflower, 7% alkali heath, 4% turkey mullein, 1% bluedicks (*Dichelostemma capitatum*), and 1% spikeweed. We planted rows 7-17 with a combination of 10% commercial hedgerow mixture, 40% locally collected common sunflower, 25% locally collected valley salt bush, and 25% locally collected quail bush. We planted rows 18-37 with a combination of 10% commercial alkali sacaton, 45% quail bush and 45% valley salt bush.

A survey of the hedgerows was done in early August 2002. Rows 1-6, which were planted with the commercial hedgerow mixture were nearly a total failure. Only 2 species that were planted were detected, those being common sunflower and quail bush. Only 46 quail bush shrubs were found in those rows during the survey. The other 31 rows were much more successful with a total of 1,835 valley saltbush, 863 quail bush, and 3,809 alkali sacaton plants counted. Rows 18 to 37 were planted in 3 single curved lines and 4 groups of straight lines (3 groups of 4 rows and 1 group of 5 rows).

Statistical comparisons, for the three primary species, were made between single curved rows ($n = 3$), inside straight rows ($n = 9$), and outside straight rows ($n = 8$) and showed the following trends. For valley salt bush there were no significant differences, but the number of shrubs was highest on the inside grouped straight lines (mean = 108 shrubs) and lowest on the single curved lines (mean = 64 shrubs). For quail bush grouped rows (mean = 37 shrubs) had significantly higher number of shrubs than single rows (mean = 13 shrubs) (Mann-Whitney U; $Z = 1.96$; $p = 0.05$). In addition, inside rows (mean = 52 shrubs) had a significantly higher number of shrubs than outside rows (mean = 19 shrubs) (Mann-Whitney U; $Z = 3.18$; $p < 0.01$). For alkali sacaton, the difference in number of clumps between single and grouped rows was not significant. The number of clumps on the inside rows (mean = 310 clumps) was significantly higher than the number of clumps (mean = 62 clumps) on the outside rows (Mann-Whitney U; Z = 2.45; p = 0.01).

These results indicate that it is advantageous to plant hedgerows in groups of rows rather than in single rows. It is likely that the reason behind these results is that hedgerows planted in groups of rows hold the water better rather than being wicked off by the surrounding dry landscape. We have noted that with the current V-shaped hedgerow ditches that much of the seed drops to the bottom of the V and is not actually planted. In the future we plan to broaden the V so the range drill seeder can pass down one side and back up the other, planting much more of the seed.

7.1.3. Seeding Restoration Mixture

On 28 November 2002, BLM planted 80 acres in the southwest corner of Section 23, east of the Alpaugh Canal. Forty acres of the planting was done using a commercial seed mixture from S&S seed containing: 7% turkey mullein; 3% alkali sacaton; 2% alkali heath; 0.3% spikeweed; 1.5% goldfield; 9% valley salt bush; 9% spiny saltbush; 3% few-flowered fescue; 3% birds-eye gilia (*Gilia tricolor*); 3% bush seepweed; 3% goldenbush; and 56% bran. Seeding rate was 11.1 lbs/ acre. The other 40 acres was planted with locally collected spikeweed at a similar seeding rate. A portion of the area was planted with the imprinter and then we switched to the Truax range drill. The heavy soil however was too wet and sticky for the range drill and we switched back to the imprinter.

The area was monitored during the winter and spring. In January, many seedlings of goldfield, spikeweed, fescue, and gilia were found in the field, but were overtopped by the non-native annuals. On 4 March 2002, the area was browning out from lack of moisture. None of the shrubs had sprouted and only a few of the goldfield, spikeweed, fescue, and gilia could be found. None of these planted annuals had set seed. In sum, the site was totally dominated by introduced exotic annual plants, which profoundly out-competed the planted natives.

7.1.4. Propane Flaming for Weed Control

Immediately before planting the restoration mixture on 40 acres in Section 23, two small areas approximately 50 ft by 30 ft were flamed with a propane weed flamer. Residual dry matter was burned off and the remaining green non-native annual forbs and grasses cooked. On 4 March 2002, the planted vegetation was still green in the flamed area, while non-flamed areas were desiccating. Many planted native species were found blooming including the goldfield, spikeweed, fescue, and gilia. Several natives that had not been planted also were found including ranchers' fireweed and California mustard (*Guillenia lasiophylla*). These findings show the importance of control of competing non-native vegetation when attempting native plant establishment. We will not be conducting any more field plantings without control of non-natives. In 2003, we will use a propane alfalfa flamer on the non-natives after they germinate and prior to planting the native seeds.

7.1.5. Planting Shrubs and Trees along Canals

On 21 March 2002, BLM planted 130 Gooding's yellow willows (*Salix gooddinggii*) and 20 Fremont cottonwoods (*Populus fremontii*) in a ditch along the Alpaugh Canal in Section 10. Planting was done using a hydro-auger, which uses a high-pressure pump to dig a hole into which the poles are placed. Poles averaged 5 ft in length and were planted 3 ft into the ground. Planting with this method is very efficient and averaged a tree planted every 2 minutes. A check of the site on 9 May showed 64 trees (43%) were still surviving.

On 1 May 2002, BLM planted 70 potted trees and shrubs along the Alpaugh Canal on the north side of the project area in sections 4 and 5. These included: 10 wild rose (*rosa californica*); 15 Fremont cottonwoods; 8 box elders (*Acer negundo*); and 42 buttonwillows (*Cephalanthus occidentalis*). On 25 November, in the same area, we followed up with a planting of 60 trees and shrubs: 20 western sycamore (*Plantanus racemosa*); 10 box elder; 10 Oregon ash (*Fraxinus latifolia*); 10 elderberry (*Sambucus mexicana*); and 10 sandbar willow (*Salix sessilifolia*). These plants are being hand watered and survival is being determined.

Quail bush shrubs planted along the Alpaugh Canal in spring 2001 had 100% survival during 2002. These plantings were not watered during 2002, but showed good growth with the largest shrubs reaching over 5 ft in height and 7 ft in diameter.

7.1.6. Shrub Islands with Drip Irrigation

During January 2002, a drip irrigation system was placed on the 80 acres that had recently been planted with the range drill in Section 23 (Figure 7-1). Twelve lines, each 1,000 ft long with a total of 1,400 emitters, were installed. The purpose of the irrigation system is to provide supplemental water to help increase the survival of the shrubs through their first growing season. Seedlings were planted at approximately 550 emitters including: 120 goldenbush; 120 valley salt bush, 10 quail bush, and 300 alkali sacaton. Seeds of golden bush, valley salt bush, and alkali sacaton were planted at the remaining 850 emitters. The southern 3 lines, which had most of the planted seedlings, have done well, with nearly 100% survival. The 130 plants on the northern 9 lines and the seeds planted on those lines had nearly a 100% failure rate. These northern lines had insufficient water during the first few weeks after planting because we were supplied with an incorrect gauge of filter. By the time the filter was replaced with a correct gauge, many of the plants had died. The seeding was especially problematic because a different water regime is needed for germination of seeds than is needed for the establishment of plants. Seeds need nearly constant moisture to germinate, while seedlings need to be watered much less frequently. In the future, we will not mix seeds and plants on the same drip system. The 300 plus plants that survived have grown, even though they were not watered after 1 July 2002. The advantages to using drip irrigation are that there are almost no weed problems and the success rate is very high. The disadvantages are the high cost of materials for the drip system and the high labor demand for installing the drip system, planting the plugs, and running the irrigation system. Drip irrigation is not a viable option for restoring large areas, but should be considered for specific situations when the need for fewer weeds and higher survival is out-weighed by the increased cost.

7.1.7. Native Seed Collection

During 2002, BLM contracted with seed collectors to collect native seed in the southern San Joaquin Valley. Seed is collected on nearby sites including: Kern National Wildlife Refuge; Allensworth State Ecological Reserve and other southern San Joaquin Valley locations managed by California Department of Fish and Game and the Center for Natural Land Management. This was the first year that we collected a portion of the seed from the Atwell Island Project area. The following native shrub seed was collected during the year: 120 lbs of iodine bush; 450 lbs of valley salt bush; 250 lbs of quail bush; 307 lbs of alkali heath; 102 lbs of goldenbush; 40 lbs of bladerpod (*Isomeris arborea*); and 1 lb of honey mesquite (*Prosopis glandulosa*). Annual forbs and grasses were also collected: 300 lbs of alkali weed (*cressa truxillensis*); 695 lbs of spikeweed; 92 lbs of California goldfields; 48 lbs of alkali daisy (*Lasthenia ferrisiae*); 1 lb of snake head (*Malacothrix coulteri*); 5 lbs of pepper grass (*Lepidium dictyotum*); 60 lbs of common peppergrass (*Lepidium nitidum*); 4 lbs of sky lupine (*Lupinus nanus*); 3 lbs of blue dicks; 9 lbs of caterpillar phacelia; and 10 lbs of alkali sacaton.

7.2. Incidental Wildlife Sightings

The BLM database of incidental wildlife sightings continued to grow. During 2002, a total of 3,120 sightings found on the Atwell Island site were recorded in the database. Included were 155 species of birds, 11 mammal, 6 reptiles, 3 amphibians, and 15 butterflies. Some noteworthy sightings include: tundra swan (*Cygnus columbianus*), Ross' goose, redhead (*Aythya americana*), golden eagle (*Aquila chrysaetos*), red-shouldered hawk (*Buteo lineatus*), Swainson's hawk (*Buteo swainsoni*), merlin, prairie falcon, peregrine falcon, mountain plover, marbled godwit (*Limosa fedoa*), burrowing owl, short-eared owl, common poorwill (*Phaleanoptilus nuttallii*), willow flycatcher (*Empidonax traillii*), Swainson's thrush (*Catharus ustulatus*), sage thrasher (*Oreoscoptes montanus*), San Joaquin pocket mouse (*Perognathus inornatus*), San Joaquin kit fox (*Vulpes macrotis*), San Joaquin Valley coachwhip, and coast horned lizard. Swainson's hawks bred successfully on the project area. Willow flycatchers were common spring migrants during May and early June, but did not remain to breed. A road-killed kit fox was found along the paved road on the project area south of Alpaugh. A breeding population of San Joaquin Valley coachwhips and coast horned lizards are located in the newly acquired unfarmed area.

7.3. Site Management

During 2002, BLM repaired and upgraded one well and pump on the northern half[1] CWR = Crop ET – Effective Precip. + Leaching Requirement (after Smith, 2001)

[2] Assumes an Irrigation Efficiency of 65%

[3] IWAR - CWR = DP

of the project area. This upgrade will ensure a continued supply of water for the restoration activities on the site.

7.4. *CHRISTMAS BIRD COUNT*

An annual bird count was conducted at Atwell Island on 16 December 2002. Participants helping with this effort included personnel from BLM, ESRP, and volunteers. Data compiled during this survey was intended for the National Audubon Society Christmas Bird Count (CBC), which is an annual survey conducted simultaneously in the Western Hemisphere during December (early winter).

A total of 96 species were observed and 11,381 individuals were recorded. Unusual sightings included: 1 American bittern, 1 ross goose, 53 cinnamon teal, 57 common mergansers, 13 white-tailed kites, 1 merlin, 1 peregrine falcon, 1 prairie falcon, 280 black-bellied plovers, 15 mountain plovers, 4 short-eared owls, 2 burrowing owls, 2 greater roadrunners, 1 chipping sparrow, and 1 vesper sparrow. The most common species recorded were red-winged blackbird (5,640), savannah sparrow (840), horned lark (771), white-crowned sparrow (603), and house finch (540), black-bellied plover (380), western meadowlark (299), and American pipit (291). Data collected during this effort was entered into the CBC database, which monitors the status and distribution of early winter bird populations across the Western Hemisphere (Sauer et al. 1996). Thirteen participants equaling 29 party hours were dedicated to this survey.

7.5. *RECREATION*

7.5.1. Game Bird Heritage Program Dove Hunt

During the summer of 2002, BLM, in cooperation with the California Department of Fish and Game and our cooperating farmer, Jackson Farms, planted 40 acres of safflower in sections 4 and 5. The safflower was chopped with a combine in late July and the area attracted a large number of doves (peak 240 counted on 26 August 2002). Two dove hunts in 2002 occurred on 1 September 2002. Hunt K was conducted from 0.5 hr before sunrise to noon and Hunt L was conducted from 1300 hr to sunset. These hunts can accommodate a maximum of 40 hunters, 20 in the morning and 20 in the afternoon. After 1 September, the area was open to dove hunting and a permit was not required.

The hunt on opening day of dove season (1 September 2002) drew the maximum number of hunters. Nearly all hunters in the morning session and many in the afternoon session reached their limit of dove.

7.6. *TOURS AND PRESENTATIONS*

The following tours and presentations were conducted by BLM staff.

- Presentation on Atwell Island project accomplishments for BLM State Office Staff.
- Presentation on Atwell Island project for the Tulare County Audubon Society.
- Gave presentation on Atwell Island project for The Wildlife Society Western Section meeting in Visalia.

- Gave tour of Atwell Island project to a group from The Wildlife Society Western Section.
- Gave tour of Atwell Island project to representatives of the California Department of Corrections and EDAW.
- Gave tour of Atwell Island project to CVPIA Restoration Group from FWS.
- Gave tour of Atwell Island project area to Patagonia's Sustainable Cotton Tour.
- Gave tour of Atwell Island project area to BLM Bakersfield FO management team and interagency Land Retirement Team.

Workshops and conferences attended by BLM staff include:

- Attended Seed for Success workshop in Sacramento – Instruction workshop on seed collecting.
- Attended workshop and open house at ConservaSeed in Courtland.
- Attended tour of Union Slough restoration project in Yolo Co.
- Attended Ecological Farming Conference and Wildfarm Alliance Workshop at Asilomar.

7.7. LITERATURE CITED

Sauer, J.R., S. Schwartz, and B. Hoover. 1996. The Christmas bird count home page. Version 95.1. Patuxent Wildlife Research Center, Laurel, MD.