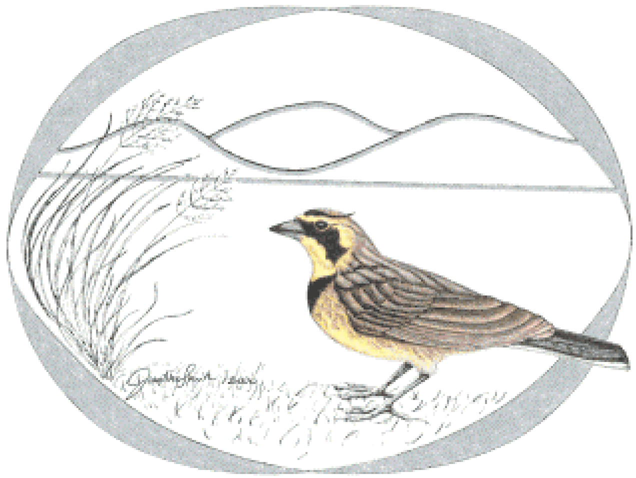
LAND RETIREMENT DEMONSTRATION PROJECT
YEAR THREE
2001 ANNUAL REPORT



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ACKNOWLEDGEMENTS

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Richard Lopez at Westlands Water District has been a tremendous help in guiding us through the convoluted web of water allocations, orders, and transfers. Without his help we may well have needlessly spent a great deal of money on unused water. We would like to thank Southern California Edison, Westside Transplants, and Intermountain Nursery for providing us with native seedlings and S & S Seeds and Pacific Coast Seeds for providing us with native seed mixes. Finally we would like to thank the California Department of Fish and Game, Fresno West Golf and Country Club, Westlands Water District, and Paul Lanfranco for allowing us to collect native seed from various locations in Fresno County. Additionally we would like to thank the Center for Natural Lands Management for permission to collect seed at the Thomas Payne Preserve for the Atwell Island site.

EXECUTIVE SUMMARY

Introduction

Vast 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. 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[1] authorized a land retirement program as recommended in the San Joaquin Valley Drainage Program Final Report[2]. An interagency team consisting of representatives from the United States Bureau of Reclamation (USBR), the United States Fish and Wildlife Service (USFWS), and the United States Bureau of Land Management (USBLM) has been assembled to accomplish the goals of the CVPIA Land Retirement Program[3]. 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 drainwater, land retirement comes with its own set of challenges including: land acquisition, redistribution of the acquired water, and habitat restoration to reduce the potential for agricultural weeds and pests that would adversely impact neighboring farming interests.

Prior to initiating land retirement on a greater scale, a 15,000-acre demonstration project has been designed to test various methods of habitat restoration. The objectives are to assess the effects of land retirement on drain water and groundwater levels, evaluate its potential to decrease bio-available selenium and other toxic compounds, and to determine relative costs and success of different restoration treatments in re-establishing native biota on the sites. Two study sites, one in western Fresno County (Tranquillity site) and the other in Tulare and Kings counties (Atwell Island site), have been established. The California State University Stanislaus, Endangered Species Recovery Program (ESRP) is leading the biological studies at both sites, conducting restoration efforts, and managing the Tranquillity site. The physical impacts of land restoration are being examined by the USBR at both sites. The USBLM is conducting restoration efforts and managing the Atwell Island site.

This annual report summarizes information collected in 2001 from both the Tranquillity and Atwell Island study sites, and also results through 2001 of the Habitat Restoration Studies, site-wide biological surveys, restoration trials and efforts at both sites, and impacts of land retirement on physical properties (groundwater, soils, geology, etc). Data

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[1] Federal Register: March 9, 1998. Vol. 63, No. 45. p11453.

[2] San Joaquin Valley Drainage Program. 1990. Fish and wildlife resources and agricultural drainage in the San Joaquin Valley, California. Vols I and II. 707pp+appendices.

[3] U.S. Department of Interior. 1997. Central Valley Project Improvement Act Section 3408(h): Land Retirement Program Guidelines. Unpubl. report, Interagency Land Retirement Team, Fresno, CA, 19 pp.

collected for the Habitat Restoration Studies include plant cover and survivorship, invertebrate richness and abundance, amphibian and reptile richness and abundance, avian richness and abundance, and small mammal richness and abundance. Site-wide data collection includes night spotlighting surveys, track station surveys, winter raptor surveys, contaminants monitoring, and plant cover and survivorship on various test plots. Physical impact data that are being collected include soil type and soil chemistry, groundwater levels, and groundwater contaminants.

Tranquillity Habitat Restoration Study

Although imprinting of native seeds in 1999 was successful in establishing native plants on our study plots in 2000, by 2001 frequency, cover, and abundance of native plants had diminished and exotic and native weedy species predominated. While conditions in the southern San Joaquin Valley region in 2000 and 2001 have not been favorable for production of desirable native plants, it is becoming clear that improved weed control is necessary for restoration of retired agricultural lands.

Invertebrate richness did not vary by treatment in any year, nor did richness vary among any given year across treatments. Abundance of invertebrates did not vary by treatment, except in 2001 where the contoured but non-restored plots had the fewest invertebrates. For most treatments, there was a trend of increasing invertebrate abundance from 1999 to 2000, then decreasing abundance in 2001. The most notable differences in richness were that block 1 had greater richness than any other block during all years and that block 3 had a relative low richness in 2000. Abundance among the blocks were most similar in 1999 and most variable in 2001, indicating that blocking effect is increasing. Invertebrate composition exhibited temporal changes. Thysanoptera dominated the invertebrate population in 1999 whereas Hemiptera and, secondarily, Thysanoptera dominated in 2000. In 2001 Orthoptera was dominant.

No amphibians or reptiles were captured on the plots, indicating that they remain scarce. Incidental sightings on the plots included a California king snake and a western fence lizard. Also, numerous western toads and a California king snake were observed in the vicinity of the study plots during site-wide survey efforts.

Richness and abundance of birds were highly variable among seasons in 2001. We expected this because of the numerous seasonal migrants that visit the study site. There were no observable differences in richness or abundance between treatments. Spring abundance increased each year from 1999 to 2001 and winter abundance increased from 2000 to 2001. Most species using the plots were grassland obligates or facultative grassland species. With the exception of horned larks, avian species of special concern were more abundant on the plots than in previous years. Two very desirable species, northern harriers and short-eared owls, were observed nesting on the plots.

Deer mice were the most abundant small mammal captured, although house mice, ornate shrews, California voles, and a single harvest mouse also were captured. The abundance of small mammals, particularly deer mice, has increased each year since 1999. The abundance of deer mice tended to be greater on plots that had a combination of restoration and contouring. Although treatment type appeared to have no effect on house mouse abundance, shrews were most abundant on restored plots and voles were most abundant on contoured plots.

Atwell Island Habitat Restoration Study

In 2001, baseline data were collected on the Atwell Island study plots while they were still covered with a barely crop. The barley crop was harvested in the fall and treatments were applied. The Atwell Island HRS site seemed to possess few floristic similarities to the Tranquillity HRS site during its baseline year. In particular, a number of aggressively weedy species that were abundant at the Tranquillity HRS site were much less abundant at the Atwell Island HRS site. The absence of these species suggests that the Atwell Island site may not be plagued by weeds to the same degree as the Tranquillity site. Nevertheless, the noxious weed fivehook bassia was fairly abundant in the Atwell Island HRS plots, which may prove to be a significant problem in future years.

Invertebrate richness among the three study blocks was relatively constant, however, species composition varied. Block 1 was dominated by 4 orders (Acari, Thysanoptera, Isopoda, and Araneae), Block 2 was dominated by 2 orders (Acari and Thysanoptera) and Block 3 was dominated by a single order (Coleoptera). Sweep samples were collected, but are not yet completely identified and analyzed.

Neither amphibians nor reptiles were observed on the study plots. Incidental sightings at the HRS site included western toads, gopher snakes, and horned lizards.

Blocks 1 (10 species) and 2 (11 species) had relatively high avian richness as compared to Block 3 (5 species). Red-winged blackbirds, horned larks, western meadowlarks, and savannah sparrows were the most common birds observed.

No small mammals were captured on the study plots. Nevertheless, one San Joaquin pocket mouse (a federal Species of Special Concern) was captured by hand near one of the plots on Block 3.

Restoration Studies at Tranquillity

Results from a trial of two seeding methods (imprinting and drilling) of native seeds, while not statistically significant, suggested that the response of individual species to these methods is highly variable. These results suggest the need for more rigorous trials to determine the most appropriate method for seeding various species.

An investigation of seeding barley by imprinting and drilling suggested that either approach is acceptable. Likewise, a trial of these two seeding methods using a seed mix of barley and native grasses yielded no statistically significant differences. Nevertheless, a greater number of introduced weedy species was noted on plots seeded with the mixture containing native grasses than on the plots seeded solely with barley. This suggests that some of the weedy species on the HRS plots may have been introduced through the inclusion of their seeds in commercially purchased native seed mixes.

Biological Monitoring at Tranquillity

As in 1999 and 2000, there was seasonal variability in species richness during spotlighting surveys in 2001. There was a trend of increasing richness from 1999 to 2001. No single species was observed during every season; however, barn owls, black-tailed hares, desert cottontails, and short-eared owls were present most seasons. Generally, barn owls, black-tailed hares, desert cottontails, and red-tailed hawks were the most abundant species.

Species richness was highest on the track stations in the summer of 2000 and spring 2001 and the lowest in fall and winter 1999. Abundance of tracks was greatest in summer of 2001 and lowest in fall and winter of 1999. The greatest frequency of visitation and the greatest rate of visitation were of small mammals, except in the summer and winter of 2000. The high variability observed in the richness, abundance, frequency and rate of tracks may be indicative of the high variability in climactic conditions of the San Joaquin Valley, rather than being indicative of responses to restoration efforts at the site.

American kestrels and northern harriers were the most common raptors seen during the raptor surveys, but red-tailed hawks, loggerhead shrikes, and white-tailed kites were also frequently observed. Northern harriers and red-tailed hawks increased in rate of occurrence each year. A peregrine falcon and a ferruginous hawk, both species of special concern, were first observed on the site in 2001. Individuals of both species were observed foraging over the study plots.

Bio-accumulation of selenium does not appear to be a concern at the Tranquillity site. Selenium levels of all biota sampled (vegetation, invertebrates, and small mammals) did not increase from 1999 to 2001. In fact, there is a trend of decreasing selenium levels in most groups sampled. Selenium levels of most biotic groups fall within typical background levels. These levels are 0.01 to 0.6 mg/kg for terrestrial vegetation, 0,1 to 2.5 mg/kg for terrestrial invertebrates, <1.0 to 4.0 mg/kg for whole bodies of small mammals, and 1.0 to 10.0 mg/kg for small mammal livers. The only plant that exceeded the vegetation background levels was *Brassica nigra*, a known selenium accumulator. The levels of selenium observed in *B. nigra* (about 1.0 mg/kg) collected from the Tranquillity site are very low considering the levels that selenium that can be accumulated (500 to 1,000 mg/kg). Selenium levels in spiders and isopods slightly exceeded typical background levels for terrestrial invertebrates. However, spiders are predators and isopods are detritivores, so selenium bio-accumulation in these taxa are expected to be higher than in beetles, crickets, and other typical terrestrial invertebrates. The levels of selenium accumulation in bodies and livers of both deer mice and shrews are at the low end of the range typical for selenium accumulation in small mammals.

Restoration Studies at Atwell Island

During the fall of 2001 the Bureau of Land Management established a series of 456 small plots (1/1000 acre) to test the effectiveness of differing soil preparations and seeding rates on germination success and survival of native shrubs, forbs, and grasses. Seed from 29 species were planted at rates of 40, 80, and 160 pounds per acre. Four methods of site preparation were used: scraping the surface, disking to 8 inches, harrowing to 4 inches, and no preparation. Supplemental nitrogen and phosphorus were added to some plots. Results of these trials will be available after the growing season in spring 2002.

Approximately 1.5 miles of hedgerows were planted with a seed mix (of *Atriplex lentiformis*, *Leymus triticoides*, *Vulpia microstachys*, *Amsinkia menziesii*, *Helianthus annus*, *Frankenia salina*, *Eremocarpus setigerus*), *Dichelostemma capitatum*, and *Hemizonia pungens*) using a range drill. A seed mix (of *Eremocarpus setigerus*, *Sporobolus airoides*., *Frankenia salina*, *Hemizonia pungens*, *Lasthenia* sp., *Atriplex polycarpa*, *A. spinifera*, *Vulpia* sp., *Gilia* sp., *Suaeda moquinii*, *Isocoma acradenia*) was also planted on approximately 240 acres using both a range drill and an imprinter. Three small areas (approximately 30 ft. x 90 ft.) that were seeded were burned immediately prior to planting.

Approximately 150 native trees and shrubs (that were rooted in supercells—10 in deep plastic containers) were planted along the Alpaugh canal and drip irrigation was installed. Drip irrigation also was installed in an 80-acre area that was planted with the range drill to supply supplemental water to shrubs during their first growing season.

A restoration effort also was conducted at an abandoned evaporation pond. Several species of salt-tolerant plants were planted as seedlings or seeds.

Biological Monitoring at Atwell Island

The most commonly observed species during spotlighting surveys, in order of decreasing abundance, were: barn owls, kangaroo rats, western toads, desert cottontails, black-crowned night herons, and great egrets. Species richness was higher in September than in December.

The greatest abundance and variety of tracks were observed during the September track station survey. In September, the most abundant tracks were of mice, insects, kangaroo rats, and western toads, whereas in December the most abundant tracks were of mice, birds, and dogs. The frequency and rate of visitation of invertebrates, amphibians, and reptiles, birds, and small mammals were greatest in the fall.

Eight species of raptors and loggerhead shrikes were observed during the winter raptor survey. The most commonly seen raptors were red-tailed hawks and northern harriers. Prairie falcons and ferruginous hawks also were intermittently observed. A total of 71 species of birds were observed during a mid-winter bird count. The most commonly observed birds were red-winged blackbirds, house finch, white-crowned sparrows, savannah sparrows, horned larks, and European starlings. Additionally, incidental sightings of 102 species of birds, 5 species of mammals, 2 species of reptiles, and 5 species of butterflies were recorded.

Bio-accumulation of selenium does not appear to be a concern at the Atwell Island site. Selenium levels of all taxa (vegetation, invertebrates, and small mammal) sampled were within typical background levels. These levels are 0.01 to 0.6 mg/kg for terrestrial vegetation, 0,1 to 2.5 mg/kg for terrestrial invertebrates, <1.0 to 4.0 mg/kg for whole bodies of small mammals, and 1.0 to 10.0 mg/kg for small mammal livers. Selenium levels of all taxa did not increase from 2000 to 2001. In fact, there is a slight trend of decreasing selenium levels.

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 highly to moderately saline, and contain elevated concentrations of selenium and boron when compared to other soils in the San Joaquin Valley. The baseline data on soil chemistry collected during 1999 are adequate for establishing project baseline soil concentrations of selenium, boron, and salinity.

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 October 2001 was 4 feet. 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 34 acres (less than 2% of the site) during the time period from October 1999 to October 2001. 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/liter). 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. Data on groundwater quality collected during 1999 are adequate for establishing baseline project conditions. No surface water ponding was observed at the site during 2001.

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 data on soil chemistry will be collected at the site during 2002 to establish project baseline soil concentrations of selenium, boron, and salinity within the study research blocks. 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. The year 2002 will be the baseline for groundwater levels and groundwater quality. Surface water monitoring will also commence in 2002.

Tours, Presentations, Conferences, and Workshops

One site tour of the Tranquillity site was given in 2001. Information obtained during our studies was presented at conferences sponsored by the western section of The Wildlife Society and The Society for Ecological Restoration, California Chapter. Additionally, presentations were given to The Westlands Resource Conservation District and to students at California State University Stanislaus. Land Retirement Team members attended a workshop on restoration sponsored by the USBLM, a workshop on field ornithological techniques sponsored by Point Reyes Bird Observatory, and attended a national conference sponsored by The Wildlife Society.

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I. INTRODUCTION

A. Background

Vast 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. 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[4] authorized a land retirement program as recommended in the San Joaquin Valley Drainage Program Final Report[5]. An interagency team consisting of representatives from the United States Bureau of Reclamation (USBR), the United States Fish and Wildlife Service (USFWS), and the United States Bureau of Land Management (USBLM) has been assembled to accomplish the goals of the CVPIA Land Retirement Program[6]. Although land retirement may provide solutions to some problems associated with agricultural drainwater, land retirement comes with its own set of challenges. Some of these include: land acquisition, redistribution of the acquired water, and habitat restoration to reduce the potential for agricultural weeds and pests that would adversely impact neighboring farming interests.

The Land Retirement Team (LRT) is entrusted with the task of implementing the CVPIA Land Retirement Program. Through this program, the United States Department of Interior (USDOI) 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). Condemnation of land is not a part of this 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 lands from irrigated agricultural production on the west side of the Valley,
- Acquire water for CVPIA purposes, and
- Enhance fish and wildlife resources.

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[4] Federal Register: March 9, 1998. Vol. 63, No. 45. p11453.
[5] San Joaquin Valley Drainage Program. 1990. Fish and wildlife resources and agricultural drainage in the San Joaquin Valley, California. Vols I and II. 707pp+appendices.
[6] U.S. Department of Interior. 1997. Central Valley Project Improvement Act Section 3408(h): Land Retirement Program Guidelines. Unpubl. report, Interagency Land Retirement Team, Fresno, CA, 19 pp.

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.mp.usbr.gov/cvpia/).

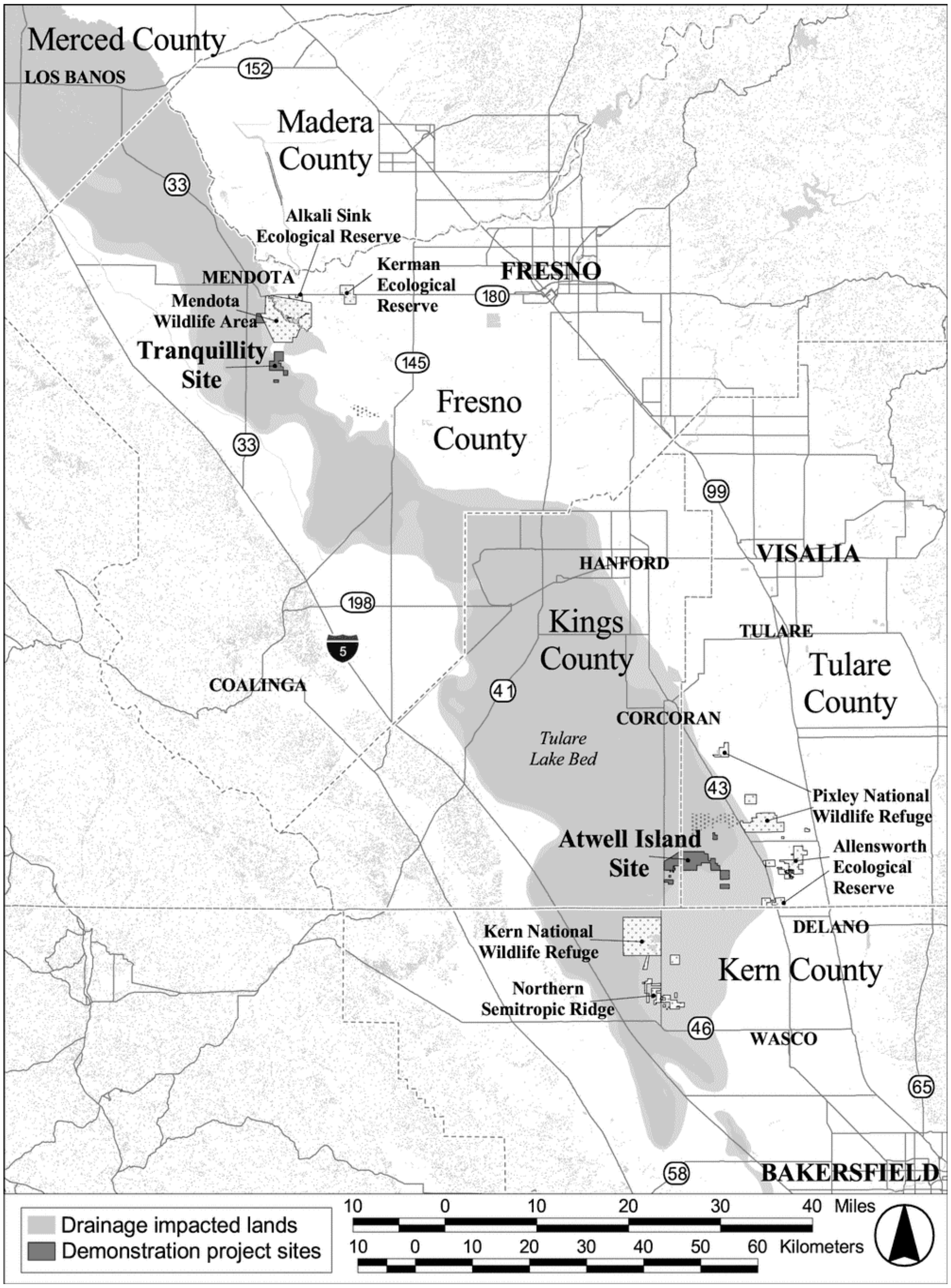

Figure 1. Drainage impacted lands in the San Joaquin Valley.

B. 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). The Land Retirement Demonstration Project (LRDP) was initiated to address concerns about the scope and degree of impacts of retirement on wildlife, drainage volume reduction, 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 provide habitat. Results will guide implementation of the larger Land Retirement Program;
- Research cost-effective means of restoring self-sustaining communities of native upland plants and animals on LRDP lands 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 resource monitoring plan was prepared by the California State University Stanislaus, Endangered Species Recovery Program (ESRP). That plan outlined habitat restoration research and protocols to monitor for potential contamination of wildlife resulting from the high selenium levels in shallow groundwater, soils, and surface accumulation of water (Selmon et al. 1999). The research and monitoring described in that plan were implemented in 1999. A separate monitoring plan was also prepared that describes sampling and analysis of physical factors including surface water, groundwater, and soils (CH2M Hill 1999).

C. 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 and will consist of approximately 7,000 acres. The Atwell Island site, formerly called the Alpaugh site, is located in Kings and Tulare counties and will be approximately 8,000 acres.

Monitoring of biota, soils, and surface and groundwater depth and quality will be implemented on the 15,000 acres of Demonstration Project lands as they are purchased. Currently, a total of 6,114 acres have been purchased. Another 2,641 acres are in escrow and title transfer is expected in 2002.

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 that site in late 2001 bringing the total to 2,086 acres (Figure 2). An additional 541 acres are currently in escrow and should be added to the site in 2002. 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 parcel obtained in late 2001 has been fallowed and grazed, but has not yet been surveyed for wildlife, or received any restoration efforts. These tasks are scheduled to occur in 2002.

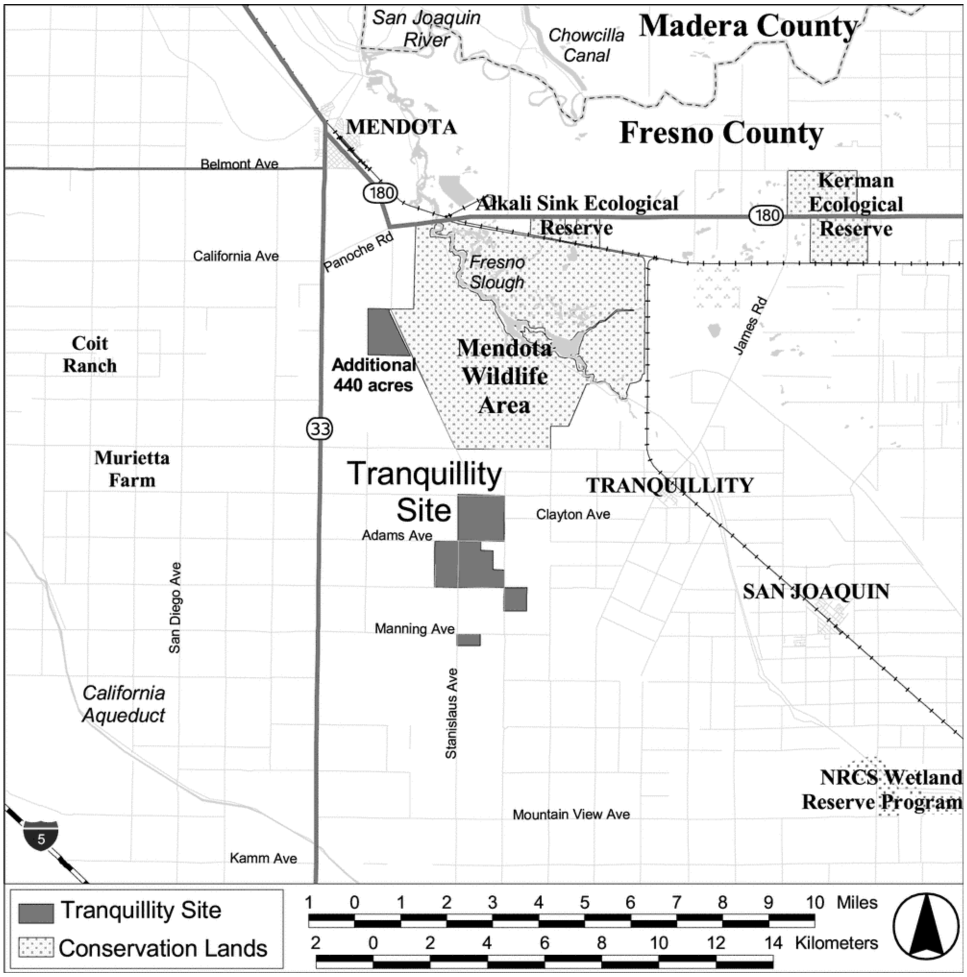

Figure 2. Current configuration of the Tranquillity site.

2. Atwell Island Site

As of February 2002, 4,028 acres had been purchased in Kings and Tulare counties in the Tulare Basin area near Alpaugh (Figure 3). This includes 1,382 acres acquired during 2001. Approximately 2,100 additional acres are currently in escrow and should be acquired in the near future, bringing the Atwell Island project area total acquired to approximately 6,128 acres. The project is authorized to increase to 8,000 acres. Of the 4,028 acres now owned by USBLM, approximately 1,300 acres are currently being farmed, 1,300 acres have not been farmed for 5 years, and 1,400 acres have not been farmed for 15 years. Surveys conducted by ESRP in 1998 indicated that several sensitive species inhabit or use some idled lands that have been purchased at this site (Uptain et al. 1998).

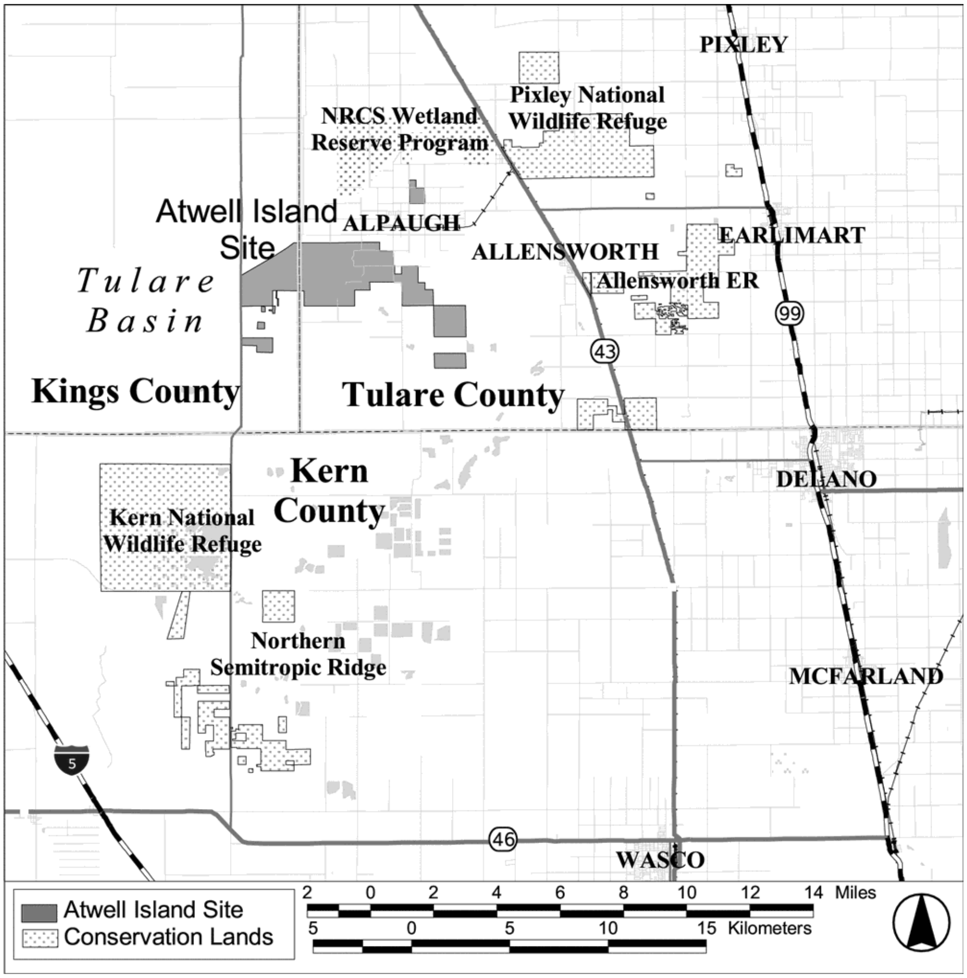

Figure 3. Current configuration of the Atwell Island site.

D. Project scope

The desired outcome for retired agricultural land is drainage reduction and the reestablishment of self-sustaining upland communities such as California prairie, Valley Sink Scrub, and Valley Saltbush Scrub (*sensu* Holland 1986). Because virtually no information is available on upland community restoration of retired agricultural land in the Valley, this Land Retirement Demonstration Project provides an opportunity to develop cost-effective restoration techniques and study the effects of habitat restoration 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:

- a study to determine the responses of wildlife to restoration efforts (Habitat Restoration Study);
- site-wide monitoring of wildlife;
- monitoring of groundwater levels and groundwater quality in relation to reduction of applied irrigation water;
- restoration-related experimentation to gather information on appropriate uses and types of cover crops, seeding rates, seeding methods, seedling planting, microtopographic relief, and mycorrhizal inoculation;
- installation of nurseries to grow locally collected seed;
- implementation of wildlife-friendly farming practices, and;
- management of lands for recreational use.

The following sections of this report describe the accomplishments and preliminary results obtained by the Land Retirement Team in the calendar year 2001. Study designs and methodologies are presented whenever necessary for clarity or when changes have been made from those previously reported.

II. HABITAT RESTORATION STUDY

A. Tranquillity

1. Study Design

An 800 acre Habitat Restoration Study (HRS) was established at the Tranquillity site in 1999 to examine specific techniques of restoring natural habitat. Data are being collected and analyzed to assess differences between four experimental treatments: restoration using imprinting with native seeds in combination with surface contouring (installation of microtopography, CR); restoration using imprinting with native seeds (NR); surface contouring (CR); and no treatment (NN, Figure 4).

Specific objectives of the HRS are:

- to determine the efficacy of revegetation with native plants as a means to facilitate upland habitat restoration;
- to determine the efficacy of microtopographic contouring as a means to facilitate upland habitat restoration;
- to examine the responses of plants and wildlife to habitat changes.

In 1999, 20 10-acre study plots were randomly established within 5 blocks (Figure 4). Each plot is surrounded by 30 acres that have been maintained with a barley cover crop to isolate the plots, and to reduce weeds and the occurrence of soil erosion. An average of 4.6 inches of water was applied to the barley using a hand-moved sprinkler irrigation system in 12-hour sets during the time period from 15 March to 30 April 2001. Barley was harvested in June 2001. Previous reports (Selmon et al. 1999, Selmon et al. 2000, and Uptain et al. 2001) describe the installation of the microtopographic contours, methods of seeding and seedling transplanting, rates of seeding, and the composition of the seed mix. Supplemental planting or contouring did not occur on the study plots in 2001.

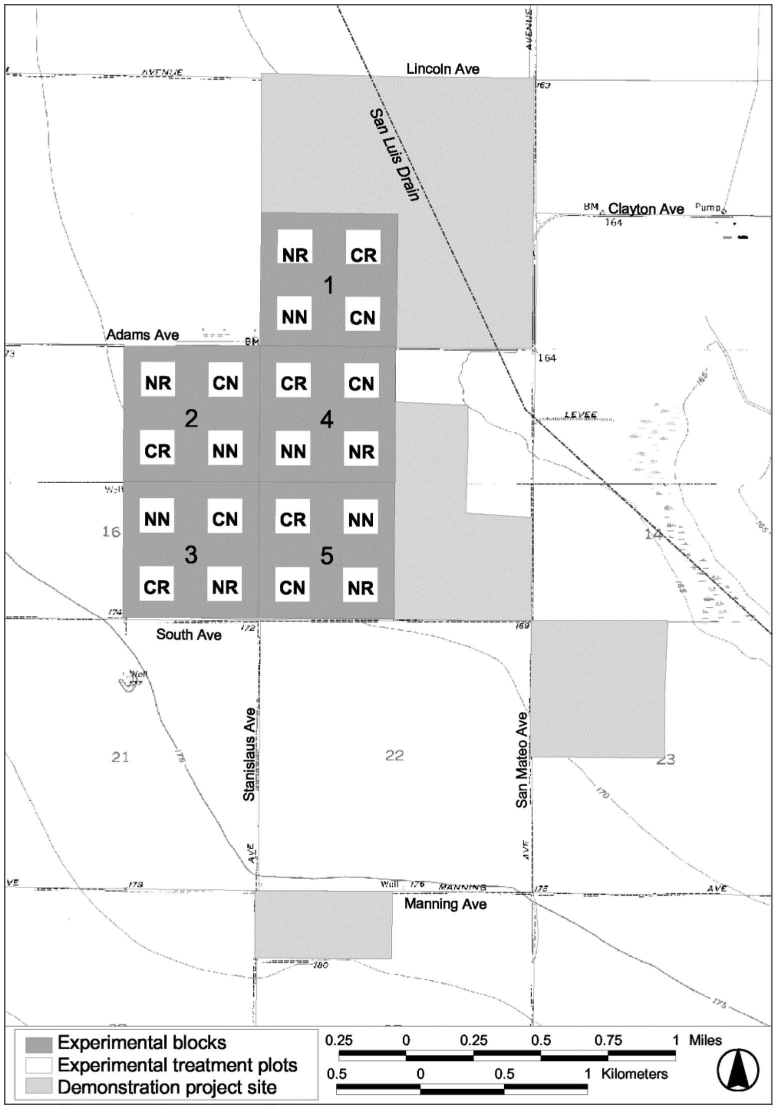

Figure 4. Map of the Tranquillity site showing the randomized block design and treatments applied to each study plot. CR = contoured and restored, NR = not contoured but restored, CN = contoured but not restored, NN = not contoured and not restored (control).

2. Biological Monitoring

Biological monitoring conducted on the Tranquillity HRS plots in the year 2001 consisted of:

- annual vegetation surveys (richness and composition)
- annual invertebrate surveys (sweep and pitfall)
- annual amphibian and reptile surveys

- quarterly avian surveys
- quarterly small mammal surveys

a. Vegetation Surveys

i. Methods

Vegetation surveys were conducted on the Tranquillity HRS plots in May, 2001 (3-4, 9 May). Twenty four vegetation samples (35 cm by 70 cm rectangular quadrats) were taken from each plot. A stratified random sampling approach was employed, with plots divided into sixth-sections and four sampling points randomly selected within each section. All species were noted, and the percent cover contributed by each species was estimated using a modified Daubenmire cover scale (Bonham 1989). Total percent cover of all vegetation within the quadrat was also estimated using the same cover scale. When identification to species level was not possible, species were assigned morpho-species names (e.g., "unknown *Atriplex*", "unknown with red cotyledons"). Plant productivity samples were not collected and will not be collected again until the last year of sampling, according to defined protocols.

Both digital and panoramic 35 mm photographs were taken on the experimental plots on (4 Sep, 21, 24 Dec 2001). Copies of the photos are archived at ESRP and USBR offices in Fresno and will be used to document temporal changes in plot vegetation.

Data were analyzed and presented differently in 2001 compared to 1999 and 2000. Accordingly, the information in this report supercedes those presented in previous annual reports (Selmon et al. 2000, Uptain et al. 2001). Descriptive statistics, Student's *t*-tests, and Analysis of Variance (ANOVA) were performed using the software package STATISTICA (StatSoft, Inc. 1999). 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 percent cover values) and were ordinated using Detrended Correspondence Analysis (DCA, Hill and Gauch 1980). Ordinations were conducted using the software package PC-Ord (McCune and Mefford 1997).

ii. Results

Twenty six species of vascular plants were observed on the Tranquillity HRS plots during vegetation sampling in 2001 (Appendix A, Table A1). In contrast, 21 species had been noted in the plots during 1999 sampling, and 31 species in 2000 (Appendix A, Table A1). Twelve of the species noted on the plots in 2000 were not noted in 2001; conversely, seven species noted during vegetation sampling in 2001 were not recorded for 2000 (Appendix A, Table A1). The sole species that was noted during vegetation sampling in 1999 and not noted in subsequent years was *Sonchus asper* (spiny sowthistle), an introduced species (Appendix A, Table A1). This species is easily confused with another common weed, *Sonchus oleraceus* (common sowthistle); hence, its omission in subsequent years most likely represents a sampling artifact.

Nine of the 26 species noted on the plots during 2001 vegetation sampling were native (Table 1). Six of these, *Bromus carinatus*, *Hemizonia pungens*, *Lasthenia californica, Leymus triticoides*, *Suaeda moquinii*, and *Vulpia microstachys*, were species that had been imprinted. Three of the seven species noted in 2001, which were not found in 2000, were native (*Amsinckia menziesii*, *H. pungens,* and *L. triticoides*; Table A1). However, none of these were noted in any great abundance, with *L. triticoides* present in seven quadrats, and *H. pungens* and *Amsinckia menziesii* each noted in a single quadrat (Appendix A, Table A2). In contrast, 8 of the 12 species that were noted in 2000 but not in 2001 were native (Table 1). Of these, two (*Frankenia salina* and *Isocoma acradenia*; Table 1) are species that were imprinted. At least one of these perceived absences (*Isocoma acradenia*) was clearly an artifact of sampling as mature individuals of this species, which is a fairly robust shrub, were noted on at least one plot later in the year (Fall, 2001).

Table 1. Seeded species and additional native species observed on the study plots at the Tranquillity HRS site. Species marked with an asterisk are those included in the seed mix.

Species	Common name	1999	2000	2001
*Allenrolfea occidentalis**	Iodine bush	-	-	-
Amsinckia menziesii	rancher's fireweed	-	-	+
Asclepias fascicularis	narrow-leaved milkweed	-	+[1]	-
Atriplex argentea	silver scale	+	+	+
*Atriplex polycarpa**	valley saltbush	-	-	-
*Atriplex spinifera**	spiny saltbush	-	-	-
*Bromus carinatus**	California brome	-	+	+
Eremalche parryi	Parry's mallow	+	+	-
*Frankenia salina**	alkali heath	-	+	-
*Heliotropium curassavicum**	heliotrope	-	-	-
*Hemizonia pungens**	common spikeweed	-	-	+
Hordeum depressum	alkali barley	+	+	-
*Isocoma acradenia**	goldenbush	-	+	-
*Lasthenia californica**	goldfields	-	+	+
*Leymus triticoides**	creeping wildrye	-	-	+
Malvella leprosa	Alkali mallow	-	+	-
Monolepis nuttalliana	Nuttall's povertyweed	-	+	-
Phacelia distans	common phacelia	+	+	+
Solanum americanum	common nightshade	-	+	-
*Sporobolus airoides**	alkali sacaton	-	-	-
*Suaeda moquinii**	bush seepweed	-	+	+
*Vulpia microstachys**	Nuttall's fescue	-	+	+

1. Species noted on the study plots but which did not occur in sampling quadrats.

By all measures, introduced (i.e., non-native) species were far more prevalent than native species in the Tranquillity HRS plots. When considered in terms of frequency (i.e., the number of samples in which a species was noted), introduced species were nearly 11 times more abundant than native species (Appendix A, Table A2). When considering only the imprinted plots (i.e., those plots that would be expected to have the largest component of native species), introduced species were still more than seven times as abundant as native species (Table 2). Nearly half of these were attributable to *Atriplex argentea*—a non-imprinted native of decidedly questionable value—thus, the number of desirable native species noted in the plots comprised about 8% of all species occurrences.

Table 2. Frequency of species noted in the imprinted plots during vegetation sampling, 2001. Species marked with an asterisk are those included in the seed mix.

Species	Origin	Plot[1]	Quadrat[2]
Atriplex argentea	Native	7	39
Avena fatua	Introduced	5	17
Beta vulgaris	Introduced	2	12
Brassica nigra	Introduced	6	39
*Bromus carinatus**	Native	2	2
Bromus diandrus	Introduced	2	2
Bromus madritensis	Introduced	4	47
Capsella bursa-pastoris	Introduced	6	49
Erodium cicutarium	Introduced	2	14
*Hemizonia pungens**	Native	1	1
Hordeum murinum	Introduced	5	48
Hordeum vulgare	Introduced	9	81
Lactuca serriola	Introduced	8	39
*Lasthenia californica**	Native	6	15
*Leymus triticoides**	Native	4	7
Melilotus indica	Introduced	6	46
Phacelia distans	Introduced	1	5
Phalaris sp.	Introduced	2	5
Salsola tragus	Introduced	2	7
Sisymbrium irio	Introduced	8	138
Sonchus oleraceus	Introduced	7	25
*Suaeda moquinii**	Native	2	2
*Vulpia microstachys**	Native	4	18
Summed quadrat frequency of introduced species:			**569**
Summed quadrat frequency of native species:			**89**

1. Frequency of plots in which a particular species was noted
2. Frequency of quadrats in which a particular species was noted.

When analyzed with respect to the contribution of the species classes to percent cover (Table 3; Table A3), the dominance of introduced species was more evident. Mean percent cover of imprinted species ranged from 0.00-1.73% (Table 3). In contrast, mean percent cover of introduced species ranged from 3.35-78.56%. In both cases, the lowest percent cover values were from the same plot (Plot 13). This plot was characterized by an abundance of last year's *Atriplex argentea* "skeletons" (the persistent stems and marcescent leaves). These stems tend to limit the germination of other species. This limiting effect of *A. argentea* on other plants can be clearly seen in Plot 13, in which 17 of the 24 quadrats were without living vegetation. Many of these samples were noted as having 50-95% of the quadrat area taken up by the dead *A. argentea* from the previous year. Generally, non-imprinted plots supported a higher percent cover of vegetation than did imprinted plots (Table 3). The differences in mean percent cover were found to be statistically significant, both between the non-seeded and imprinted treatments (ANOVA $F = 6.408$; $p = 0.034$) and among the five blocks ($F = 6.408$, $p = 0.008$).

Table 3. Overview of species grouped by origin at Tranquillity HRS. Values in the cell represent the estimated site-wide mean percent cover (calculated from the summed cover data divided by the total number of quadrats). Roman numerals indicate the block in which the plot was situated, followed by the number of the plot (in parentheses).

Origin	Contoured/Imprinted					Non-contoured/Imprinted				
	I (2)	**II (7)**	**III (11)**	**IV (13)**	**V (17)**	**I (1)**	**II (5)**	**III (12)**	**IV (16)**	**V (20)**
Imprinted	0.02	1.73	0.06	0.00	0.00	0.08	0.98	0.33	0.17	0.00
Native	1.71	0.00	18.90	0.15	0.02	1.54	0.00	3.23	6.29	0.00
Introduced	30.23	15.00	15.90	3.35	36.06	54.10	22.23	17.02	17.71	25.00
Cultivar	0.56	16.31	1.94	0.02	0.15	0.19	13.58	4.48	0.81	0.00
Not Identifiable	0.08	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.0
Total:	**32.60**	**33.04**	**36.79**	**3.52**	**36.23**	**55.94**	**36.79**	**25.06**	**24.98**	**25.00**
Origin	**Contoured/Non-Imprinted**					**Non-contoured/Non-Imprinted**				
	I (4)	**II (6)**	**III (10)**	**IV (14)**	**V (19)**	**I (3)**	**II (8)**	**III (9)**	**IV (15)**	**V (18)**
Imprinted	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Native	0.13	0.00	0.25	0.63	0.00	0.13	0.02	3.56	4.29	0.02
Introduced	60.21	20.63	15.77	22.35	67.73	78.56	24.40	38.88	15.17	54.25
Cultivar	0.19	6.46	6.19	0.15	0.00	0.56	17.60	1.31	0.15	0.00
Not Identifiable	0.13	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.13
Total:	**60.65**	**27.08**	**22.21**	**23.13**	**67.73**	**79.25**	**42.04**	**43.75**	**19.60**	**54.40**

The effects of variability throughout the study area (i.e., "block effect") can be clearly seen in the ordinations of the vegetation data (Figure 5). Plots situated in close proximity in ordination space possess stronger floristic similarities than those situated further apart. If treatment effects were predominant, it would be expected that plots with the same color would be grouped in ordination space (i.e., the two dimensional frame in which the data are plotted). In contrast, if block effects were predominant, it would be expected that plots with the same shape would be grouped. In the first year of vegetation sampling (Figure 5), the majority of the study plots were situated in close proximity. This was not unexpected as the study plots (which had not yet been imprinted) were dominated by barley. In subsequent years, the plots diverged substantially from their initial positions (Figure 5). The most evident pattern in the two years following imprinting is a tendency for plots within the same block to be closely situated in ordination space (Figure 5). Clearly, the orientation of the plots was influenced to a great degree by physical differences among the blocks. Another noteworthy pattern was the orientation of plots in blocks 1 and 5. These were grouped closely by block, with each group constituting one of the endpoints for Axis 1 (Figure 5). These spatial relationships suggest that blocks 1 and 5 were the most dissimilar, and that treatment effects were minimal in these two blocks relative to the effects of other factors (e.g., weed load).

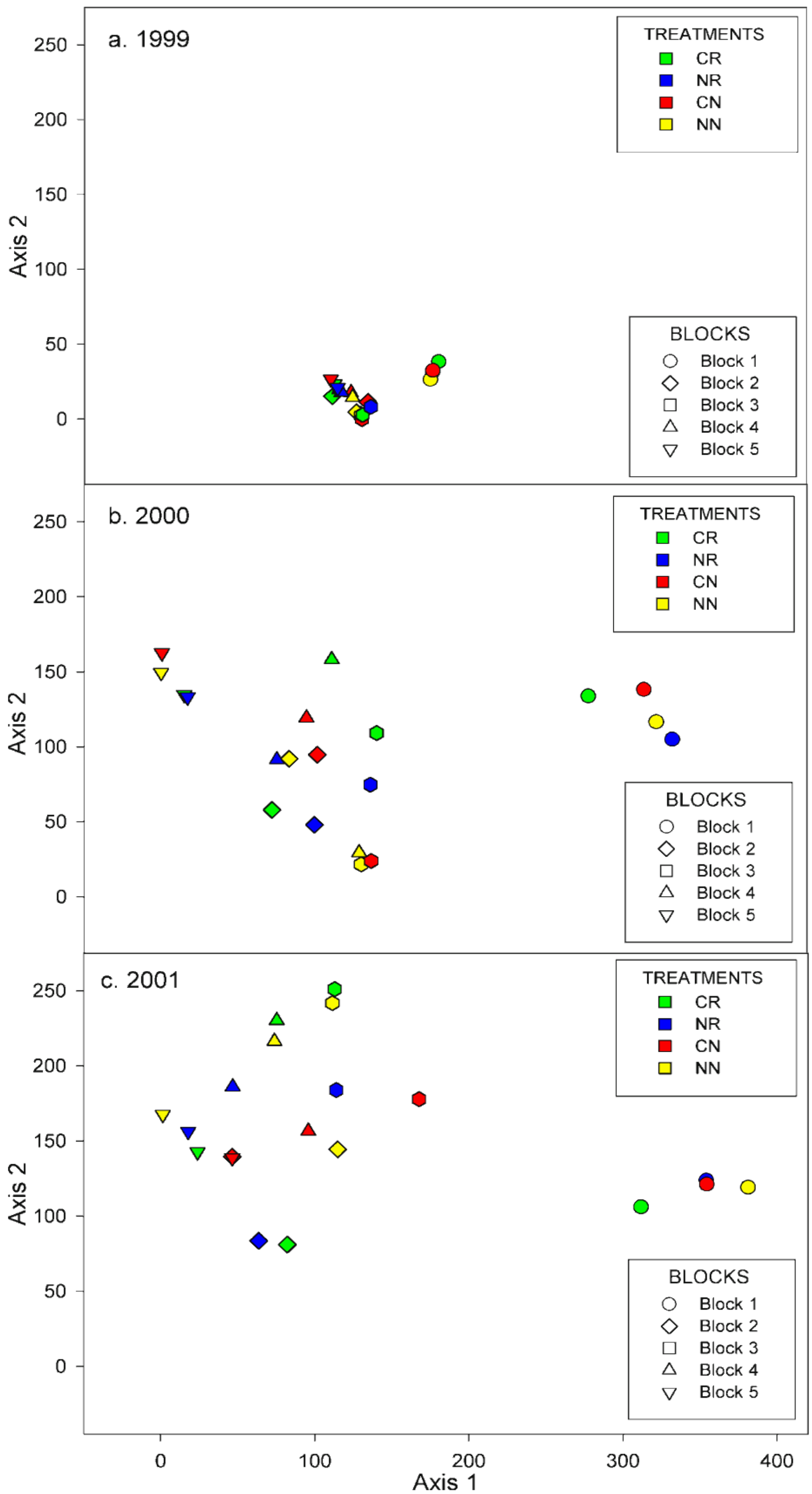

Figure 5. Ordinations by Detrended Correspondence Analysis (DCA) of the Tranquillity HRS plot vegetation. See text for interpretation.

Additional insight into the floristic structure of the study plots is obtained by graphing the relative abundance of species (i.e., their percent contribution to the total vegetation present) against their rank (e.g., most abundant, etc.). These "rank abundance graphs" were generated for the data from the 3 years of vegetation sampling (Appendix B, Figures B1-B5). These graphs can be interpreted by examining the position (i.e., the rank) of the various species and also by considering the slope of the plotted line. A steeper slope suggests dominance by a single species, or by a few species, while a more gradual slope suggests a tendency towards "evenness" (i.e., a more equitable contribution from a greater number of species). It is apparent from these graphs (Appendix B, Figures B1-B5) that in 2000 the seeded plots (i.e., treatments CR and NR) were both more diverse and tended towards greater evenness than the non-seeded plots (i.e., less likely to be dominated by a single species). Nevertheless, it is also apparent that in 2001 both diversity and evenness had diminished from the levels recorded for 2000.

The overall dominance of introduced species also is apparent in the rank abundance graphs (Figures Appendix B, Figures B1-B5). Only a single study plot in 2000 (Appendix B, Figure B4-a) and in 2001 (Appendix B, Figure B3-a) had a native species providing the greatest amount of cover. In both cases, the dominant species was *Atriplex argentea*, an ‘undesirable’ native.

As might be expected, many of the non-native species noted in the Tranquillity HRS plots were ruderals. Six of these were included in the CalEPPC list of Pest Plants of Greatest Ecological Concern (California Exotic Pest Plant Council, 1999; Table 4). Of these, three species, *Avena fatua*, *Bromus madritensis* subsp. *rubens* and *Brassica nigra*, could be described as frequent, with only *A. fatua* present in any real abundance (Appendix A, Table A1). Two species, *B. madritensis* and *Convolvulus arvensis* (Table 4), were listed as noxious weeds (Class "C") by the California Department of Food and Agriculture (2001).

Table 4. Known "pest plants" observed in the Tranquillity HRS plots. See key for an elaboration of their status as weeds.

Species	CalEPPC Status[1]	CDFA Status[2]	Frequency[3]			Cover[4]			Site cover[5]		
			1999	2000	2001	1999	2000	2001	1999	2000	2001
Avena fatua	a	-	2	4	83	3.00	1.75	15.72	<0.01	<0.01	2.72
Bassia hyssopifolia	b	-	-	-	1	-	-	0.5	-	-	<0.01
Brassica nigra	b	-	39	40	73	3.01	7.91	21.71	0.24	0.66	0.80
Bromus madritensis subsp. *rubens*	c	-	94	89	94	2.80	21.46	32.07	0.55	3.98	6.28
Convolvulus arvensis	d	c	2	1	-	0.50	0.50	-	<0.01	<0.01	-
Salsola tragus	e	c	-	-	13	-	-	13.96	-	-	0.38

1. California Exotic Pest Plant Council (CalEPPC) status: a. Preliminarily listed as an abundant and widespread grass that may pose significant threat; b. CalEPPC List B. Control required in nurseries, control elsewhere at the discretion of local County Agricultural Commissioner; c. CalEPPC List A-2. Documented as an aggressive invader in fewer than 3 Jepson Manual geographic subdivisions; d. Considered but not listed. Plants that, after review of status, do not appear to pose a significant threat to wildlands; e. Need more information. Plants for which current information does not adequately describe nature of threat to wildlands, distribution or invasiveness.
2. California Department of Food and Agriculture (CDFA) status: c. Weeds that are so widespread that the agency does not endorse state or county funded eradication or containment efforts except in nurseries or seed lots.
3. Frequency: the number of quadrats in which the taxon was noted (out of 480 quadrats sampled per year). Species with no values listed were those encountered during the Pre-project Inventory (2000) that were not observed in sampling quadrats during the Baseline survey (2001).
4. Estimated mean percent cover of the taxon calculated from only those quadrats in which the species was noted. Percent cover values were estimated from midpoints of the cover class (e.g., a species with an estimated cover of 5-25% was evaluated as having a cover of 15%).
5. Estimated site wide mean percent cover calculated from the summed cover data divided by the total number (384) of quadrats.

iii. Discussion

Of particular interest, 5 of the 13 species that were imprinted when the study plots were established (*Allenrolfea occidentalis*, *Atriplex polycarpa*, *Atriplex spinifera*, *Heliotropium curassavicum*, and *Sporobolus airoides*; Table 1), have not been noted during vegetation sampling. However, the absence of at least one of these species also was due to random sampling procedures, as numerous individuals of *Atriplex polycarpa* were in evidence on many of the imprinted plots. Sampling methodology will need to be refined for subsequent years, in order to reduce this type of error. Nevertheless, of the remaining four species no individuals were noted either in the quadrats or elsewhere on the plots. The poor performance of these species raises the question whether they should be utilized in future restoration efforts at the Tranquillity HRS site. Nevertheless, it should be noted that the absence of these species could also be explained by any number of factors–e.g., poor quality seed, insufficient rainfall, unsuitable soil conditions, etc.

The absence or paucity of a number of these species is puzzling. *Allenrolfea occidentalis* is a common and very conspicuous component of remnant areas of non-tilled ground in the general area of the study site. Yet, it has not been established in either the Tranquillity HRS study plots nor in the 160-acre restoration in Section 23 (see the Site-wide Activities section). Furthermore, two different seeding techniques were used for this species, with the seed imprinted in the study plots and hand broadcast following the imprinting of other species at Section 23 (see Uptain et al. 2000). As with other members of the Chenopodiaceae (Khan et al. 2002), *A. occidentalis* is generally more successfully established if some treatment is applied to help break dormancy (Gul and Weber 1997). Additionally, we have observed that, in natural habitats, *Atriplex* species seem to require the correct combination of circumstances to achieve germination. It may very well be that the dry conditions that have characterized the initial three years of the Habitat Restoration Study have been the principal factor limiting *Atriplex* establishment in the study plots.

The dearth of *Hemizonia pungens*, (i.e., noted in a single sample) is of particular interest. This species is extremely abundant in various remnant native habitat patches in the Tranquillity area, and germinates sufficiently early in the growing season to be capable of competing with the weeds at the HRS site. Additionally, an examination of historic records and existing relict vegetation in the San Joaquin Valley indicated that tarweeds (i.e., *Holocarpha* spp. and *Hemizonia* spp.) were dominant in low precipitation areas and on infertile soils (Holstein 2001). The absence of *Heliotropium curassavicum* is similarly confounding, as this species is very common in disturbed habitats (e.g., roadsides, edges of fields) throughout the general HRS area. Yet, despite the high degree of disturbance associated with soil preparation and imprinting, *H. curassavicum* has yet to be noted in any of the areas in which it has been imprinted. In both cases, the failure of these species to become established may well be attributable to their ecotype having originated from outside the San Joaquin Valley, but we lack sufficient information on seed sources to state this with certainty.

The general impression from the initial vegetation sampling of the imprinted study plots (i.e., 2000) was that the restoration efforts had been reasonably successful (Uptain et al. 2001). However, based on this year's sampling it appears that the success of the restoration may be ephemeral. Some species that appeared to be well-established in 2000 (e.g., *Bromus carinatus*, *Lasthenia californica* and *Vulpia microstachys*) diminished in both frequency and percent cover by the following year's sampling. Additionally, we had hoped that a portion of the seeds that had been imprinted but which did not germinate in 2000 would persist in the seed bank and germinate during the subsequent year (*sensu* Heady 1977). This does not seem to have been the case, as only two imprinted species—*Hemizonia pungens* and *Leymus triticoides*—were more abundant in 2001 than in 2000. However, in both instances, these species were rarely encountered (*H. pungens* in one quadrat; *L. triticoides* in seven quadrats); hence, it does not appear that there was any significant germination of seeds in the year following imprinting. Nevertheless, it should also be noted that both 2000 and 2001 were poor years for native plant production throughout the southern San Joaquin Valley (E. Cypher, pers. com.). Therefore, it may well be that viable seeds from imprinting remain in the seed bank, and that these will be able to become established if appropriate weather conditions occur in 2002.

We also observed in 2000 that some native species that hadn't been included in the seed mix (e.g., *Asclepias fascicularis*) had become established as volunteers on the study plots (Uptain et al. 2001). With the exception of the undesirable tumbleweed, *Atriplex* *argentea*, there was little evidence that non-imprinted native plant species were becoming established on the study plots in 2001.

b. Invertebrate Surveys

i. Methods

Pitfall sampling to determine invertebrate richness and abundance was conducted from 20-22 June, 2001. Invertebrates were collected from 20 pitfalls configured in 5 arrays on each of the 20 study plots. The methods used to collect pitfall samples are described in previous reports (Selmon et al. 2000, Uptain et al. 2001). Because there were some corrections made to the information contained in the invertebrate databases, the information in this report supercedes that which was presented in previous annual reports (Selmon et al. 2000, Uptain et al. 2001).

The vertical structure of the vegetation on many study plots has developed sufficiently to provide habitat for invertebrates. Pitfall sampling adequately samples ground-dwelling invertebrates, but it does not adequately sample invertebrates occupying this upper tier of vegetation. To rectify this, sweep sampling for invertebrates was added to the HRS sampling protocols in August 2000 to gather richness, abundance, and composition information for these invertebrates. Methods used to collect sweep samples were presented in Uptain et al. (2001). Sweep sampling was conducted on 30 April; 1, 7 and 30 May; 25 June; and 10-11 September 2001. Those data are currently being sorted, identified, and added to the database. Accordingly, the information presented below does not include results of the sweep sampling effort, but rather, richness, abundance, and composition is based solely upon invertebrate collections from pitfalls.

ii. Results

Invertebrate richness did not vary by treatment in any year, nor did richness vary among any given year across treatments (Figure 6). However, some trends are apparent. There was a trend of lower richness for all treatments 2000, in 1999 the non-contoured but restored plots (NR) had the highest richness, and in 2001 the control plots had the highest richness. Mean abundance of invertebrates did not vary by treatment, except in 2001 where the contoured but non-restored plots had the fewest invertebrates (Figure 7). For most treatments, there was a trend of increasing invertebrate abundance from 1999 to 2000, then decreasing abundance in 2001.

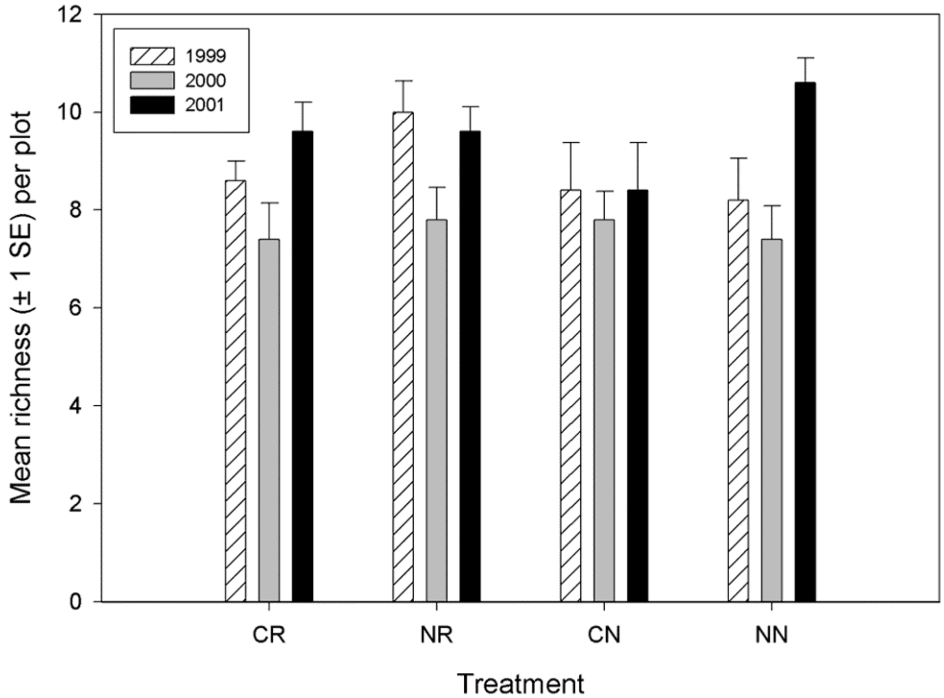

Figure 6. Invertebrate richness (generated from pitfall data) by treatment at the Tranquillity site.

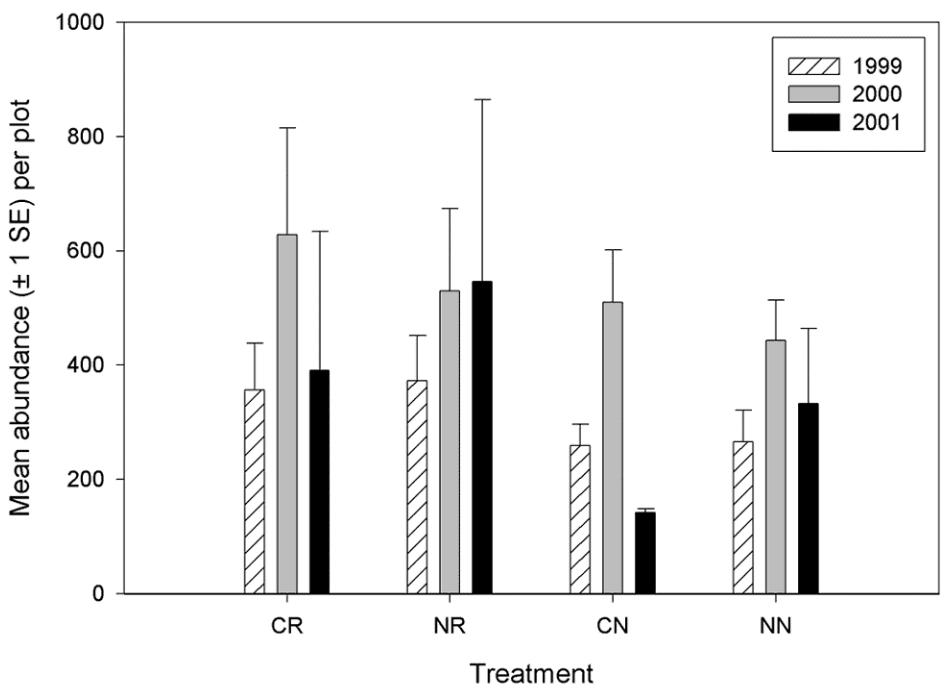

Figure 7. Invertebrate abundance (generated from pitfall data) by treatment at the Tranquillity site.

There were differences in invertebrate richness and abundance among the blocks (Figures 8 and 9). The most notable differences in richness were that block 1 had greater richness than any other block during all years and that block 3 had a relative low richness in 2000. Abundance among the blocks were most similar in 1999 and most variable in 2001, indicating that blocking effect is increasing. Furthermore, there is no defined pattern of blocking effect on abundance that is consistent through the years (i.e., certain blocks do not tend to remain higher or lower in abundance than other blocks from year to year). However, the total number of invertebrates collected over the 3-year period was less on blocks 1 and 5 than on the other three blocks.

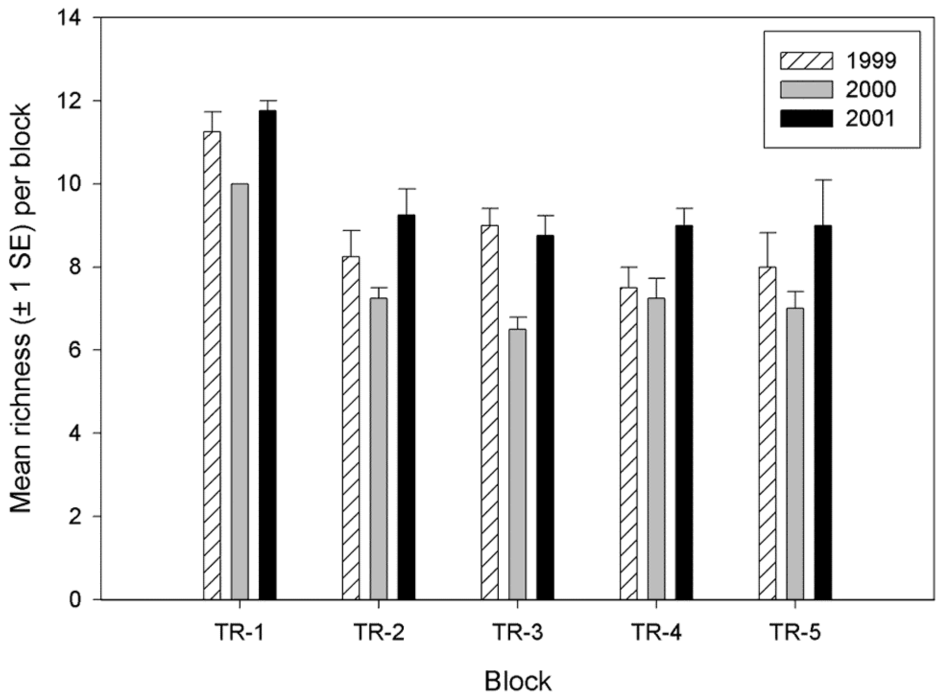

Figure 8. Invertebrate richness by block at the Tranquillity (TR) site.

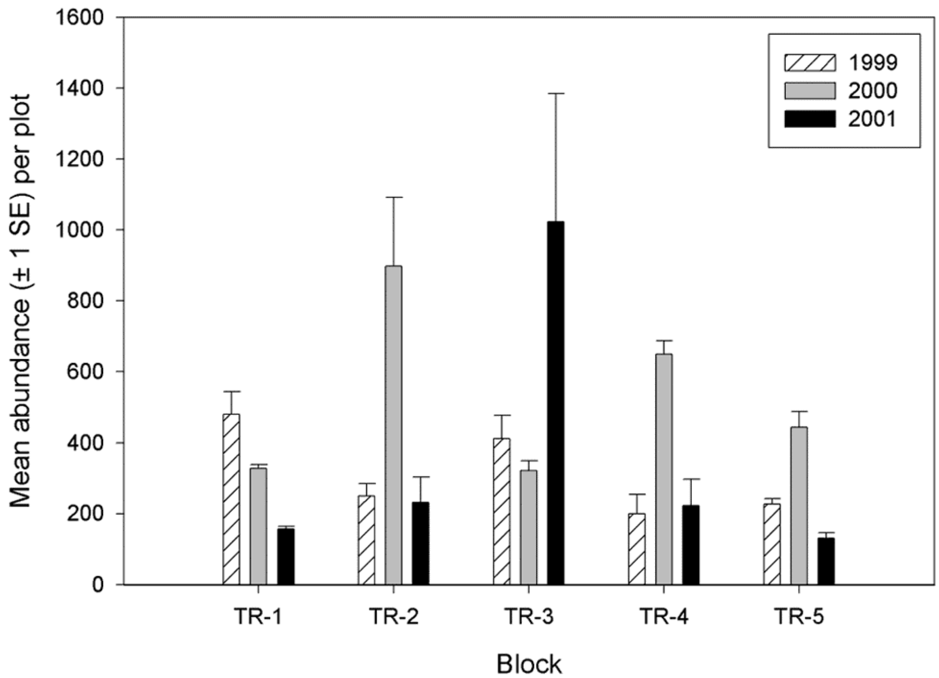

Figure 9. Invertebrate abundance by block at the Tranquillity (TR) site.

Invertebrate composition exhibited temporal changes (Table 5). Thysanoptera dominated the invertebrate population in 1999 whereas Hemiptera and, secondarily, Thysanoptera dominated in 2000. In 2001 Orthoptera was dominant. Although there were just a few orders that were dominant in each year, there was a trend towards increasing evenness from 1999 to 2001 (Table 5).

Table 5. Composition (abundance of each order divided by total abundance) of invertebrates collected in pitfall traps at the Tranquillity site, 1999 to 2001.

Order	1999 Composition	2000 Composition	2001 Composition
Araneae	12.02%	6.12%	15.87%
Coleoptera	11.63%	2.01%	7.42%
Dermaptera	6.56%	1.11%	0.50%
Hemiptera	1.25%	43.50%	1.26%
Homoptera	0.01%	0.00%	13.91%
Isopoda	0.88%	6.42%	8.66%
Orthoptera	2.81%	11.22%	43.04%
Thysanoptera	64.07%	25.75%	4.19%
Other	0.77%	3.87%	5.15%

iii. Discussion

We suspect that the decline in richness in 2000 was due to a rapid change in the weather as spring progressed. The spring of 2000 was long and cool, rapidly shifting to a hot summer. When the scheduled sampling was finally conducted, invertebrate richness had likely declined from earlier in the season. There was a trend toward increasing evenness in the invertebrate communities over the blocks, however. We are not surprised that there was an increase in blocking effect in 2000 and 2001 over that observed in 1999 because in 1999, all blocks were planted in barley and should have been relatively similar in vegetative structure. We expect, however, that as communities develop on the site over time that any remaining blocking effects will be due to edaphic differences among blocks.

c. Reptile and Amphibian Surveys

i. Methods

In previous years, reptiles and amphibians were only sampled in conjunction with the invertebrate pitfall sampling and by incidental observations. In 2001, we augmented this approach by walking 2 transects and monitoring 4 cover boards on each plot (Figure 10). These surveys were conducted on 11-13 July 2001; focused surveys for amphibians were scheduled for December 2001, but were cancelled due to poor weather conditions precluding access to the site.

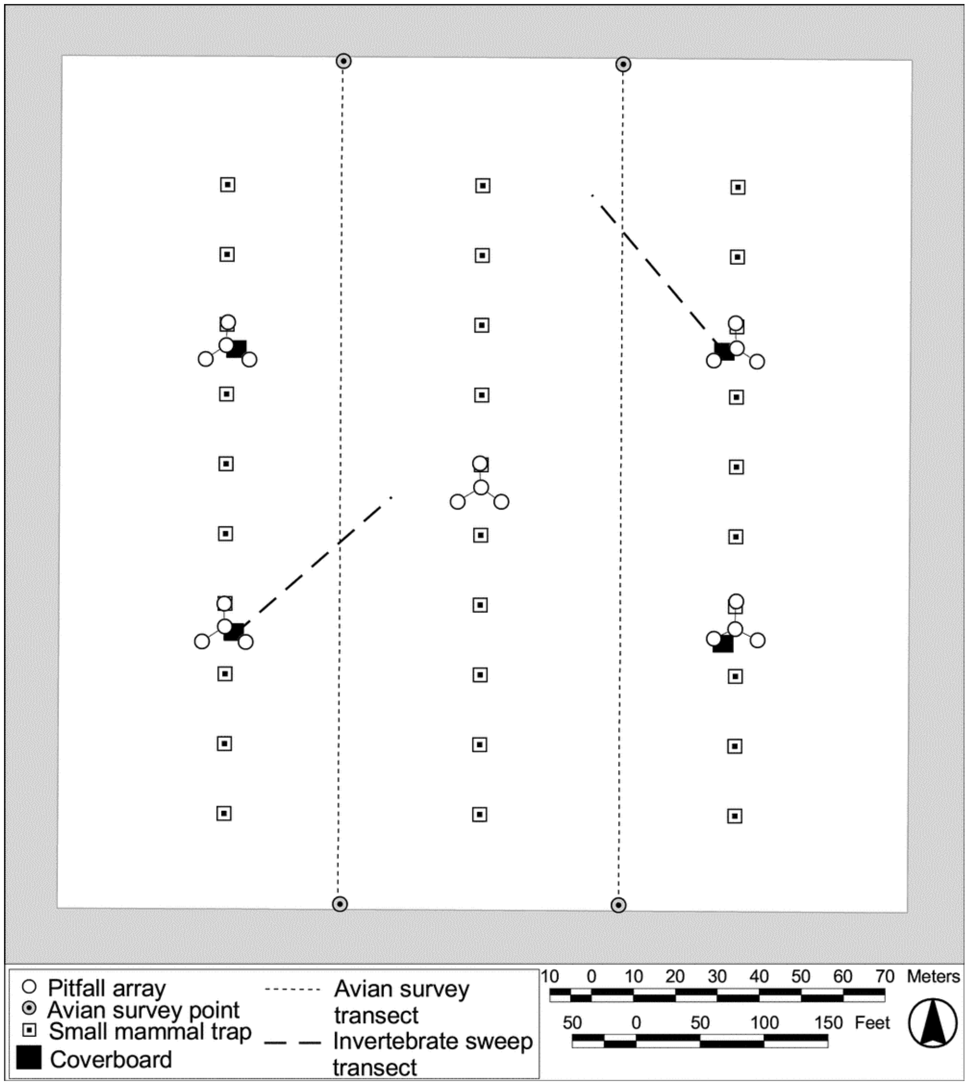

Figure 10. Locations of pitfall arrays, sweep transects, cover boards, avian transects, and small mammal trapping lines on Tranquillity HRS plot.

ii. Results

No reptiles or amphibians were found during the 3-day focused surveys, nor were any found in the pitfall arrays. There was one unconfirmed sighting of a western fence lizard (*Sceloporus occidentalis*) on Plot 7 and a confirmed sighting of a California king snake (*Lampropeltis getulus californiae*) on Plot 4. Both of these sightings occurred in April 2001. Numerous western toads (*Bufo boreas*) and 1 California king snake were observed off of the research blocks while conducting site-wide surveys (see section III A 2).

iii. Discussion

For a variety of reasons it is not surprising that amphibians and reptiles still are absent from the research plots. Some of these are:

- after two years, the study plots contain habitat that is minimally suitable for reptiles and amphibians
- the study plots are isolated by large buffer areas of barley, making access to the plots by reptiles and amphibians from surrounding areas problematic
- the small size of the study plots relative to the habitat needs of some reptiles and amphibians may limit the number of species able to colonize the study plots
- there is little remaining habitat for reptiles and amphibians in the vicinity of the study plots, which presumably has resulted in depressed populations throughout the area

The most common amphibian in the vicinity is the western toad. This species would seem be the most likely candidate to colonize the study plots. However, with the reduction in irrigation water and the lack of moisture, the plots are minimally suitable for this species. Accordingly, we do not expect to record a high abundance of western toads on the study plots.

d. Avian Surveys

i. Methods

Bird surveys were conducted on each plot on a quarterly basis to determine seasonal avian richness, abundance, and composition. Sampling was conducted on 17-19 January, 18-20 April, 18-20 July, and 2-4 October 2001. Methods used for sampling follow those presented in previous reports (Selmon et al. 2000, Uptain et al. 2001).

ii. Results

A total of 28 species was observed on the study plots in 2001. Avian species richness ranged from 1.0 to 6.4 and mean abundance of individuals ranged from 0.13 to 154.3 in 2001. Both richness and abundance showed high variation by season with high values for both categories occurring in the winter (Figures 10 and 11). No differences were detected between treatments for either species richness or mean abundance in 2001.

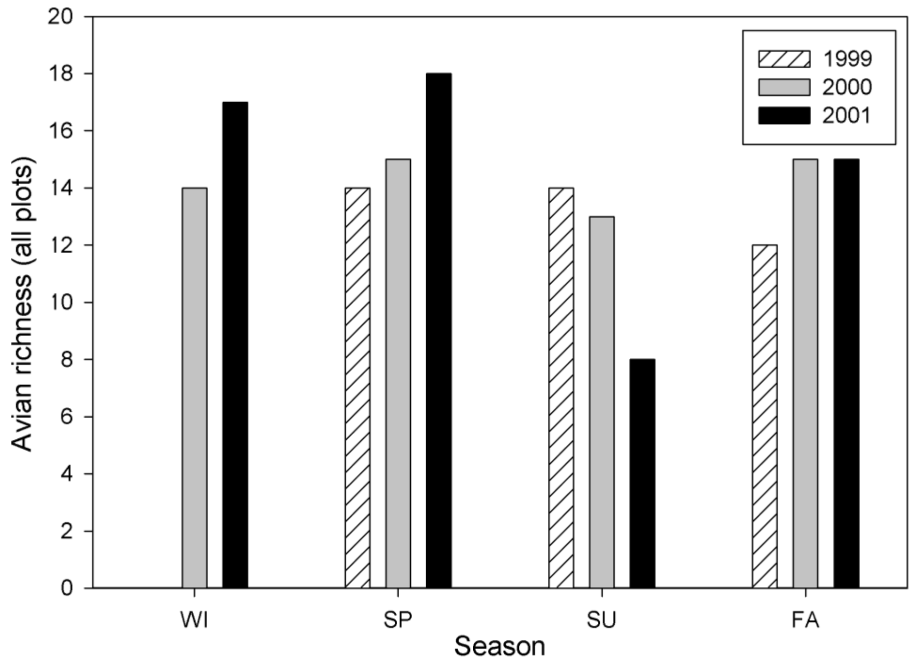

Figure 11. Avian richness by season at the Tranquillity site.

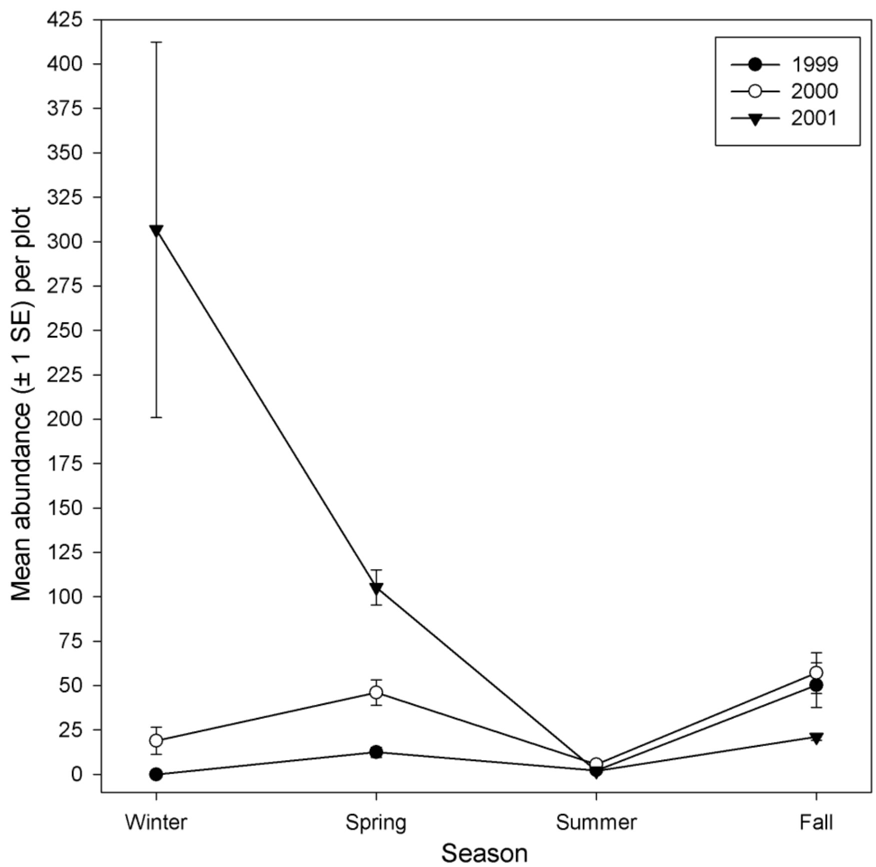

Figure 12. Avian abundance by season at the Tranquillity site.

Mean abundance and species richness also were examined across years. Mean abundance consistently increased across treatments from 1999 to 2001 in the spring, and from 2000 to 2001 in the winter. This was concomitant with an increase in species richness for the same time period. The mean total abundance was consistently lower across treatments in the fall of 2001 than in the previous 2 years.

Six species of special concern in California (CSC) or federal special concern species (FSC) were observed on the study plots. Short-eared owls (*Asio flammeus*) (CSC) showed a dramatic increase in abundance in 2001. Only a few individuals had been reported in the previous 2 years, but in 2001 this species ranked within the top five most abundant birds for the summer season (Table 6). This species was breeding on one of the control plots, where it was most frequently observed. However, short-eared owls also were observed on plots with all other treatments. Burrowing owls (*Athene cunicularia*) (FSC, CSC) were not observed on any plots in 1999 or 2000, but one individual was observed occupying a burrow on a control plot in 2001. Northern harriers (*Circus cyaneus*) (CSC) also showed an increasing population trend and were confirmed to be breeding on the plots. One species of special concern, the horned lark (*Eremophila alpestris*) appears to have declined on the study plots since 1999.

Table 6. Avian relative abundance and ranked species composition on the Tranquillity site study plots, 1999 to 2001.

Winter 1999			Winter 2000			Winter 2001		
Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]
			BRBL	50.80	1	SAVS	49.80	1
			SAVS	9.63	2	BRBL	19.65	2
	N/A		MOPL	8.02	3	WEME	17.41	3
			LBCU	6.95	4	RWBL	3.62	4
			AMKE	5.88	5	WCSP	2.82	5
Spring 1999			**Spring 2000**			**Spring 2001**		
Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]
RWBL	54.58	1	RWBL	77.59	1	RWBL	77.34	1
BRBL	18.33	2	BRBL	10.82	2	SAVS	9.27	2
YHBL	8.33	3	WEME	6.73	3	WCSP	3.92	3
WEME	6.67	4	MALL	0.99	4	SOSP	3.59	4
MALL	3.33	5	CLSW	0.66	5	WEME	2.06	5
			NOHA	0.66	5			
			RNPH	0.66	5			
			SAVS	0.66	5			
Summer 1999			**Summer 2000**			**Summer 20001**		
Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]
AMKE	21.74	1	WEME	57.94	1	WEME	25.64	1
WHIM	17.39	2	RWBL	19.63	2	BARS	17.95	2
WEME	15.22	3	WTKI	3.74	3	NOHA	17.95	2
CORA	8.70	4	AMKE	2.80	4	WTKI	15.38	3
NOHA	8.70	4	BAOW	2.80	4	LOSH	7.69	4
LOSH	6.52	5	BARS	2.80	4	SEOW	7.69	4
			WEKI	2.80	4	WEKI	5.13	5
			CORA	1.87	5			
			SOSP	1.87	5			
Fall 1999			**Fall 2000**			**Fall 2001**		
Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]	Species[1]	R.A.[2]	Rank[3]
AMPI	24.71	1	SAVS	64.68	1	SAVS	46.01	1
WEME	22.46	2	WEME	21.11	2	WEME	42.02	2
SAVS	19.25	3	RWBL	3.13	3	SOSP	2.66	3
BRBL	13.37	4	WTKI	2.51	4	HOLA	1.60	4
HOLA	11.66	5	BRBL	2.30	5	WCSP	1.60	4
						BRBL	1.33	5

1. Key to avian codes: AMKE , American Kestrel; AMPI, American Pipit ;BAOW, Barn Owl; BARS, Barn Swallow; BRBL, Brewer's Blackbird; CORA, Common Raven; HOLA, Horned Lark; LOSH, Loggerhead Shrike; NOHA, Northern Harrier; RWBL, Red-winged Blackbird; SAVS, Savannah Sparrow; SEOW, Short-eared Owl; SOSP, Song Sparrow; WCSP, White-crowned Sparrow ;WEKI, Western Kingbird; WEME, Western Meadowlark; WHIM, Whimbrel; WTKI, White-tailed Kite.
2. Relative abundance (R.A.) is the percent contribution of a single species to total abundance for all study plots.
3. Rank is sorted in ascending order (most to least abundant) with only the five highest ranked species listed.

iii. Discussion

The majority of the avian species (59%) recorded on the study plots are considered to be grassland specialists (Appendix B). Grassland specialists are separated into two categories: obligate grassland specialists, which are exclusively adapted to and entirely dependent on grassland habitats, and facultative grassland specialists, which are not entirely dependent on grasslands but use them commonly (Vickery et al. 1999). Nine avian species on the study plots are categorized as obligate grassland specialists and 13 as facultative grassland specialists. The development of a more complex plant community on LRDP lands has been accompanied by changes in the avian community dynamics. Many of the grassland specialists have increased in numbers following the cessation of cultivation and the establishment of permanent herbaceous cover.

Species composition shifted seasonally (Figure 13). Blackbirds (Brewer's and red-winged blackbirds)(*Euphagus cyanocephalus, Agelaius phoeniceus*) predominated in winter and spring, western meadowlarks (*Sturnella neglecta*) generally predominated in summer, and savannah sparrows (*Passerculus sandwichensis*) and western meadowlarks predominated in the fall. Large mixed-species flocks of 500 or more blackbirds were frequently seen in the barley and on the plots during the winter 2001 census. Flocks of this magnitude were not observed in 1999 and only occasionally during 2000. These mixed flocks were generalized as "blackbirds" because of the large numbers and an inability to reliably distinguish composition. Accordingly, they were not included in the rank abundance table (Table 6) or in the seasonal relative abundance figure (Figure 13). Although not shown graphically or in tabular form, Brewer's and red-winged blackbirds increased exponentially in abundance in 2001. It is likely that the increase of these facultative grassland specialists is a result of the barley cover crop that is maintained in the buffers and the lack of cultivation on the study plots. Savannah sparrows and western meadowlarks, two obligate grassland specialists, showed a similar response to changes in vegetative cover. Both have been more prevalent on the study plots since 1999.

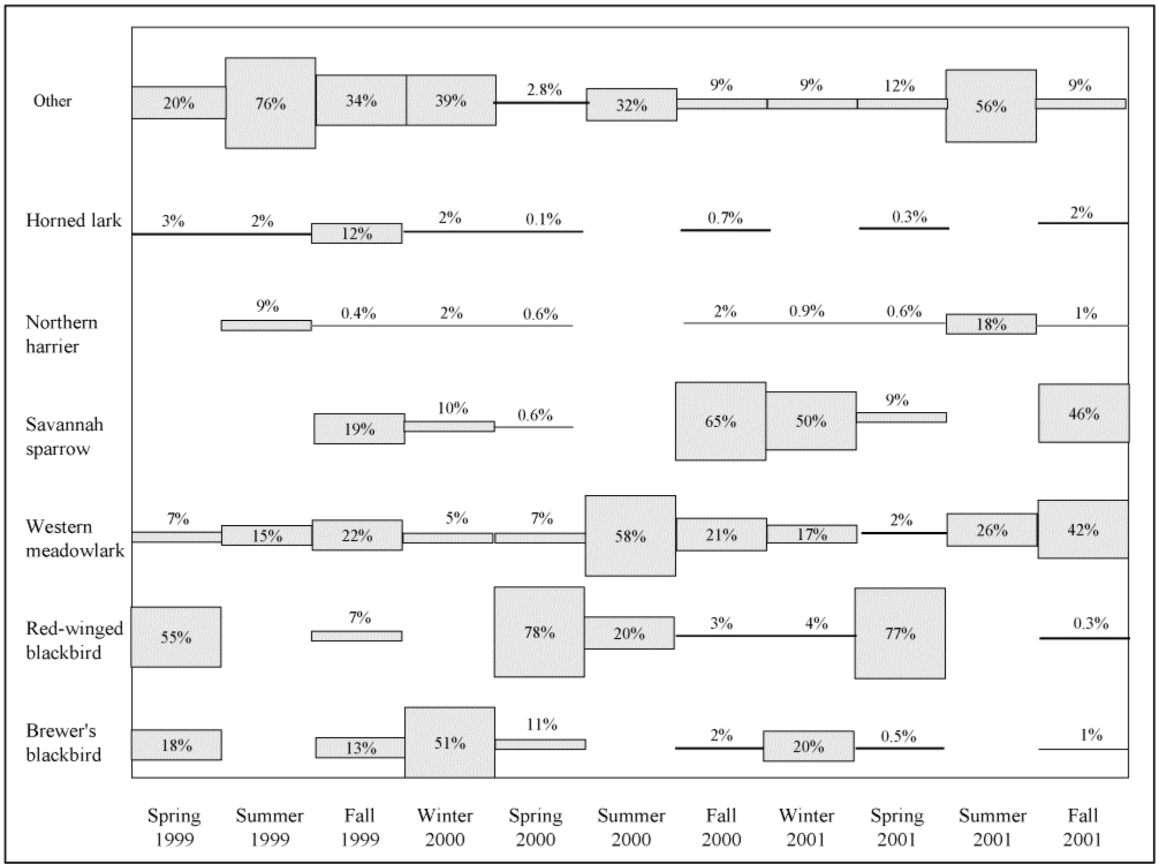

Figure 13. Seasonal relative abundance of selected avian species at the Tranquillity site.

Only two grassland specialists appear to have decreased in abundance on the study plots. Horned larks and American pipits (*Anthus rubescens*) were both present in relatively high numbers in 1999, but have since declined. Horned larks and American pipits prefer open areas with short vegetation or bare ground for both breeding and wintering habitats (Beason 1995, Kauffman 1996). The dense tall cover of London rocket (*Sisymbrium irio*) and barley (*Hordeum vulgare*) probably made most of the study plots unsuitable for both of these species. Nevertheless, they are still frequently recorded in the cultivated buffer region surrounding the plots.

Relative abundance values for the spring season of 2001 were consistently higher across all treatments than for either of the two previous spring seasons. In contrast, relative abundance for the fall season of 2001 was consistently lower across all treatments than for the previous two fall seasons. This disparity may be the result of annual fluctuations in the timing of migration. Decreasing day length along with weather conditions stimulates fall migration departures (Gill 1995). It seems likely that the 2001 fall census may have occurred in the transitional period subsequent to the departure of the fall migrants, but prior to the arrival of the wintering species.

e. Small Mammal Surveys

i. Methods

Small mammal trapping was conducted on each plot on a quarterly basis to determine seasonal richness and abundance of species. Trapping was conducted on 27 February-2 March; 30 April-3 May; 6-9 August; and, 5-8 November, 2001. Sherman live-traps were used for and trapping methods followed those presented in previous reports (Selmon et al. 2000, Uptain et al. 2001). Additionally, small mammals (especially shrews) were sampled using the pitfall traps established for sampling invertebrates.

ii. Results

During nocturnal live-trapping in 2001, a total of 2,362 small mammals were captured on the experimental plots. A total of 2,314 deer mice (*Peromyscus maniculatus*), 46 house mice (*Mus musculus*), one western harvest mouse (*Reithrodontomys megalotis*), and one California vole (*Microtus californicus*) were captured.

A trend of increasing small mammal abundance across all years during each sampling season (Figure 14) was observed. This was especially apparent in the number of captures of deer mice. As winter data were collected only in 2001, it is not yet possible to discuss trends for this season.

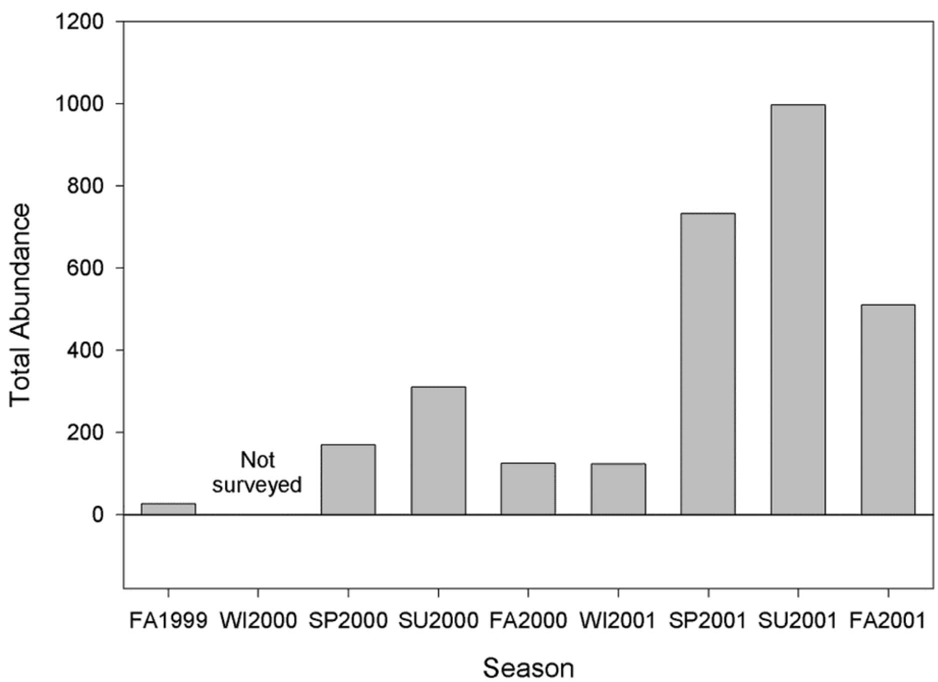

Figure 14. Abundance of small mammals by season at the Tranquillity site.

Plots receiving treatments generally had greater numbers of small mammals than did the control plots (Figure 15). During most seasons, small mammal abundance tended to be greater on the contoured and restored plots (CR) than on the plots that only received contouring (CN). This holds true for all seasons and years except fall of 1999 (which preceded treatment installation) and fall of 2000. Because deer mice comprised approximately 98% of all captures of small mammals, these trends essentially were only representative of the deer mouse population. The type of treatment appeared to have no effect on house mice abundance. House mice were captured only on the control plots in every season, and their abundance did not seem to be correlated with treatment. The one western harvest mouse was captured on a plot that was seeded with native plants, and the only vole was captured in a plot treated with contouring.

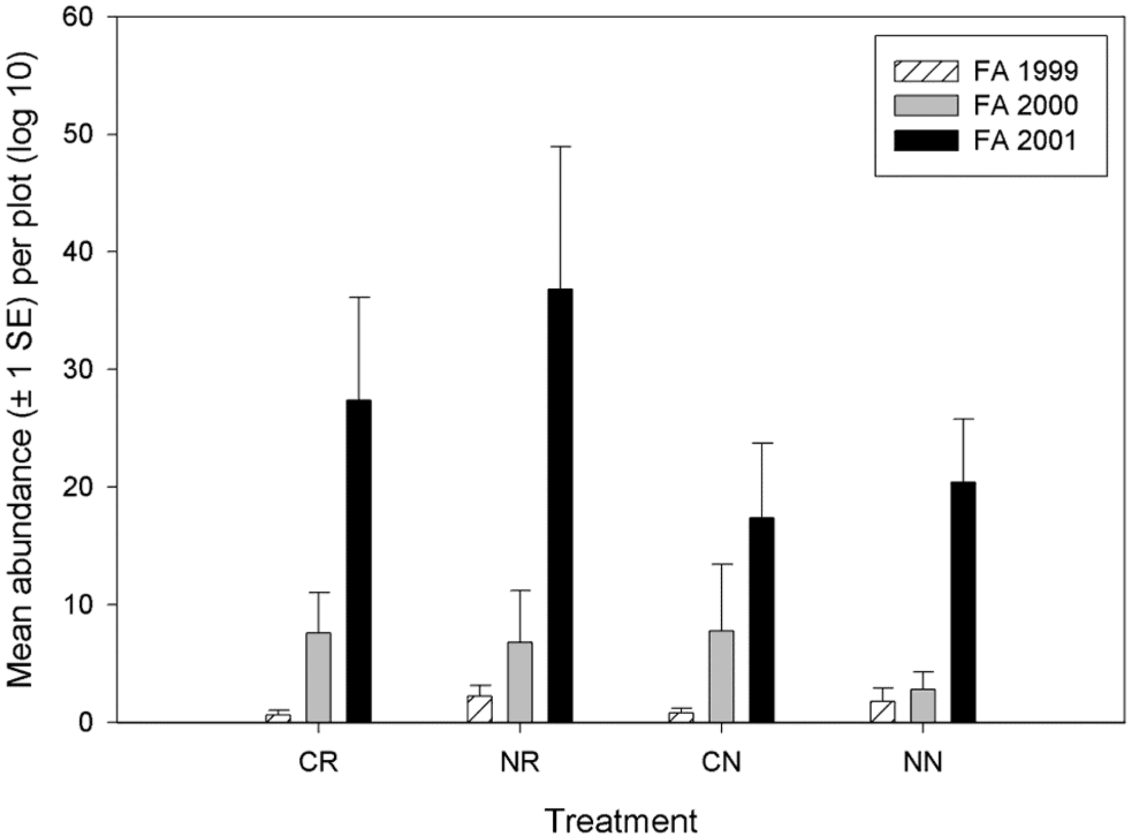

Figure 15. Abundance of small mammals by treatment at the Tranquillity site.

Small mammal abundance varied by block, especially in 1999 and 2000. In 2001, block effects diminished, with the exception of Block 1, which had consistently low numbers of small mammal throughout all years (Figure 16).

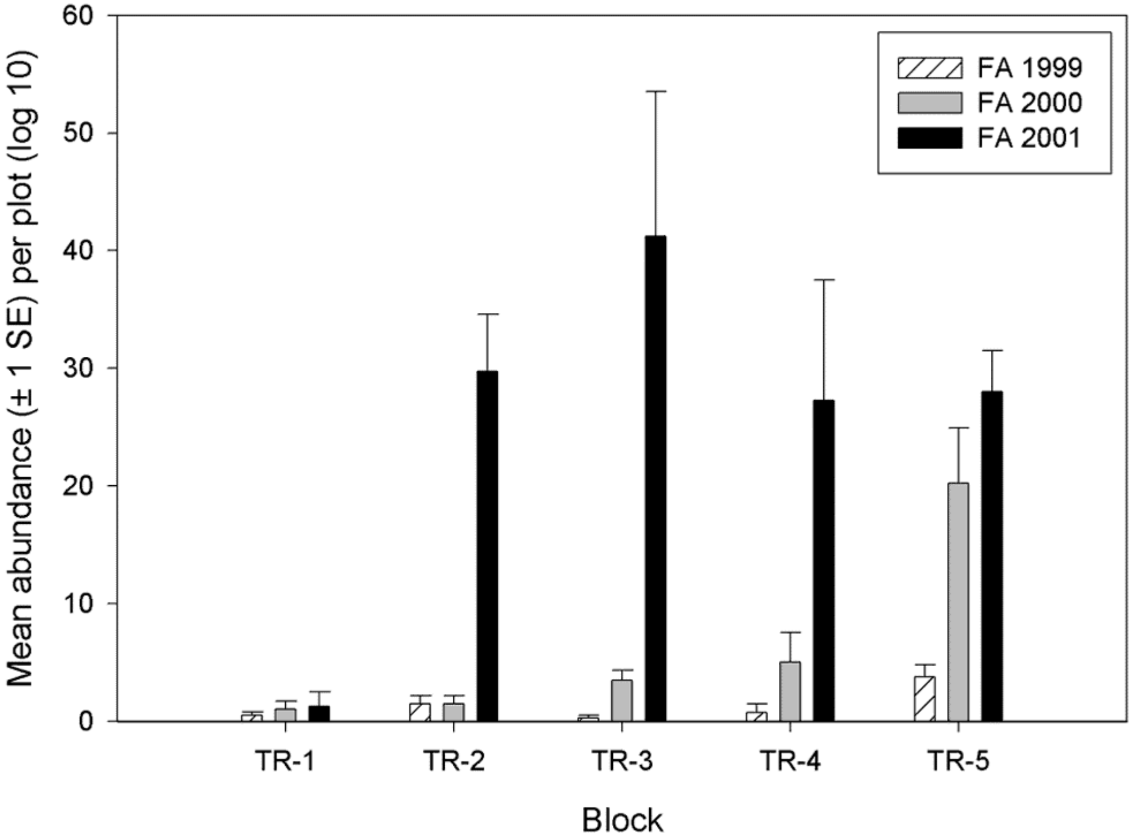

Figure 16. Abundance of small mammals by block at the Tranquillity site.

All of the ornate shrews (*Sorex ornatus*) and most of the voles (*Microtus californicus*) were captured in pitfall traps. A total of 25 shrews and 37 voles were captured in 2001 (Table 7). Most of the shrews (88%) were captured on plots that were seeded with native plants. That trend also held true for shrews captured in 2000, when 67% of shrews were captured on seeded plots (Table 7), but the trend did not hold true for 1999 (prior to the treatments being established). By contrast, 62% of the voles that were captured in 2001 were captured on contoured plots and 38% of the voles were captured from seeded plots. In 1999 and 2000, vole captures were not numerous enough for an evaluation of treatment effects.

Table 7. Shrews and voles captured in pitfall traps on the Tranquillity site study plots, 1999 to 2001.

Year	Species	Common name	Plot treatment [1]	Number captured
1999	*Sorex ornatus*	Ornate shrew	CR	1
			CN	10
			NR	2
			NN	1
	Microtus californicus	California vole	CR	1
			CN	1
			NR	1
			NN	0
2000	*Sorex ornatus*	Ornate shrew	CR	7
			CN	3
			NR	5
			NN	3
	Microtus californicus	California vole	CR	0
			CN	0
			NR	0
			NN	0
2001	*Sorex ornatus*	Ornate shrew	CR	11
			CN	0
			NR	11
			NN	3
	Microtus californicus	California vole	CR	4
			CN	19
			NR	10
			NN	4

1. Key to plot treatments: CR, contoured and restored plots; CN, contoured and non-restored plots; NR, not contoured and restored plots; NN, not contoured and not restored plots

iii. Discussion

Deer mice are a pioneering species (Zeiner et al. 1990), i.e., a species that occurs in relatively high numbers in the early seral stages of secondary succession. Hence, it is not surprising that their numbers have increased dramatically on the study plots. Typically, deer mice may have home ranges of up to 10 acres (Stickel 1968), but based upon the abundance encountered, home ranges are probably much smaller on the Tranquillity HRS study plots. The high density of deer mice probably can be attributed to an abundant food supply on the plots as well as in adjacent buffers and a lack of periodic disturbance. As the plant community develops on the sites we would expect the deer mouse population to decline and other species such as harvest mice, shrews, voles, and kangaroo rats to become more abundant. As fossorial species (especially gophers, kangaroo rats, and ground squirrels) become established, additional niches would be created and would become available for a wide variety of vertebrate and invertebrate species.

It is not surprising that all captures of shrews were in pitfalls. The bait used in live-traps generally does not attract shrews, whereas invertebrates in the pitfalls provide auditory and olfactory cues for shrews (Churchfield 1990) and an attractive food source. Although the captures in pitfalls provide an index of abundance of shrews on the study plots, a mark-recapture study could provide statistical estimates of abundance and density, assuming sufficient numbers of shrews and multiple captures of the same individuals. Nevertheless the increase in the abundance of shrews on the plots and the seeming tendency of shrews to prefer plots that were seeded with native vegetation are important observations, another observation may prove to be as important. Shrews were relatively abundant on the plots in 1999 prior to treatment installation. This indicates that shrews may have been present on the site during years of agricultural production prior to the HRS study. If this is the case, then ornate shrews may be more abundant and widespread in the San Joaquin Valley than was previously thought.

That voles also were captured more frequently in pitfalls than in live-traps is not surprising. Increases in vole abundance also were observed, especially in 2001, and affinities for certain plot treatments were noted (see Table 7). The most voles were found on plots that were contoured but not restored by seeding with native plants.

The first capture of a western harvest mouse was in 2001. That capture was on a plot that was seeded with native vegetation. This was not surprising given the affinity of the western harvest mouse to feed on native vegetation (Ingles 1947). We expect western harvest mice to become more abundant on the plots as the land is left undisturbed. The value of undisturbed lands to all small mammal populations is apparent from our data.

B. Atwell Island

1. Study Design

The study design for the Habitat Restoration Study at Atwell Island is similar to that at Tranquillity, but differs in some important aspects. At Atwell Island there are 3 replicated blocks, each containing 16 experimental plots (Figure 17). A representation of the configuration of a study block is shown in Figure 18. The plots are 2 acres in size, each nested within a 10-acre parcel. As with Tranquillity, the areas between plots are maintained with a barley cover crop to isolate the plots. Four treatments were applied to the plots in winter 2001: seeding with native plants and contouring, seeding with native plants only, contouring only, and no treatment. The treatments were randomized within blocks of four plots configured in a 2 by 2 grid.

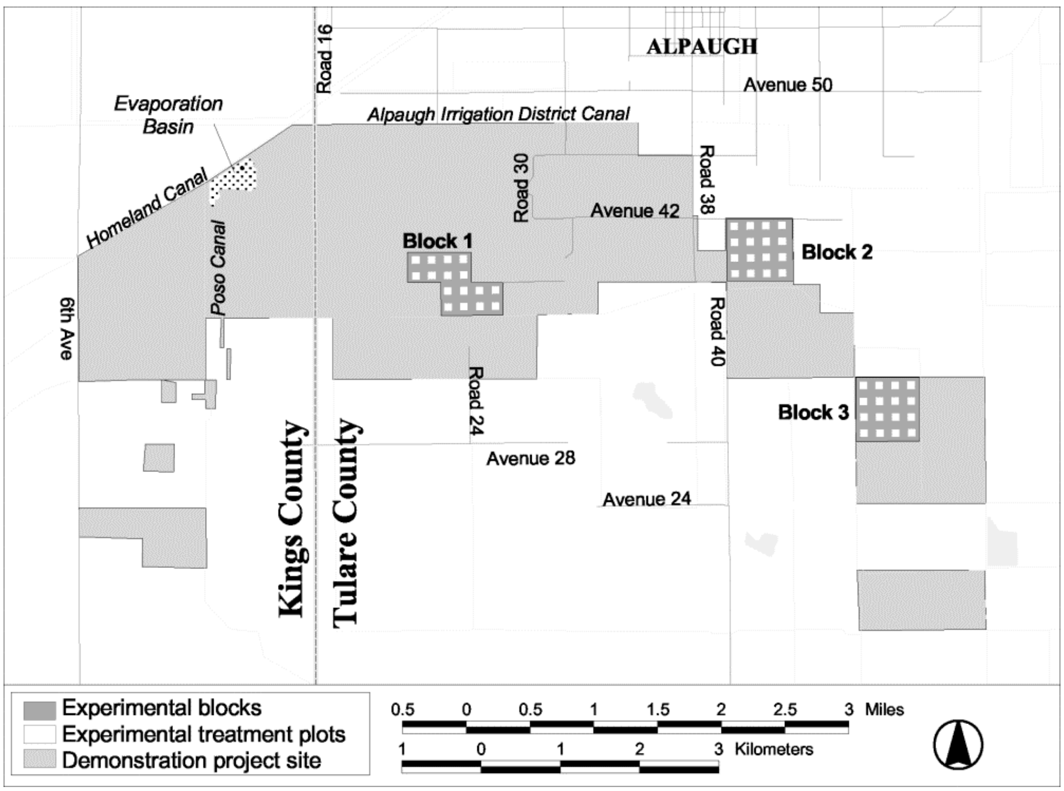

Figure 17. Map of the Atwell Island site showing the randomized block design.

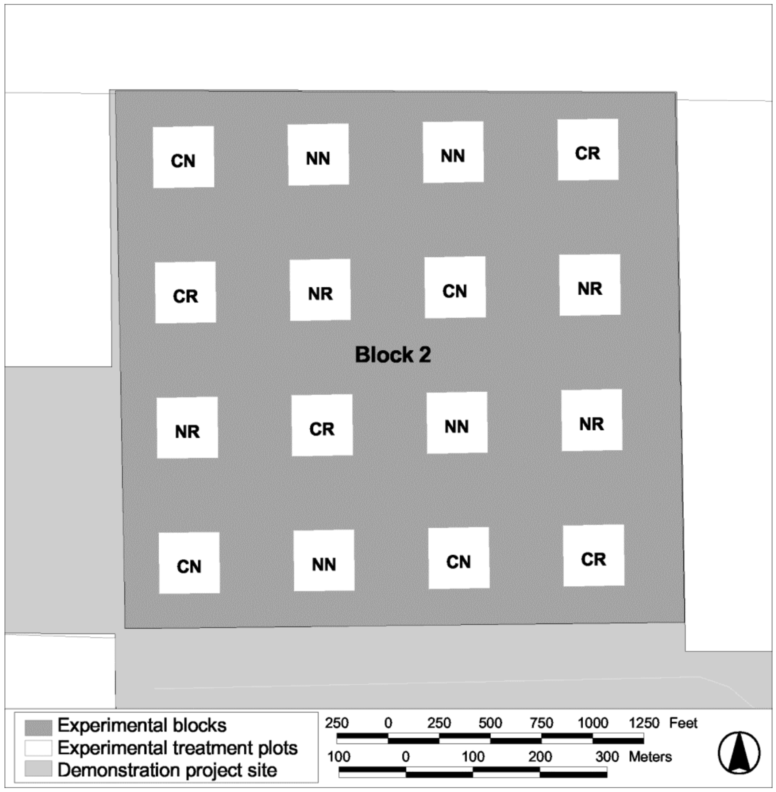

Figure 18. Map of an experimental block at the Atwell Island site showing the placement of treatments plots.

Microtopographic contours (berms) were installed on 4-6 December (Block 1), 7-9 December (Block 2), and 10-12 December (Block 3). Contours are of the same general size and shape as those that were installed on the plots at the Tranquillity HRS site. However, there are fewer contours on plots at Atwell Island (49 contours per plot) than there are on plots at Tranquillity site (240 contours per plot) because of the much smaller plot size. Native plant seeding at Atwell Island was conducted on 27 December (Block 1), 18-19 December (Block 2), and 19 December (Block 3). Seeding was accomplished using an imprinter; the seed mix and seeding rate were identical to that used on the Tranquillity HRS site (see Selmon et al. 2000 and Uptain et al. 2001). However, the locations where seeds were collected differed somewhat between the two sites and in neither trial were seeding rates standardized for germination and purity. Because of the low success rate and high cost of planting seedlings on the Tranquillity HRS plots, no seedlings were planted on the Atwell Island plots.

2. Biological Monitoring

Baseline biological surveys was conducted on the Atwell Island HRS plots in 2001 prior to treatment application and while the barley cover crop was still in place. Surveys consisted of:

- vegetation surveys (composition and cover)
- invertebrate surveys (sweep and pitfall)

- amphibian and reptile surveys
- avian surveys
- small mammal surveys

HRS survey methods, results and discussions are presented in the following sections. No temporal comparisons can be made at this time because only baseline data have been gathered. Results of the site-wide survey efforts are presented in the Site-Wide Activities section.

a. Vegetation Surveys

i. Methods

In April 2000, a pre-project inventory was undertaken on the Atwell Island property. Based on recent land use patterns (Uptain et al., 2001), three distinct areas were identified at the site (Figure 19). Lists of all observed vascular plant species were compiled for each area (Appendix A, Table A4). Subsequently, two of the three HRS study blocks were positioned on areas that had been surveyed (blocks 2 and 3; Figure 19). The area on which the third HRS study block (Block 1; Figure 19) was established was previously in agricultural production. As such, the area did not support a significant native flora.

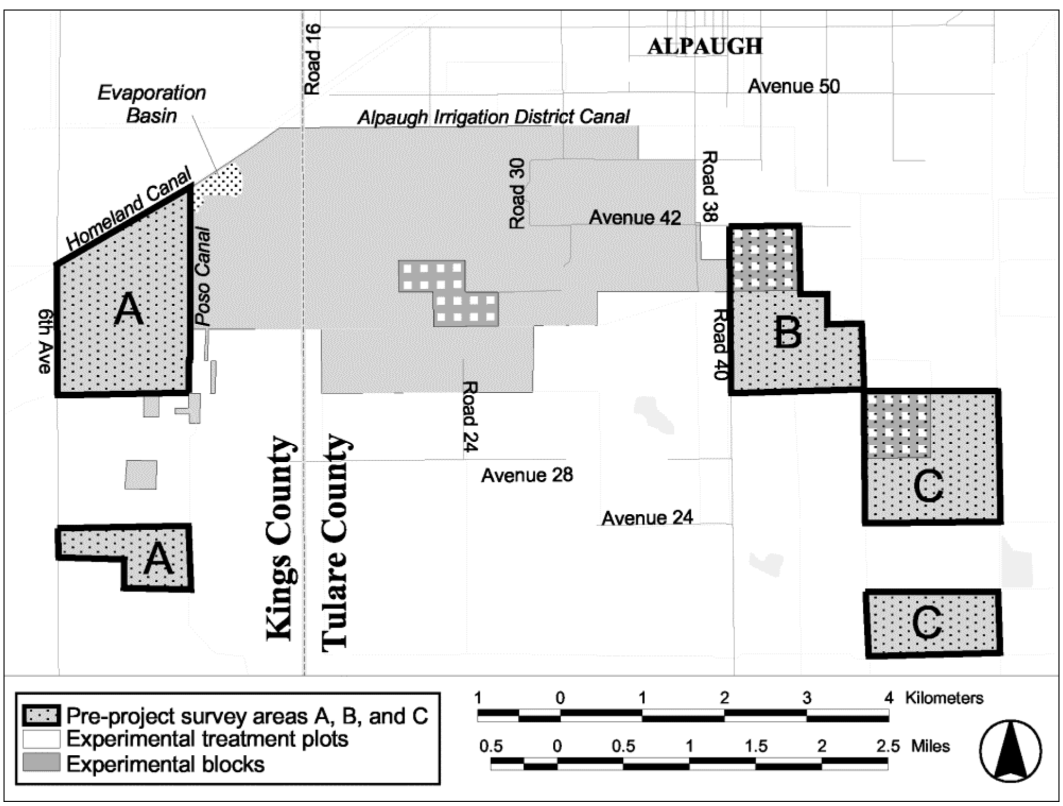

Figure 19. Locations of research areas at the Atwell Island site.

Baseline vegetation sampling was conducted on the Atwell Island HRS plots in May, 2001 (3-4, 9 May). Eight vegetation samples (35 cm by 70 cm rectangular quadrats) were taken from each plot. Stratified random sampling was employed, with plots divided into quarters and two sampling points chosen at random from within each quarter-plot. All species were noted, and the percent cover for each species was estimated using a modified Daubenmire cover scale (Bonham 1989). Total percent cover of all species within the quadrat was also estimated using the same cover scale. Whenever possible, species were identified completely; failing this, species were assigned morpho-species names.

To document temporal changes in the study plot vegetation, photopoints were established along the southern midline of the plots where digital and 35 mm panoramic photographs were taken. Initial photos were taken on 13 June, 2001; subsequent photo sampling will occur approximately quarterly. Copies of all photos are archived at the ESRP and USBR offices in Fresno.

ii. Results

Thirty-two species of vascular plants were observed on the Atwell Island site during the 2000 pre-project inventory (Columns A-C; Appendix A, Table A4). Of these, all but two species, *Allenrolfea occidentalis* and *Tamarix parviflora*, were present in the general areas on which the HRS plots were subsequently installed (i.e., areas A and B; Figure 19). The following year, 49 taxa were noted during baseline sampling of the HRS plots (Appendix A, Table A4). Of these, 26 were completely identified, 9 were identified to the level of genus, 4 to the level of family, and the remaining 10 were identified by morpho-species names.

As expected, *Hordeum vulgare* (Barley) was ubiquitous and abundant, being present in all quadrats and possessing the largest average percent cover of all species (Appendix A, Table A4). An additional six species, *Hordeum murinum*, *Melilotus indica*, *Phalaris minor*, *Amsinckia menziesii*, *Avena sativa*, and *Erodium cicutarium*, were present in at least a quarter of the study quadrats. Of these, only *A. menziesii* is native (Appendix A, Table A4). Of the 30 species whose origin could be ascertained, 24 were introduced while only 6 were native (Appendix A, Table A4). By all measures, introduced species were far more prevalent than native species in the Atwell Island HRS study plots (Figure 20).

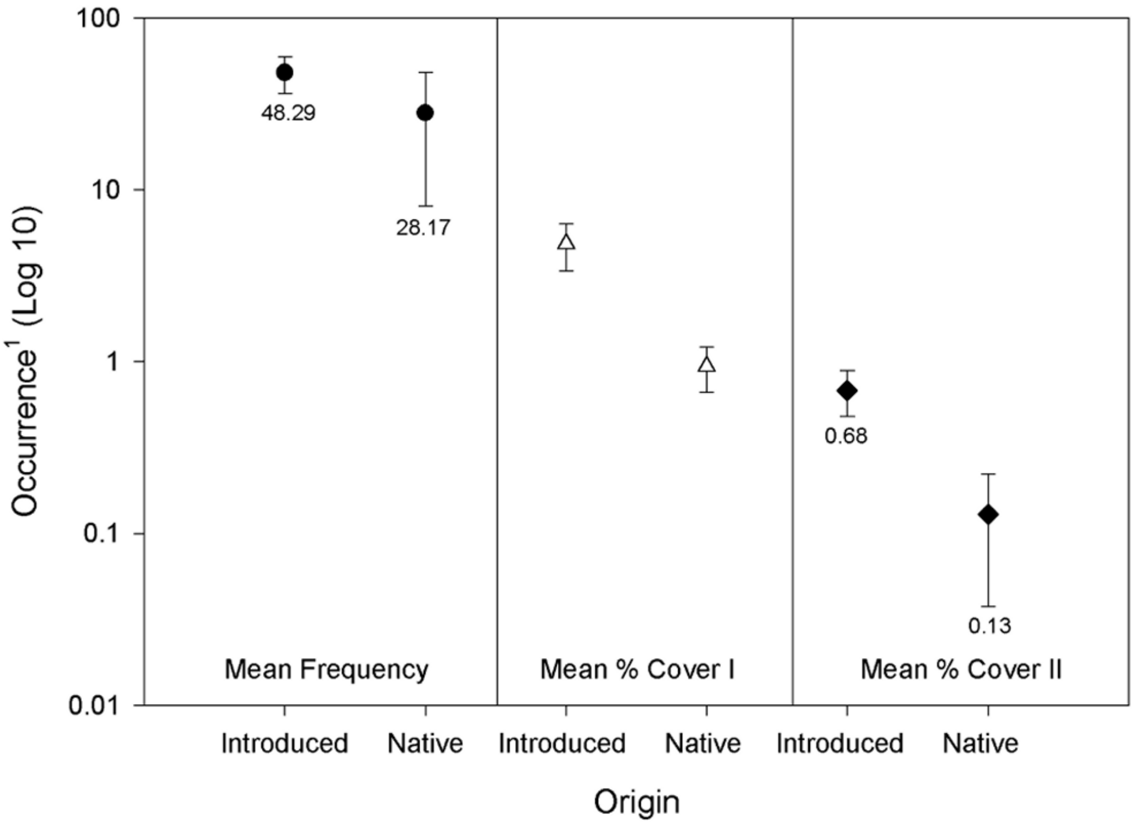

Figure 20. Differences in abundances between introduced and native species on the Atwell Island HRS plots. 1. Occurrences: Mean Frequency— the mean number of quadrats in which a species was noted; for the abundance estimates, the estimated percent cover; Mean % Cover I—Estimated average percent cover of the taxon calculated from only those quadrats in which the species was noted; Mean % Cover II—Estimated site-wide average percent cover calculated from the summed cover data divided by the total number (384) of quadrats.

Excluding barley, thirteen species noted during baseline sampling were not observed during the pre-project inventory. The status of an additional sixteen species was uncertain, due to their identity not being completely known. Also of note, eleven of the thirty species observed in areas B and C during the pre-project inventory were not observed in the HRS plots during baseline sampling (Appendix A, Table A4).

To compare conditions at the Atwell Island HRS during its "baseline" year to those at the Tranquillity HRS during its baseline year, the 20 most abundant species from each site were tabulated and graphed (Figure 21; Table 8½). The ten most abundant species in the Tranquillity HRS plots are labeled sequentially. The ten most abundant species in the Atwell Island HRS plots are also numbered sequentially; however, if a species was also among the ten labeled Tranquillity species, the number used for the Tranquillity data was applied to the plot of the Atwell Island data. For example, the second most abundant species at Atwell Island (*Avena sativa*) was not among the ten most abundant species at Tranquillity; hence, it was assigned its own number (11; Figure 21). In contrast, *H. murinum*, the fourth most abundant species at Tranquillity was the third most abundant species at Atwell Island, and hence was identified by a "4" in the plot of the Atwell Island Rank-Abundance data (Figure 21).

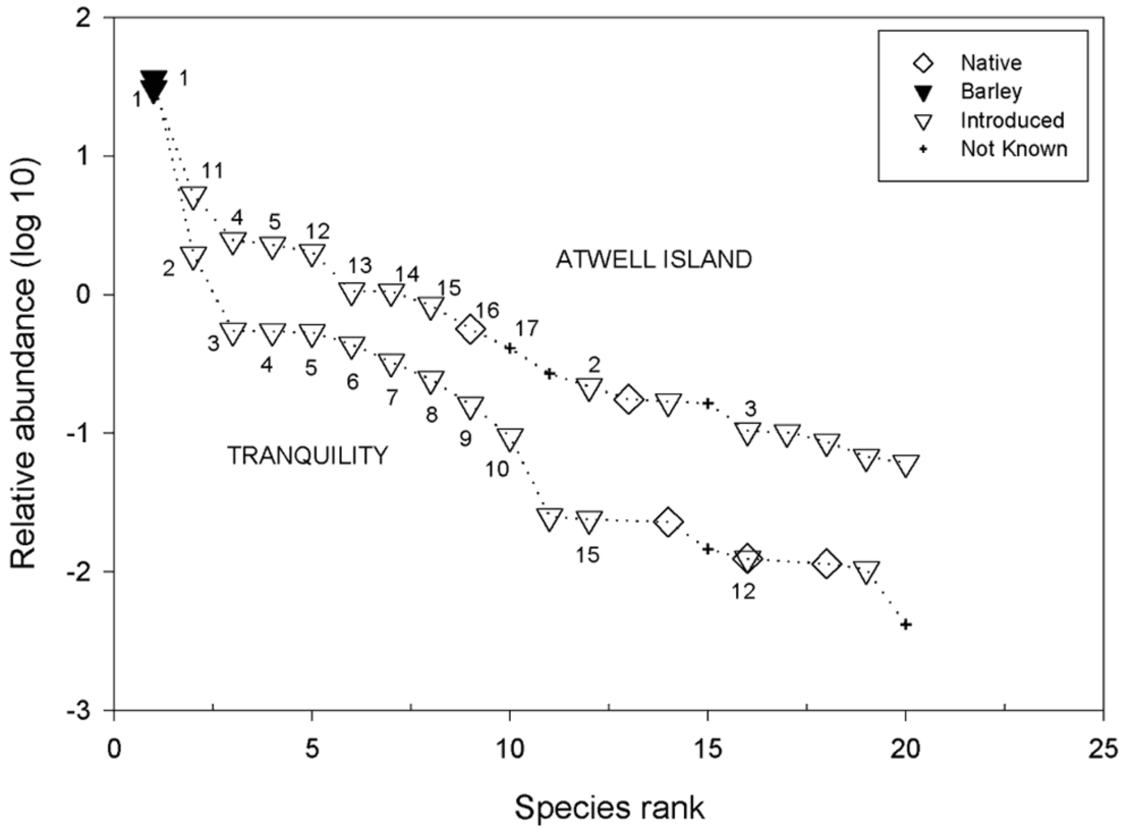

Figure 21. Rank-abundance of baseline plant species data from the Tranquillity (1999) and Atwell Island (2001) Habitat Restoration Studies, showing the 20 species with the greatest average abundance for each site. Only the ten most abundant species at each site were assigned numeric labels. Numbers pertain to species listed in Table 8.

Table 8. The ten most abundant species at the two HRS sites during baseline sampling. Species are presented in descending abundance for each site. Abundance values are based on average percent cover in quadrats.

Code[1]	Tranquillity Site	Code[1]	Atwell Island Site
1	*Hordeum vulgare* (Barley)	1	*Hordeum vulgare* (Barley)
2	*Sisymbrium irio*	11	*Avena sativa*
3	*Bromus madritensis* subsp. *rubens*	4	*Hordeum murinum*
4	*Hordeum murinum*	5	*Melilotus indica*
5	*Melilotus indica*	12	*Phalaris minor*
6	*Capsella bursa-pastoris*	13	*Medicago polymorpha*
7	*Beta vulgaris*	14	*Erodium cicutarium*
8	*Brassica nigra*	15	*Bassia hyssopifolia*
9	*Senecio vulgaris*	16	*Amsinckia menziesii*
10	*Sonchus* sp.	17	*Polygonum* sp.

1. Codes apply to Figure 21

The dominance of barley during the first year of sampling in the HRS study plots can be clearly seen for both Tranquillity and Atwell Island (Figure 21). The two sites shared few floristic similarities beyond the abundance of barley. The second and third most abundant species at the Tranquillity HRS—*Sisymbrium irio* and *Bromus madritensis* subsp. *rubens*—were present at the Atwell Island HRS, but were ranked much lower (11^{th} and 15^{th}, respectively). *Avena sativa*, the second most abundant species at the Atwell Island HRS (Figure 21), was not noted at the Tranquillity HRS during baseline vegetation sampling. The fourth and fifth most abundant species at the Tranquillity HRS—*Hordeum murinum* and *Melilotus indica*—also were present at the Atwell Island HRS; however, their abundances at the latter were much lower (11^{th} and 15^{th} ranked species, respectively).

In all, 7 of the 10 most abundant species at the Atwell Island HRS were not among the 10 most abundant species at the Tranquillity HRS site (Figure 21). At both sites, introduced species were far more prevalent than native species (Figure 20; Figure 21). This is clearly demonstrated by the absence of all but one native species (*Amsinckia menziesii*) among the ten most abundant species at either site (Figure 21).

As with the Tranquillity HRS site, many of the non-native species in the Atwell Island HRS plots were ruderals. Four of these were included in the CalEPPC list of Pest Plants of Greatest Ecological Concern (California Exotic Pest Plant Council, 1999; Table 9).

Table 9. Known "pest plants" observed in the Atwell Island HRS Plots. See key for an elaboration of their status as weeds.

Species	CalEPPC Status[1]	Freq.[2]	Cover[3]	Site cover[4]
Bassia hyssopifolia	b	12	26.9	0.84
Brassica nigra	b	8	4.2	0.09
Bromus diandrus	a	11	2.1	0.06
Bromus madritensis subsp. *rubens*	c	50	0.8	0.10

1. California Exotic Pest Plant Council (CalEPPC) status: a. Preliminarily listed as an abundant and widespread grass that may pose significant threat; b. CalEPPC List B—control required in nurseries, control elsewhere at the discretion of local County Agricultural Commissioner; c. CalEPPC List A-2—documented as an aggressive invader in fewer than three Jepson Manual geographic subdivisions.
2. Frequency: the number of quadrats in which the taxon was noted. Species with no values listed were those encountered during the Pre-project Inventory (2000) that were not observed in sampling quadrats during the Baseline survey (2001).
3. Estimated mean percent cover of the taxon calculated from only those quadrats in which the species was noted. Percent cover values were estimated from midpoints of the cover class (e.g., a species with an estimated cover of 5-25% was evaluated as having a cover of 15%).
4. Estimated site-wide mean percent cover calculated from the summed cover data divided by the total number (384) of quadrats.

Of the listed species, only two–*Bromus madritensis* subsp. *rubens* and *Bassia hyssopifolia*–could be described as frequent, with only *B. hyssopifolia* present in any real abundance (Table 9). No species observed in the Atwell Island HRS plots were among those listed as noxious weeds by the California Department of Food and Agriculture (2001).

iii. Discussion

We do not know if species observed in areas B and C during the pre-project inventory, but not observed on the HRS plots during baseline sampling were excluded from the site or if their absence was merely short term (due to lack of appropriate conditions for germination and growth) or longer-term (due to extirpation). This should be discernable with future sampling. Seven of the 11 species were native (Appendix A, Table A4); two—*Heliotropium curassavicum* and *Isocoma acradenia*—represent taxa that are included in the restoration seed mix. This suggests that they are unsuitable for inclusion in the early stages of restoration; yet, because abundance data were not recorded during the pre-project inventory, these species may have been present in low abundance. If this were the case, their absence during baseline sampling would not be unexpected. However, it is also necessary to add the caveat that the study blocks represent only a portion of the area surveyed during the pre-project inventory. Hence, it is likely that at least some of the species not noted during baseline sampling may persist on other parts of the property.

The low floristic similarity between the two HRS sites may bode well for restoration efforts at Atwell Island. A number of the introduced species that were abundant in the Tranquillity HRS plots and adjacent lands (e.g., *Sisymbrium irio*, *Bromus madritensis* subsp. *rubens*, *Beta vulgaris*) were much less prevalent at the Atwell Island HRS plots.

In contrast, *Bassia hyssopifolia*—a fairly noxious weedy species—was not noted for the Tranquillity HRS plots during baseline sampling yet was fairly abundant in the Atwell Island HRS plots (Table 9). Therefore, the impression of the Atwell Island HRS as being fairly weed-free relative to the Tranquillity HRS is conditional. Furthermore, as has been seen in the Tranquillity studies, a species that is initially present in low abundance can quickly become predominant (e.g., *Sisymbrium irio*).

b. Invertebrate Surveys

i. Methods

A single pitfall array was established in the center of each plot. Each array consisted of four, 3-gallon buckets connected by 20-foot sections of galvanized steel flashing (Figure 22). The buckets were sunk into the soil so that the rim of the bucket was at ground level, with the lid of the bucket situated slightly above the rim on wooden stakes. Pitfalls were opened the morning prior to the survey and remained open for approximately 24 hours before being checked. Pitfall array checks were conducted for 4 consecutive days beginning just after sunrise on 12-15 June 2001. Small mammals were counted and released from the pitfalls at the beginning of each survey. Pitfall arrays were removed after sampling so that the barley could be harvested and the treatments applied to the plots. Arrays will be reinstalled in 2002 prior to the first post-treatment sampling effort.

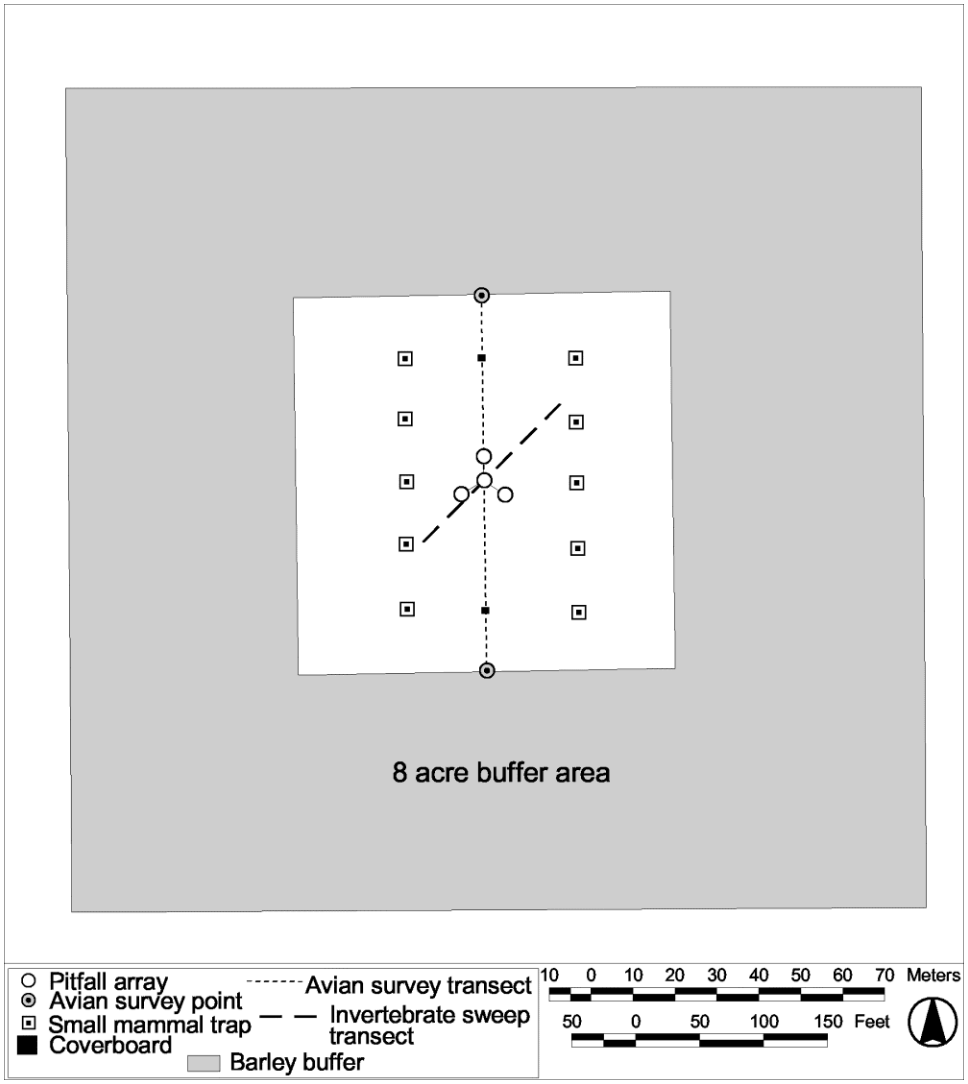

Figure 22. Locations of pitfall arrays, sweep transects, cover boards, avian transects, and small mammal trapping lines on an Atwell Island HRS plot.

Sweeps of vegetation were conducted to capture invertebrates occupying the upper tier of vegetation. Vegetation sweeps were conducted on 14 and 18 June 2001. Sampling consisted of walking a 50 m long sampling transect and sweeping vegetation with an insect net 50 times. Transects were placed so that they intersected the pitfall arrays and were centered in the plots (**Figure 22**). The same transects will be sampled in subsequent years. Invertebrates collected from the sweeps were transferred to Ziploc™ bags, put on ice, and, upon arrival at the lab, frozen. Invertebrates were identified to the level of family and counted. Abundance, richness, and composition information obtained by sweep sampling is currently being analyzed.

ii. Results

Richness among the blocks was relatively constant at 13 to 16 orders per block. However, species composition varied tremendously (Table 20). Block 1 was dominated by Thysanoptera (49.7%) and Orthoptera (25.81%) whereas Block 2 was dominated by

Acari (31.25%), Thysanoptera (20.47%), Isopoda (14.56%), and Araneae (13.94%). Block 3 was dominated by a single order, Coleoptera (76.84%).

Table 20. Composition (abundance of each taxa divided by the total abundance) of invertebrates collected in pitfall traps in the 3 study blocks at the Atwell Island site, 2001.

Order	Block 1	Block 2	Block 3
Acari	0.02	31.25	0.79
Araneae	8.04	13.94	9.34
Blattaria	0	0.09	0.01
Centipede	0	0	0.23
Coleoptera	11.94	7.45	76.84
Collembola	0.24	0.05	0
Dermaptera	0.38	0.41	0.55
Hemiptera	0.48	0.30	0.18
Homoptera	0	0.02	0.01
Hymenoptera	2.82	5.46	0.49
Isopoda	0.53	14.56	5.20
Lepidoptera	0.01	0.02	0
Mantodea	0	0	0.01
Orthoptera	25.81	4.40	1.49
Scorpiones	0.01	0.23	0.80
Solifugae	0	0.18	0.02
Thysanoptera	49.70	20.47	0.58
Thysanura	0.01	1.17	3.47

iii. Discussion

Invertebrate data were collected on the study plots during the summer when the plots were covered in mature, dry barley. Treatments have since been installed on the plots and we suspect invertebrate richness and abundance will increase as more natural conditions develop on the site.

c. Amphibian and Reptile Surveys

i. Methods

Reptiles and amphibians were sampled in conjunction with the invertebrate pitfall sampling efforts and through incidental observations by field biologists when they were on the study site. In 2002 we will implement focused sampling for reptiles and amphibians by walking a single transect and by checking two cover boards that will be installed on each plot (**Figure 22**).

ii. Results

No reptiles or amphibians were captured in the pitfalls and there were no incidental sightings of reptiles or amphibians on any of the plots. Some reptiles and amphibians were observed in the vicinity of the research blocks during site-wide surveys (see section III B 2).

iii. Discussion

During baseline data gathering, the study plots were planted with a cover crop of barley that was sprinkler irrigated. Prior to the barley planting, the fields were disked. These activities and past farming operations effectively reduced the likelihood of amphibians or reptiles being present on the study plots prior to the treatments being applied.

d. Avian Surveys

i. Methods

Bird surveys were conducted on 7-9 May, 25-27 July, and, 16-18 October, 2001 in order to estimate richness, abundance, and use of the research blocks. Two census points and one north-south line transect were established in each study plot (**Figure 22**). The line transect traversed the space between each census point, a distance of 90m, and was walked within a 2-3 minute time period. Census data was collected at each point for 5 minutes. Avian sampling occurred for 3 consecutive mornings each quarter.

ii. Results

A total of 14 bird species were observed on the Atwell Island study plots, but the greatest species richness occurred on blocks 1 and 2 with 10 and 11 species, respectively (Table 21). Species richness on Block 1 was greatest in the spring whereas species richness on Block 2 was greatest in the fall. Only four species were observed on Block 3. Red-winged blackbirds constituted the majority of sightings on all blocks, but they were only present during the spring census when barley was present on the plots. Horned larks were very abundant on Block 2 in the fall. Western meadowlark numbers seemed to remain relatively constant across seasons and blocks. Savannah sparrows were only detected on the plots during the fall census. Four bird species of special concern were observed on the Atwell Island study blocks (Table 21), the most ubiquitous and abundant of these was the horned lark.

Table 21. Bird species observed and abundance (mean number observed per day) on the 3 study blocks at the Atwell Island site, 2001.

Species	Status	Block 1			Block 2			Block 3		
Loggerhead Shrike	CSC/FSC	0	0	0	0	0	0.33	0	0	0
Northern Harrier	CSC	0	0	0	0	0	0.33	0	0	0
Long-billed Curlew	CSC	0	0.67	0	0	0	0	0	0	0
Western Meadowlark		2.00	0.67	4.67	1.33	0.33	5.67	7.67	1.33	1.67
Western Kingbird		0.33	0	0	0	0.33	0	0	0	0
Tree Swallow		0	0	0	0	0	6.67	0	0	0
Savannah Sparrow		0	0	0.33	0	0	1.67	0	0	0
Red-winged Blackbird		69.33	0	0	55.00	0	0	107.00	0	0
Mourning Dove		0.67	0	0	0.33	0	0	0	0	0
Mallard		0	0	0	0.67	0	0	0	0	0
Cliff Swallow		0.33	0	0	0	0	0	0	0	0

1. Key to status: CSC, California species of concern; FSC, Federal special concern species.

iii. Discussion

Although the species richness and abundance of birds on the study blocks may appear to be low, it was not surprising given the condition of the study plots. The spring census was conducted prior to barley growth, the summer census period the barley was mature, and during the fall census the barley had been harvested and the plots were covered in stubble. We believe that once restoration has occurred on the plots, bird species richness and abundance will increase.

e. Small Mammal Surveys

i. Methods

Small mammal trapping was conducted on 22-25 October, 2001 to estimate richness and abundance. Two trap lines were established within each plot, each 40 m long and containing 5 Sherman live traps spaced 10 m apart (**Figure 22**). Traps were baited with white proso millet seed and one dry paper towel was placed in each for shredding material. Baiting of traps began approximately 1 hour before sunset and traps were checked approximately 2 hours after sunset. All animals captured were identified to species, sexed, weighed, marked by clipping fur, and reproductive status determined.

ii. Results

Although a total of 1,920 trap nights were conducted during the survey, no small mammals were captured. One pocket mouse (*Perognathus inornatus*) a Federal Species of Concern, was captured by hand on 21 October in the barley buffer north of Plot 39 on Block 3.

iii. Discussion

The complete lack of captures suggests that there were very few small mammals on the study plots when the blocks were planted in barley. Planting the cover crop (disking of the field and planting and watering the barley) in combination with past farming activities on the study blocks, likely reduced the potential for small mammals to occur.

III. SITE-WIDE ACTIVITIES

This section describes the restoration research, biological monitoring, and management actions that have been conducted during 2001 on the Tranquillity and Atwell Island study sites. Included are results and updates from restoration trials that were implemented in past years and descriptions of trials that were implemented in 2001.

A. Tranquillity

1. Restoration Studies

Locations of the various restoration study areas at the Tranquillity site are presented in Figure 23.

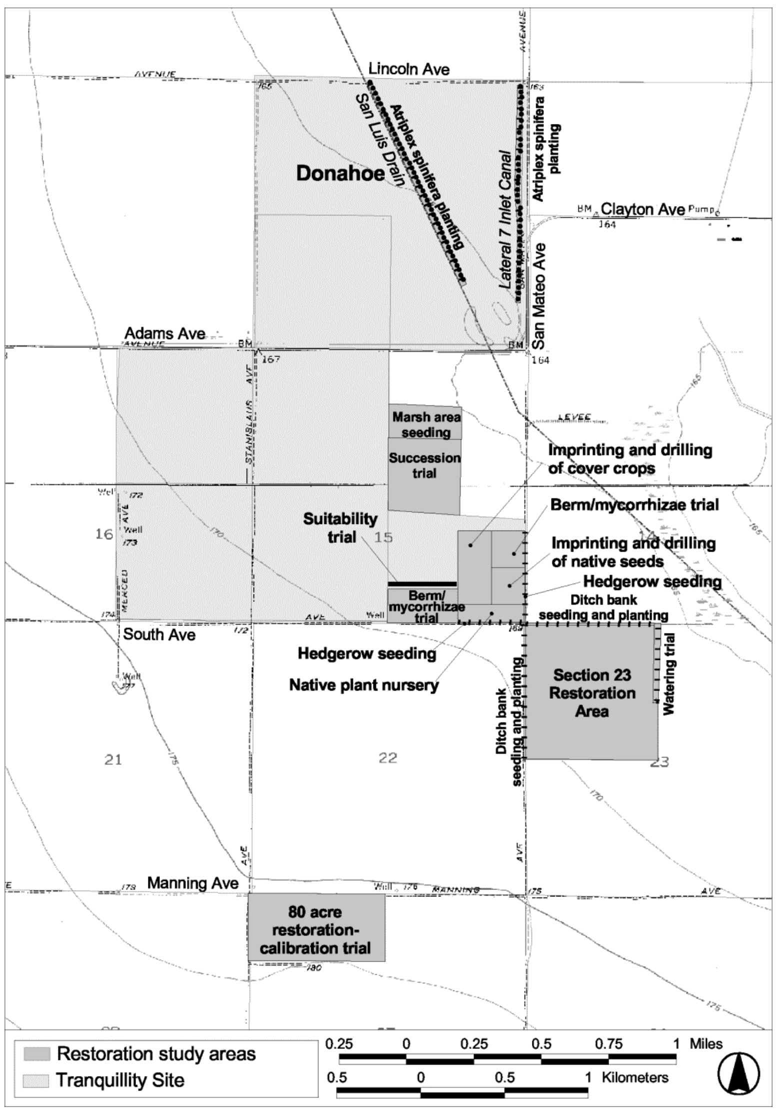

Figure 23. Locations of the various restoration study areas at the Tranquillity site.

a. Imprinting vs. Drilling of Native Seeds

In this and the following trial (imprinting vs. drilling of cover crops), methods to introduce native seeds without the expensive ground preparation often required with traditional seed drills were explored. Tillage brings weed seed to the soil surface and breaks down soil structure. Hence, it was anticipated that less soil disturbance would decrease weed density and promote the establishment of mycorrhizal networks in the soil, both of which tend to favor native plants (St. John 1995).

i. Methods

The performance of two seeding techniques, imprinting and drilling, was investigated (see Uptain et al., 2000 for a detailed description of these techniques). Installation of the experiment was undertaken in the fall of 2000. Six experimental plots approximately 1.5 acre in size were installed; three plots were imprinted and three were drilled with native seed (Figure 24). The seed mixture contained seeds of nine native species (Table 22). Vegetation sampling was conducted the following spring (May 15, 2001). Vegetation sampling was accomplished by taking eight samples (35 x 70 cm) per plot. Estimates of plant species cover and composition were obtained by the methodology described for the permanent study plots.

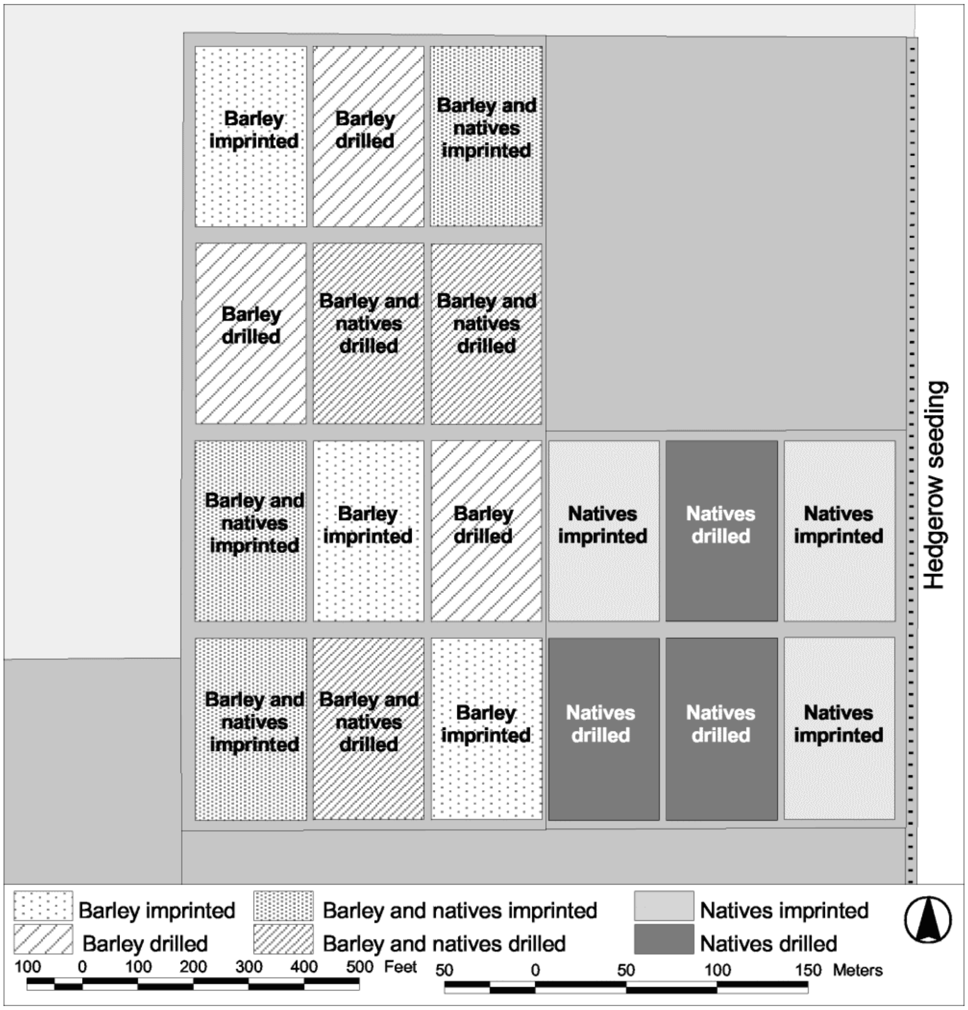

Figure 24. Location of the Imprinting vs. drilling of native seed trial, and the Imprinting vs. drilling of cover crops trial.

ii. Results

Five of the nine species included in the seed mix were encountered during sampling; all five were present in both the imprinted and drilled plots (Table 22). *Lasthenia californica* was the most abundant imprinted species (Figure 25 A); however, this species was much less successfully established through drilling (Figure 25 B). In general, the abundance of the remaining successfully seeded species (i.e., those that were encountered during sampling) varied little between seeding techniques (Table 22; Figure 25). An exception was *Amsinckia menziesii*, which appeared to be more successfully established by drilling than by imprinting.

Table 22. Overview of species encountered in imprinting vs. drilling of native seed. Species marked with an asterisk are those used in the seed mix. Species with no percent cover are those that were included in the seed mix but which were not encountered during sampling. Note: species are listed in descending order of performance in both trials (i.e., the sum of total mean percent covers from both the imprinted and drilled treatments).

Scientific name	Taxon code[1]	Origin	Imprinted[2]	Drilled[3]
Melilotus indica	MEIN	Introduced	38.42	43.56
Sisymbrium irio	SIIR	Introduced	26.69	27.83
*Lasthenia californica**	LACA	Native	3.47	0.03
Hordeum murinum	HOMU	Introduced	1.69	0.56
*Hordeum depressum**	HODE	Native	1.42	0.53
Capsella bursa-pastoris	CABU	Introduced	0.97	0.97
*Vulpia microstachys**	VUMI	Native	1.03	0.61
Atriplex argentea	ATAR	Native	0.44	0.36
*Amsinckia menziesii**	AMME	Native	0.08	0.58
*Leymus triticoides**	LETR	Native	0.19	0.44
Phalaris sp.	PHSP	Not known	0.42	----
Hordeum vulgare	HOVU	Introduced	----	0.17
Bromus madritensis	BRMA	Introduced	----	0.17
Salsola tragus	SATR	Introduced	0.17	----
Atriplex sp.	ATSP	Not known	----	0.03
*Atriplex polycarpa**	----	Native	----	----
*Isocoma acradenia**	----	Native	----	----
*Sporobolus airoides**	----	Native	----	----
*Suaeda moquinii**	----	Native	----	----

1. As referred to in Figure 25.
2. Mean percent cover in samples taken in the imprinted plots.
3. Mean percent cover in samples taken in the drilled plots.

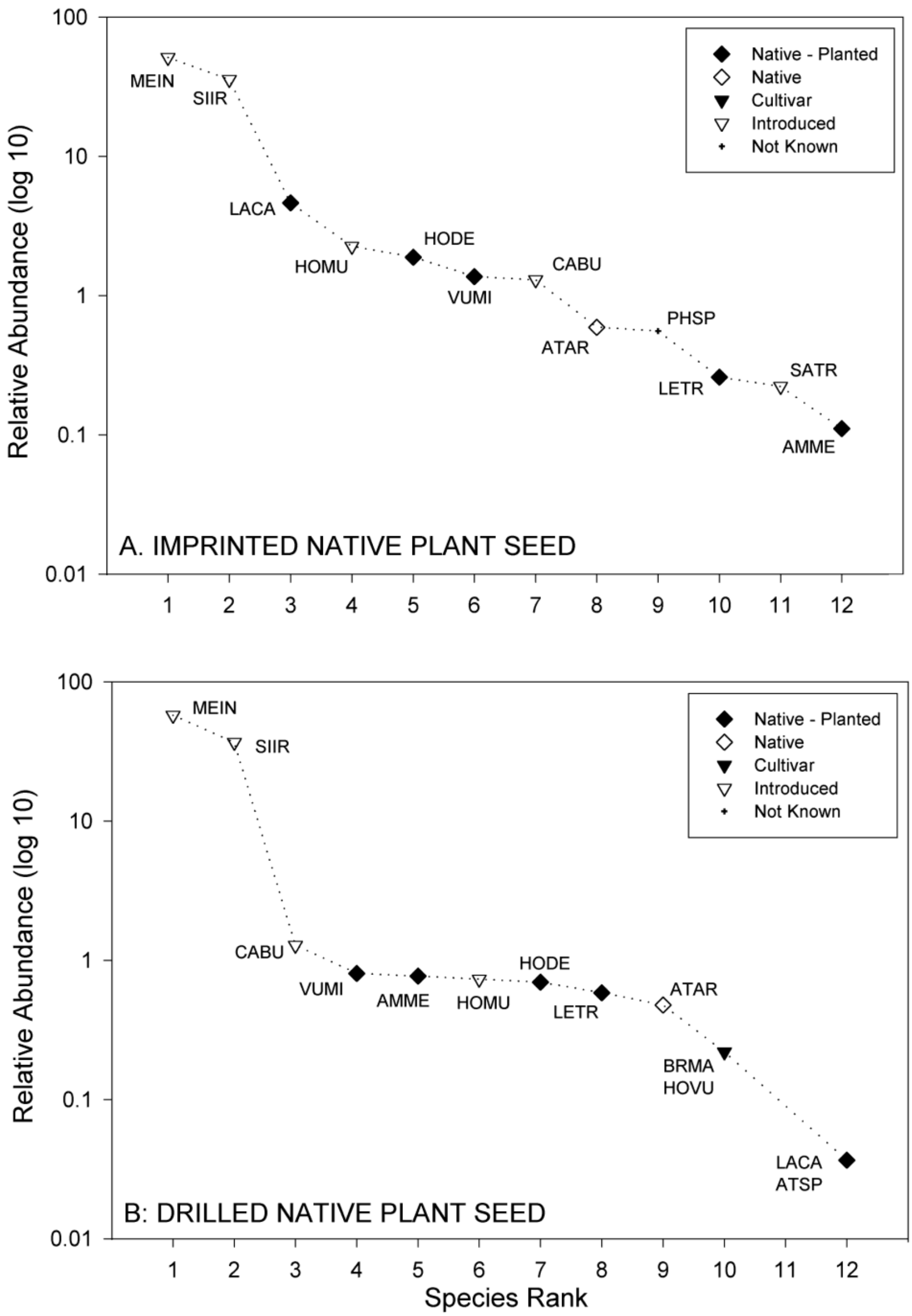

Figure 25. Rank-abundance of species encountered in the imprinted plots (A) and drilled plots (B). A key to species is provided in Table 22.

In order to compare the results statistically, the data were arcsine transformed and a *t*-test conducted. The difference between the two treatments was not found to be statistically significant when considering all seeded species; the sole species in which there was a significant difference between treatments was *Lasthenia californica* ($P = 0.0167$).

The mean percent cover of the target species seeded by imprinting was nearly three times the value for drilling (Table 23). Nevertheless, non-planted species were by far the most abundant component of the vegetation (Figure 25). The dominance of "non-planted species" is clear when the data is tabulated by species "class" (Table 23); for both treatments, the mean percent cover contributed by introduced species was more than an order of magnitude greater than that of the seeded species.

Table 23. Summary of species encountered in imprinting vs. drilling of native seed trial.

Species class	Imprinted[1]	Drilled[2]
Planted	6.194	2.194
Not planted	68.389	73.444
Not known*	0.417	0.028

1. Mean percent cover of species in the imprinted plots.
2. Mean percent cover in the drilled plots.

* Species that were only partially identified.

iii. Discussion

Of particular note were the different results obtained by imprinting and drilling *Lasthenia californica*. This species has been one of the more successful in the restoration mix and the difference between the two techniques suggests that it would be inefficient to attempt to establish this species by range-drilling. In contrast, *Amsinckia menziesii* appeared to be more successfully introduced when drilled; but the results were not statistically significant. Nevertheless, *A. menziesii* is now being considered for inclusion in future restoration efforts. We need to decide if this species should be seeded by some method other than imprinting (e.g., broadcasting following the imprinting of the other species).

Three of the species that were included in the seed mix, but which weren't encountered during sampling—*Atriplex polycarpa*, *Isocoma acradenia*, and *Sporobolus airoides*—also had fairly limited success in the permanent plots. Their seeming inability to become established through either of the seeding methods used here suggests that their inclusion in the seed mixes for future restoration efforts may not be appropriate. These species might still be successfully introduced into restored lands by broadcasting or as transplanted seedlings. These species might also demonstrate better success when drilled or imprinted on different soil types. Additionally, it may well be that their success will be limited to years with additional rainfall or with a different temporal distribution of rainfall.

Of overriding importance is the very low percent cover of the seeded species relative to non-planted species (Table 23). It seems likely, given the conditions at the Tranquillity site, that neither imprinting nor drilling will be sufficient to assure the establishment of native vegetation without some form of weed control.

b. Imprinting vs. Drilling of Cover Crops

It may often be necessary to accomplish large-scale restoration in phases. Cover crops will most likely be an important restoration tool in these situations, particularly if they can be planted with minimum ground preparation (see Uptain et al. 2000 for an elaboration of the potential benefits associated with cover cropping).

i. Methods

As in the preceding trial, the performance of two seeding techniques, imprinting and drilling was investigated. Comparisons were investigated using two seeding regimes: 1) a barley monoculture; and, 2) barley mixed with three native grasses (*Bromus carinatus, Leymus triticoides, Vulpia microstachys*). Installation of the experiment was undertaken in the fall of 2000. Three replicates of each treatment were installed on 12 experimental plots, each approximately 1.5 acre in size (Figure 24). Vegetation sampling was conducted the following spring (14-15 May 2001). Eight samples (35 x 70 cm) per plot were taken. Estimates of species cover and composition were obtained using the methodology described for the permanent study plots.

ii. Results

Barley

Barley was by far the most abundant species in both the imprinted and drilled treatments (Table 24). Although a few non-seeded species were present in the study plots, these contributed little to the overall vegetative cover (Table 24; Table 25; Figure 26 A and B). All non-seeded species encountered in the plots were non-natives (Table 24). Barley was not established better by imprinting than by drilling (Table 25).

Based on the tabulated data, it appeared that barley was more successfully established by imprinting than by drilling (Table 25). However, in a t-test of the arcsine transformed data the difference between the two treatments was not found to be statistically significant (t= 1.051 ; p= 0.3522).

Barley and native species

Barley was by far the most abundant species in both the imprinted and drilled treatments (Table 24). Of the remaining three seeded species, two were encountered in both the imprinted and drilled plots, while the fourth (*Bromus carinatus*) was not recorder for either seeding method (Table 24). More non-seeded species (seven, Table 24) were encountered in this trial than were encountered in the preceding trial (i.e., imprinting vs. drilling of barley). Non-seeded species were of both native and non-native origin (as well as two species of unknown origin). Non-seeded species comprised a greater percentage of total vegetation cover than in the preceding trial (Table 25; Figure 26 C and

D). Drilling yielded a somewhat greater mean percent cover of seeded species than did imprinting (Table 25). Nevertheless, a *t*-test of the arcsine transformed data indicated that differences between the treatments were not significant ($t = 1.052$; $p = 0.35$). Likewise, no significant differences between treatments were found for any individual species.

From an examination of the data compiled by species "class" (i.e., cover crop vs. non-planted species), it appeared that seeding barley alone was more effective at excluding introduced species than was the mixture of barley and native grass species (Table 25). A *t*-test of the arcsine transformed data indicated that this perceived difference was not statistically significant ($t = -4.07544$; $p = 0.002$). However, it is suspected some of the difference between the treatments was due to weedy species may have been introduced with the native grass seed.

Table 24. Overview of species encountered in imprinting vs. drilling of cover crops. Species marked with an asterisk are those used in the seed mix. Species with no percent cover are those that were included in the seed mix but which were not encountered during sampling. Note: species are listed in descending order of total mean percent cover (i.e., the sum of all treatments).

Species	Origin	Barley Imprinted[1]	Barley Drilled[2]	Barley and natives Imprinted[1]	Barley and natives Drilled[2]
*Hordeum vulgare**	Cultivar	67.78	55.83	49.58	51.67
Melilotus indica	Introduced	2.39	1.42	8.92	3.42
Sisymbrium irio	Introduced	1.19	0.08	1.22	1.19
*Vulpia microstachys**	Native	--	--	1.03	1.25
*Leymus triticoides**	Native	--	--	0.86	0.58
Grass A	Not known	--	--	0.31	0.44
Capsella bursa-pastoris	Introduced	--	0.22	0.33	0.19
Grass B	Not known	--	--	0.06	0.19
Avena fatua	Introduced	--	--	0.03	0.17
Brassica nigra	Introduced	--	--	0.17	0.00
Hordeum murinum	Introduced	0.06	--	0.06	0.03
Atriplex argentea	Native	--	--	--	0.06
Amsinckia menziesii	Native	--	--	0.03	--
Phalaris sp.	Not known	--	--	--	0.03
*Bromus carinatus**	Native	--	--	--	--

1. Mean percent cover in samples taken in the imprinted plots.
2. Mean percent cover in samples taken in the drilled plots.

Table 25. Summary of species classes encountered in imprinting vs. drilling of cover crops.

Species class	Barley Imprinted1	Barley Drilled2	Barley and natives Imprinted1	Barley and natives Drilled2
Cover crop	67.78	55.83	51.47	53.50
Non-planted	3.64	1.72	11.11	5.72

1. Mean percent cover in samples taken in the imprinted plots.
2. Mean percent cover in samples taken in the drilled plots.

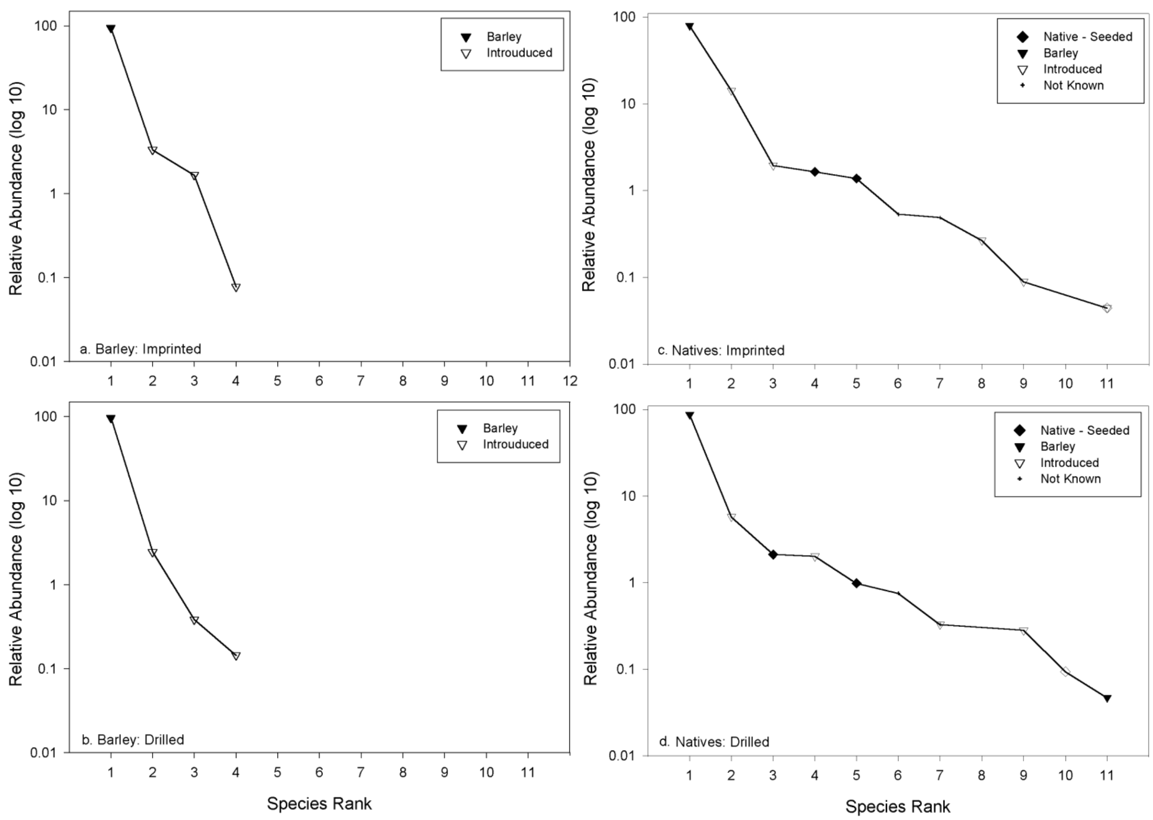

Figure 26. Rank abundance of species encountered in imprinting and drilling of cover crops: a and b (barley only), and c and d. (barley with native grasses).

iii. Discussion

The absence of statistically significant differences between imprinting and drilling of barley suggests that either approach was of approximately equal applicability, at least within the context of the set of conditions at the site.

Of particular interest was the difference in the number of introduced species in the two trials (Table 24). While some of these differences can undoubtedly be ascribed to sampling artifacts, the results suggest that weedy species are being introduced to the site by their inclusion in commercially purchased native seed.

The extremely poor response of *Bromus carinatus* to both seeding methods is very interesting. This species responded fairly well to imprinting in the Tranquillity HRS plots (i.e., present in about 25% of the quadrats in imprinted plots). However, in this years vegetation sampling it was noted in only two quadrats. This decline in frequency, along with the poor performance of *B. carinatus* in the seeding trial, may indicate that the dry conditions that were characteristic of 2001 may have been unsuitable for the germination and growth of this species. It should also be noted that as many of the grasses present in the plots were too young to be confidently identified, the performance of some species may have been better than indicated by the data.

c. Section 23 Restoration

i. Methods

The 160 acres at the Tranquillity site comprising the northwest quadrant of Section 23 were restored commencing in December. Seventeen species were imprinted from seed (Table 26, Uptain et al. 2001). Additionally, 5,500 seedlings of three species (*Allenrolfea occidentalis*, *Atriplex polycarpa*, and *Sporobolus airoides*) were planted at the site.

Vegetation sampling was undertaken in May, 2001. The 160-acre area was divided into two halves, with 24 vegetation samples (35 cm by 70 cm rectangular quadrats) taken from each area. All species were noted, and the percent cover was estimated for each species using a modified Daubenmire cover scale (Bonham 1989). Total percent cover of all species within the quadrat was estimated using the same cover scale. Whenever possible, species were identified completely; failing this, species were assigned morpho-species names.

ii. Results

Eighteen taxa were encountered during vegetation sampling (Table 26). Of these, seven were native, seven were clearly introduced, one (barley) was a non-native species that had been planted the year before, and three species could not be definitely assigned as to origin (Table 26). Of the seven native species, five had been imprinted; thus, of the seventeen species imprinted in the restoration area, only about one quarter (29.1%) were noted during vegetation sampling.

Table 26. Overview of species encountered during vegetation sampling of the 160-acre restoration area for 2001 (Section 23, Tranquillity site). Species marked with an asterisk are those used in the seed mix.

Species	Common name	Freq.[1]	Cover[2]	Site cover[3]	Origin[4]
Phalaris sp.	canarygrass	43	10.95	9.81	N.A.
Brassica nigra	black mustard	40	20.43	17.02	I
Avena fatua	wild oats	37	16.61	12.80	I
*Amsinckia menziesii**	farmer's fireweed	25	2.98	1.55	N
*Lasthenia californica**	goldfields	17	1.09	0.39	N
Beta vulgaris	common beet	13	12.62	3.42	I
Hordeum vulgare	Barley	11	3.41	0.78	B
Melilotus indica	sourclover	11	4.73	1.08	I
Phacelia distans	common phacelia	10	2.70	0.56	N
Sisymbrium irio	London rocket	6	0.50	0.06	I
Hordeum murinum	foxtail Barley	5	1.00	0.10	I
*Vulpia microstachys**	small fescue	5	1.00	0.10	N
*Gilia tricolor**	bird's eye Gilia	3	1.33	0.08	N
Atriplex argentea	silver scale	2	1.75	0.07	N
Hordeum depressum	alkali Barley	2	0.50	0.02	N
Erodium cicutarium	red-stemmed filaree	1	0.50	0.01	I
Unknown *Atriplex*	saltbush	1	0.50	0.01	N.A.
Unknown	N.A.	1	0.50	0.01	N.A.

As with the Tranquillity HRS plots, the most frequently encountered species at the 160-acre restoration site were non-imprinted. The most frequently encountered species (*Phalaris* sp.; Table 26) was not identifiable to species and, as both native and non-native representatives of the genus are known for California, it was not possible to identify its origin. Still, no species of the genus were included in the restoration mix and the only species of *Phalaris* noted to date at the Tranquillity site has been *P. minor* (an introduced species). It seems likely that this was also the species collected during sampling at the 160-acre restoration site. Overall, six species occurred in at least 25% of the sampling quadrats (Table 26); of these, only two —*Amsinckia menziesii* and *Lasthenia californica*—were imprinted.

In order to ascertain the relative success of the planted species, the cover data were tabulated by class (i.e., planted, non-planted, etc.). By all measures, non-planted species far exceeded the contribution of imprinted species (Table 27). In order to better consider the contribution of particular species and species classes to the restored vegetation, a rank-abundance curve was plotted from the sampling data (Figure 27). The general predominance of non-imprinted species is clearly evident, as the four most abundant species were either introduced or, in the case of the aforementioned *Phalaris* sp., of uncertain status. Nevertheless, the gradual slope of the curve suggests relatively high evenness in the first year's vegetation (*sensu* Kent and Coker 1992).

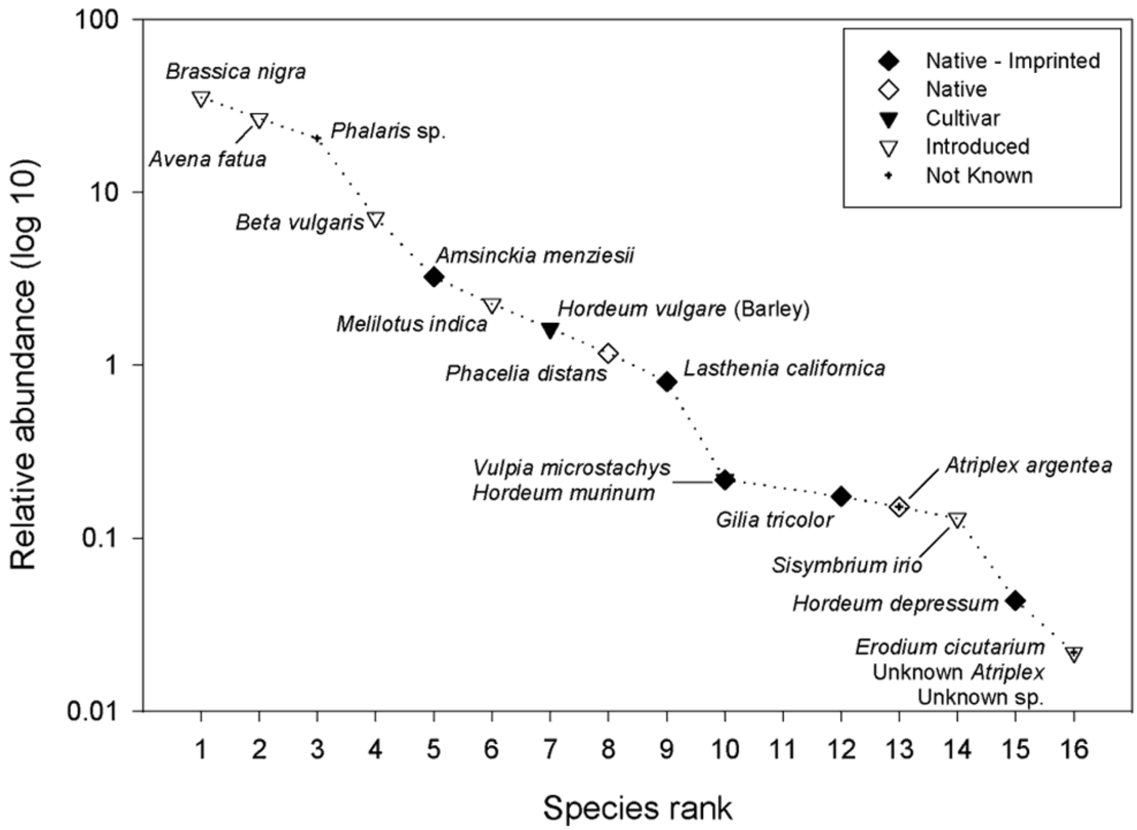

Figure 27. Rank-abundance of species encountered during vegetation sampling of the Section 23 restoration.

Table 27. Summary of species classes encountered during vegetation sampling of the Section 23 restoration.

Species class	Freq.[1]	Cover[2]	Site cover[3]
Planted	50	6.40	2.13
Non-planted	127	61.33	35.16
Cover Crop	11	3.41	0.781
N.A.	45	11.95	9.83

1. Frequency: the number of quadrats in which the taxon was noted.
2. Estimated mean percent cover of the taxon calculated from only those quadrats in which the species was noted. Percent cover values were estimated from midpoints of the cover class (e.g., a species with an estimated cover of 5-25% was evaluated as having a cover of 15%).
3. Estimated site-wide mean percent cover calculated from the summed cover data divided by total (48) of quadrats.

iii. Discussion

Although many native species were noted in the restored area, introduced taxa were far more abundant (Table 26; Table 27). The preponderance of a number of aggressively weedy species, such as *Brassica nigra*, *Beta vulgaris*, *Sisymbrium irio*, and *Atriplex argentea*, will make it difficult for native species to gain dominance. The restoration study on this area was compromised when the area was mistakenly grazed by sheep in late September-early October. By the time the sheep were removed from the study site, virtually all the transplanted perennial species that had become established were grazed to ground level. We do not know the effects on the seed bank but anticipate that the grazing will favor the weedy species.

Of the four imprinted species that were noted during sampling, two—*Lasthenia californica* and *Vulpia microstachys*—also were present in the seed mix used in establishing the Tranquillity HRS plots. The establishment of both species was fairly successful in the plots during the first year, and their performance in the 160-acre restoration area suggests that their continued inclusion in the restoration mix is warranted. The successful establishment of *Amsinckia menziesii* (i.e., the fourth most abundant species, Figure 27) from imprinted seed also is noteworthy. *A. menziesii* appears to be capable of competing against non-native weeds. Its use in future restoration mixes should be considered. Nevertheless, *A. menziesii* was much more successfully seeded by drilling than by imprinting (see section III A 1 a) and initial indications from the Native Plant Nursery suggest that this species may be successfully established by broadcasting. Hence, it may be optimal to introduce *A. menziesii* by broadcasting after other species have been imprinted. Also of note was the fairly successful establishment of another native species, *Phacelia distans*, the eighth most abundant species (Figure 27). Although not included in the seed mix, *P. distans* is common in some areas adjacent to the Tranquillity site and its use in further restoration activities should be considered.

d. Hedgerow Seeding

Vegetation on field borders may harbor pests, therefore these areas are usually disked or sprayed with herbicide. Hedgerows of native species situated along field borders may be an alternative to disking or herbicide use. Hedgerows may be maintained with minimal management, may tend to favor beneficial insects, and also can provide important habitat for birds and other wildlife (Clark and Rollins 1996).

An approximately 10-foot wide hedgerow situated along the southern and eastern edge of the ancillary trial area (Figure 23) was imprinted with native seeds in December 2000 (Table 28). Berms were constructed along the edges of the hedgerow to allow the area to be flood irrigated. In January 2001, seedlings of *Atriplex lentiformis*, *Leymus triticoides*, *Nassella pulchra* and *Sporobolus airoides* were planted along the berm adjacent to the hedgerow.

Table 28. Seed mix and application rate for the hedgerow seeding at the Tranquillity site. Seed source information provided by seed vendor.

Scientific name	Common name	Seed source	Lbs./acre
Amsinckia menziesii	rancher's fireweed	San Bernardino	3
Atriplex lentiformis	quailbush	Taft	3
Atriplex polycarpa	valley saltbush	Fresno County	5
Dichelostemma capitatum	blue dick	Camp Pendleton	3
Eremocarpus setigerus	doveweed	Kern County	3
Frankenia salina	alkali heath	Southern CA	8
Helianthus annuus	sunflower	Ensenada	8
Heliotropium curassavicum	heliotrope	Temecula	3
Leymus triticoides	creeping wild rye	Fresno County	8
Sporobolus airoides	alkali sacaton	Unknown	3
Vulpia microstachys	Nuttall's fescue	Fresno County	8

Vegetation monitoring was limited to periodically recording observations throughout the year. *Atriplex lentiformis* was observed to do well in 2001. *Helianthus annuus* germinated well in this habitat and set fruit. However, *H. annuus* is an annual species and it still remains to be seen whether or not it will prove capable of re-seeding itself as disturbance in this area is lessened. *Leymus triticoides* also grew well in this area. Periodic monitoring will continue in 2002.

e. Marsh Area Seeding

Historically, a seasonal wetland was formed by agricultural runoff from lands adjacent to LRDP lands. This water would often overflow into LRDP property, forming a marshy area on the order of 8 acres. In 2000 this area was imprinted with a native seed mix of 14 species. Regrettably, later in the year this area was inadvertently disked. Although formal sampling could not be conducted, individuals of four of the imprinted species (*Frankenia salina, Lasthenia californica, Heliotropium curassavicum*, and *Suaeda moquinii*) were observed along the fringes of the disked area. Additionally, some sterile grasses were observed growing in the same area, but these could not be confidently identified.

In January 2002, a 9.6-acre area was re-imprinted using the same seed mix as was used in 2000 (Table 29). Currently, LRDP controls the flow of water to the canal that formerly provided the runoff water, and the marshy area now receives significantly less water than in previous years. Hence, species that naturally occur in both mesic conditions and in upland habitats were selected for the seed mix. To monitor the success of the trial, vegetation sampling will be conducted in spring, 2002.

Table 29. Species seeded in the marsh area at the Tranquillity site, 2002.

Scientific name	Common name	Lbs./acre
Atriplex polycarpa	valley saltbush	0.10
Dichelostemma capitatum	blue dick	0.63
Eleocharis macrostachya	spikerush	0.10
Frankenia salina	alkali heath	0.31
Heliotropium curassavicum	heliotrope	0.31
Isocoma acradenia	goldenbush	0.21
Juncus balticus	Baltic rush	0.21
Lasthenia californica	goldfields	0.42
Leymus triticoides	creeping wild rye	1.67
Lupinus bicolor	miniature lupine	0.10
Mimulus guttatus	monkeyflower	0.21
Poa secunda	bluegrass	0.10
Sporobolus airoides	alkali sacaton	0.83
Suaeda moquinii	bush seepweed	0.21

f. Ditch Bank Seeding and Planting

Ditches are a common feature of the agricultural landscape and are often managed with herbicides and blading to prevent the accumulation of weedy species. Native plants may prevent weedy species from overtaking ditches while providing excellent cover for wildlife.

A ditch was created on the northern and western boundary of the Section 23 restoration area (Figure 23). Seedlings of *Leymus triticoides* and *Nassella pulchra* were planted along the ditch banks in December, 2000. In January, 2001 the ditch was seeded by hand with a mix of species that would typically do well along an irrigation ditch (Table 30). The ditch was flood irrigated shortly after seeding and was not watered again.

Table 30. Seed mix and application rate for ditch bank seeding at the Tranquillity site. Seed source information provided by seed vendor.

Scientific name	Common name	Seed source	Lbs./acre
Amsinckia menziesii	fiddleneck	San Bernardino	12.5
Cressa truxillensis	alkali weed	Camp Pendleton	8.0
Eleocharis macrostachya	spikerush	Grass Valley	4.2
Frankenia salina	alkali heath	San Diego County-Coast	8.0
Helianthus annuus	sunflower	Ensenada	8.0
Heliotropium curassavicum	heliotrope	Temecula	17.0
Hordeum depressum	low Barley	Riverside	21.0
Leymus triticoides	creeping wild rye	Fresno County	21.0
Malvella leprosa	alkali -mallow	Unknown	8.0
Nassella pulchra	purple needle grass	Central Valley	12.5
Poa secunda	bluegrass	West Lower Central Valley	42.0
Sporobolus airoides	alkali sacaton	Unknown	12.5
Vulpia microstachys	Nuttall's fescue	Fresno County	21.0

Vegetation monitoring was limited to periodically recording observations throughout the year. From these observations, it appeared that both *Leymus triticoides* and *Nassella pulchra* had become successfully established. Nevertheless, it remains to be seen whether or not the majority of these individuals will survive the dry season. Periodic monitoring will continue in 2002.

g. Native Plant Nursery

Because of the need to maintain local genotypes, seeds collected from local sources are preferable to commercially obtained seeds. A potentially serious problem exists when seeds or plants of different genotypes are introduced. In this manner, 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 very important to use local seed stock to the maximum extent when implementing restoration projects.

Locating sufficient sources of native seed of local genotype has proven extremely problematic. Remnant native seed banks 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 costly, and offer seed collected from geographically disjunct locations. In order to circumvent these limitations, the establishment of a Native Plant Nursery was begun in 2001 at the Tranquillity site.

Seeds from selected native species were collected during the 2001 growing season. Permission and any required permits were obtained from private landowners and government agencies. In order to minimize the mixing of local with non-local genotypes, collections were undertaken in as close a proximity to the Tranquillity site as possible. The health of the population was assessed prior to collection. No more than 5% of a population's seeds was harvested, and diseased or damaged plants were excluded from collection. Seed collections made during 2001 are listed in Table 31. With the exception of one location (Fancher and Belmont; Figure 28), all seed was collected from within 15 miles of the Tranquillity site.

Table 31. Dates, species collected, and locations of 2001 native seed collections.

Date	Species collected	Location
1 May 2001	*Phacelia distans*	Westlands property
	Castilleja exserta	Fancher and Belmont
	Lasthenia chrysantha	Fresno West Golf and CC
	Castilleja exserta	
25 June 2001	*Hemizonia pungens*	Kerman ecological reserve, North
26 June 2001	*Hemizonia pungens*	Kerman ecological reserve, South
16 July 2001	*Hemizonia pungens*	Lanfranco property
	Asclepias fascicularis	Kerman ecological reserve, South
17 July 2001	*Hemizonia pungens*	Kerman ecological reserve, North
24 July 2001	*Asclepias fascicularis*	
	Hemizonia pungens	
7 September 2001	*Suaeda moquinii*	
	Hemizonia pungens	
28 September 2001	*Sporobolus airoides*	Alkali Sink ecological reserve
	Frankenia salina	
	Suaeda moquinii	Kerman ecological reserve, North
	Frankenia salina	
	Atriplex polycarpa	
8 October 2001	*Isocoma acradenia*	Kerman ecological reserve, South

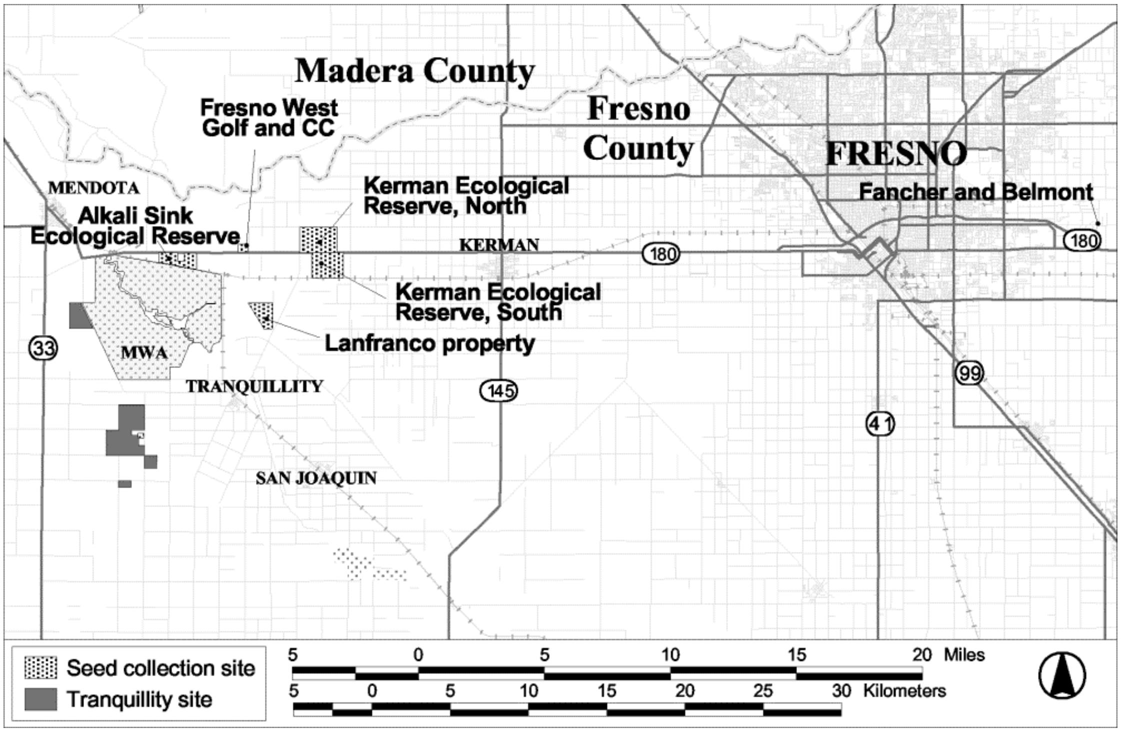

Figure 28. Locations of native plant seed collection sites near the Tranquillity site.

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 collecting usually 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* spp., *Isocoma acradenia*, and *Allenrolfea occidentalis* generally do not produce mature fruits until late summer or early fall, thereby extending collecting into November.

Due to an unusually warm and early spring in 2001, the collection window for many of the showy annuals was shortened. Thus, little seed was harvested from species such as *Lasthenia chrysantha*, *Castilleja exserta*, and *Phacelia distans*. Nevertheless, a long summer and mild fall allowed for an ample collection of *Isocoma acradenia*, and *Hemizonia pungens*.

Harvested seed was stored in paper bags, labeled with identifying codes (species, seed-lot, etc.), and dried in a seed dryer at the ESRP lab. In some cases, seed was processed to remove chaff and foreign matter. This process proved to be sufficiently difficult and time-consuming so as to preclude its general application. Additional seed was available from seed collections undertaken in 2000 (see Uptain et al, 2001), and we plan to plant these seeds in the Nursery. A complete list of the species available for planting is presented in Table 32.

Table 32. Native plants seed available for planting in the native seed nursery at the Tranquillity site. Species marked with an asterisk are those also used in the restoration seed mix.

Family	Binomial	Common name	Life-history
Asclepiadaceae	*Asclepias fascicularis*	narrow-leaved milkweed	perennial herb
Asteraceae	*Helianthus annuus*	sunflower	annual herb
Asteraceae	*Hemizonia pungens**	spikeweed	annual herb
Asteraceae	*Isocoma acradenia**	goldenbush	shrub
Asteraceae	*Lasthenia chrysantha*	alkali goldfields	annual herb
Boraginaceae	*Amsinckia menziesii*	farmer's fireweed	annual herb
Capparaceae	*Wislizenia refracta*	jackass clover	annual herb
Caryophyllaceae	*Spergularia macrotheca*	Sand Spurrey	perennial herb
Chenopodiaceae	*Atriplex polycarpa**	valley saltbush	shrub
Chenopodiaceae	*Suaeda moquinii**	bush seepweed	perennial herb
Euphorbiaceae	*Eremocarpus setigerus*	doveweed	annual herb
Frankeniaceae	*Frankenia salina**	alkali heath	perennial herb
Hydrophyllaceae	*Phacelia distans*	common phacelia	annual herb
Lamiaceae	*Trichostema lanceolatum*	vinegarweed	annual herb
Liliaceae	*Dichelostemma capitatum*	blue dicks	perennial herb
Poaceae	*Sporobolus airoides**	alkali sacaton	perennial herb
Scrophulariaceae	*Castilleja exserta*	purple owl's clover	annual herb

* Species marked with an asterisk are those also used in the restoration seed mix.

The nursery area was disked, bermed, furrowed, and culti-packed in November, 2001. Berms were flat-topped and were sufficiently wide so as to provide space for a number of individuals. The nursery was designed to accommodate flood irrigation, as needed. Ten acres have been set aside for the nursery (see Figure 23); however, it is anticipated that only 3 acres will be used in 2002. As our stock of native seed is augmented from seed produced in the nursery and from continued collection from native populations we expect that larger areas will be put into production in subsequent years.

Some areas adjacent to the nursery site support large populations of two apparently aggressively weedy species: *Sisymbrium irio*, and an unidentified trifoliate species (possibly *Medicago polymorpha*). It seems clear that vigilant weeding, watering, and maintenance will be necessary to ensure the successful propagation and establishment of the native species. Additionally, we are considering the use of herbicides to prepare the seed bed for the fall seeding effort in 2002.

h. *Atriplex spinifera* Planting

One priority of our restoration research has been the development of strategies for introducing native vegetation into *Bromus madritensis* subsp. *rubens* (red brome) dominated habitats. *B. madritensis* characteristically forms a heavy thatch, which inhibits the establishment of native vegetation and negatively impacts many terrestrial vertebrates, especially small mammals and lizards. *Atriplex spinifera* (spiny saltbush), a shrub in the Chenopodiaceae (goosefoot family), is an important component of the Valley Saltbush Scrub community, as 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 ("the Donahoe") of the Tranquillity site, an area characterized by a non-native grassland dominated by *B. madritensis.*

Although mature *A. spinifera* shrubs grow on the Donahoe, no seedlings have been identified during the three years we have studied the area. And, although *A. spinifera* seed has been included in the seed mix used in various restoration activities at both the Tranquillity and Atwell Island habitat restoration study sites, there has been little indication that this species can be successfully introduced by imprinting. Likewise, attempts at germinating seeds in nursery trials have met with little success.

In an attempt to investigate other means of establishing *A. spinifera* on restored land, we contracted with Ray Leclerc, owner of the Intermountain Nursery in Auberry (Fresno Co., California), to propagate *A. spinifera* from cuttings taken from existing shrubs on the Donahoe. To maximize the number of individuals produced from the original cuttings, these were rooted and then maintained as stock plants. Once a viable group of stock plants was established, cuttings were taken from these plants and used to grow out more plants. In this manner, more than 600 plants of different cohorts (i.e., age classes) were grown for transplanting to the Donahoe. Plants were maintained in approximately gallon-sized peat pots until transplanting, and were watered as deemed appropriate (approximately bi-weekly) while in the nursery.

To give us a better understanding of the species' requirements, shrubs were transplanted in groups (shrub islands) with four different configurations: 1) 10 individuals with 10-ft spacing between plants; 2) 10 individuals with 5-ft spacing; 3) 5 individuals with 10-ft spacing; and, 4) 5 individuals with 5-ft spacing. All individuals were characterized as belonging to two age classes, "old plants" and "young plants". Individuals in the oldest cohort were easily distinguished from all younger plants. Cuttings for the older plants had been rooted before the summer of 2001, such that their foliage had developed the summer-dormant appearance of spiny saltbush. Their stems were woody, their leaves small and gray-green, and their root systems were developed enough to hold soil for transplanting. Although a number of cohorts comprised the young-plants age class, identifying characteristics were not sufficiently differentiated to allow a finer resolution. Leaves that were larger, fleshier, and greener distinguished all of these younger plants, which had been rooted during the summer of 2001. These plants had less root mass than the older plants; hence, it was necessary to leave some of the youngest plants in their pots when transplanted. In these cases, pots were slashed vertically at three or four locations and the pot bottom was removed. 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 23)

Transplanting was conducted November 14-29 2001. Most plants were removed from the peat pots and placed in the soil up to the plants' potting soil level. A well was created around each plant in order to concentrate water around the plant. Plants, which were left in their pots when transplanted also, were buried to the level of the potting soil. The upper lips of the pots served as wells with which to collect water. All plants were watered when planted. Subsequently, plants were watered on a weekly basis until the site received soil-soaking rains in late December. Survivorship of the plants will be monitored periodically throughout the 2002 growing season.

i. Future Directions

i. 80-acre restoration—calibration trial

As part of the restoration activities in 2002, an 80-acre block located south of Manning Ave (Figure 23) will be restored using the same seed mixture as was used for the HRS plots. To better control seed application in future restoration efforts, the Manning Avenue restoration effort will be used to refine imprinter calibration.

Our imprinter was custom made and was not calibrated by the shop that fabricated it. To date, we have data from the imprinting of both the Atwell Island HRS plot installation (setting 20 = 25 lbs/acre) and the USBLM's restoration activities at Atwell Island (setting 30; = 33.2 lbs/acre). The 80-acre parcel will be divided into four equal-sized areas and each area will be seeded with the imprinter set at a different setting (imprinter settings: 15, 25, 35, 45). Data from this trial will be compared with data from the two restoration experiments at Atwell. The amount of seed used in imprinting will be plotted against imprinter settings, and a linear regression will be calculated for the data.

ii. Succession trial

In this trial, two factors will be examined: 1) the ability of native grasses to become established when imprinted over an existing barley crop; and, 2) the relative abilities of barley and imprinted native grasses to spread beyond the confines of their seeded area.

Since the inception of the habitat restoration study, barley (*Hordeum vulgare*) has been used as a cover crop, to control weeds and prevent soil erosion (Selmon et al, 2000). Although this species has demonstrated some utility, at times its establishment has proven costly and somewhat problematic. Additionally, although the seed purchased for these studies was ostensibly of sterile barley, it has proven capable of re-seeding itself in the highly motile (i.e., shrinking, swelling, and cracking) soils at the Tranquillity site.

To date, areas cover-cropped with barley have generally been disked prior to imprinting. Although this strategy has been fairly successful in removing the greatest portion of the barley, disking represents an additional disturbance to the soil and may favor the establishment of weeds. An alternative approach to disking is imprinting seed directly over the cover crop. However, questions remain as to whether or not imprinted species will, 1) be able to become established; and, 2) be able to resist incursions by adjacent vegetation. In this trial we attempt to address these questions by monitoring temporal changes in strips of land planted with barley with those planted with native grasses (*Bromus carinatus*, *Hordeum depressum*, *Leymus triticoides*, and *Vulpia microstachys*).

The trial will occupy 80 acres to the north of the berm-trial area and south of the marsh-mix planting area (see Figure 23). Installation will commence in February, 2002. A stratified random blocking design will be used, with the area divided into 5 blocks. Each block will be divided into 3 strips; each strip will contain either: 1) barley (existing); 2) the native grass mix imprinted over existing barely; or, 3) the standard (for our HRS studies) 13 species restoration mix imprinted over disked ground. Seeding order will be determined randomly. The trial will be monitored periodically; if species establishment is successful, quantitative sampling will be conducted near the end of the growing season.

iii. Berm/mycorrhizal trial

This trial was designed to examine the effects of two factors: berm "architecture" and mycorrhizal inoculation. Observations at the Tranquillity HRS plots have led us to hypothesize that the establishment of micro-topography on the plots (in this case, through the construction of earthen berms) aids in the establishment of vegetation after imprinting, and may also benefit wildlife. Previously, uniform berms were installed to minimize sampling bias. Berms were compacted and rebuilt so that compaction by the imprinter would not substantially reduce the final height of the berms compared with berms that were not imprinted. This approach to berm construction required a substantial amount of time and labor. It may be more desirable to maximize the amount of bermed habitat in a restoration area by creating more (less "perfect") berms in the same amount of time. This aspect of the trial will test whether it is better to make two passes (thus, compacting the berm), or if simply making a quick berm with only one pass works just as well for facilitating native plant germination and survival.

The Tranquillity site has been in agricultural production for decades. Agricultural activities (primarily scraping and disking) can eliminate beneficial mycorrhizal fungi in the soil. Mycorrhizae—the symbiosis between a plants roots and beneficial soil fungi—aid in nutrient uptake in almost all species of plants. Half of the plots will be inoculated with commercial mycorrhizal fungi obtained from ConservaSeed. The mycorrhizal fungi will be applied by mixing it with the seed mix prior to imprinting the plots. Application rate will be ca. 60lbs/acre. Particular attention will be given to species that are mycotrophs and net-builders to see if they perform better in the inoculated plots.

The berm and mycorrhizal trial will be installed in February or March 2002 and will occupy 10 acres in 5 blocks, each with 4 (0.5 acre) plots. A stratified random blocking design will be used. The blocks will be located north and west of the nursery (Figure 23). Each plot will contain seven evenly spaced berms oriented east to west. Berms will be spaced 30 ft apart from their centers, and will begin 10 ft from the north edge of the plot. A barley buffer will be maintained to the north and south of the plots. Plots will be separate on the eastern and western sides by approximately 85' wide strips. However, these will be planted to barley. The berms will be continuous through adjacent plots (i.e., the berms do not stop within the plot boundaries, but continue into adjacent plots).

Prior to installation of the berms, the ground will be prepared by disking and harrowing with a spring-toothed harrow. The berms will be created using a 2-disk border disc and a cultipacker. Plots will be imprinted with the usual restoration seed mix at the rate of 50 pounds per acre with mycorrhizal inoculum added to the designated plots.

iv. Watering trial

The watering requirements for two plant species, *Atriplex polycarpa* and *Leymus triticoides* will be investigated. Objectives are to determine whether these species, when transplanted from plugs: 1) require watering to survive through the first summer; and, 2) at which point watering can be terminated while still ensuring a high survival rate.

Seedlings were grown by Westside Transplants (Firebaugh, CA) in the latter half of 2001. It is anticipated that the trial will commence in early 2002. Seedlings will be planted along the eastern edge of the northwestern corner of Section 23 (Figure 23). Each species will be planted in "plots" consisting of either 9 *A. polycarpa* or 18 *L. triticoides* individuals. Spacing between plants will be 4 ft for both species. Spacing was based on maximum planting densities as recommended by the USDA.

Plots will be arranged in a randomized block design of five blocks. Each block will contain four plots, with each plot being assigned one of four, randomly assigned, watering regimes. Watering will be conducted once a week. In order to facilitate watering, plots will be situated in close proximity (ca. 25-30') from the road that delineates the eastern side of the study area. Watering will be carried out using a pickup truck outfitted with a small gas-powered pump and three 55-gallon tanks. Anticipated watering rate is approximately 0.75 gallon of water/plant/week. Experimental treatments will be: 1) no watering after the estimated final rain of the season; 2) watering for 2 months after the final rain; 3) watering for 3 months after the final rain; and, 4) watering for 4 months after the final rain.

v. 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. 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 (listed in alphabetical order):

- 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
- ability to withstand high levels of sunlight

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 we have imprinted in other trials, was selected to serve as a control.

Installation of the trial is scheduled for late winter, 2002. Each species will be imprinted in a 0.33-acre strip (~ 12 x 1,200 ft). In order to facilitate comparisons among species, seeding rates will be calibrated so that each species is seeded at 35 PLS (pure live seeds) per square foot. The trial will be monitored periodically; if species establishment is successful it will be quantitatively sampled towards the end of the growing season.

2. Biological Monitoring

IN 2001, ESRP conducted monitoring on a site-wide basis that is not directly related to the Tranquillity Habitat Restoration Study. Monitoring consisted of:

- spotlighting surveys;
- track station surveys;
- winter raptor surveys; and
- contaminants sampling (vegetation, invertebrates, and small mammals).

The locations where the spotlighting, track station, and winter raptor surveys were conducted is presented in Figure 29. Because the contaminants locations are relatively complex, the locations where sampling occurred is presented in a separate figure in the contaminants section (section 2 d) of this document.

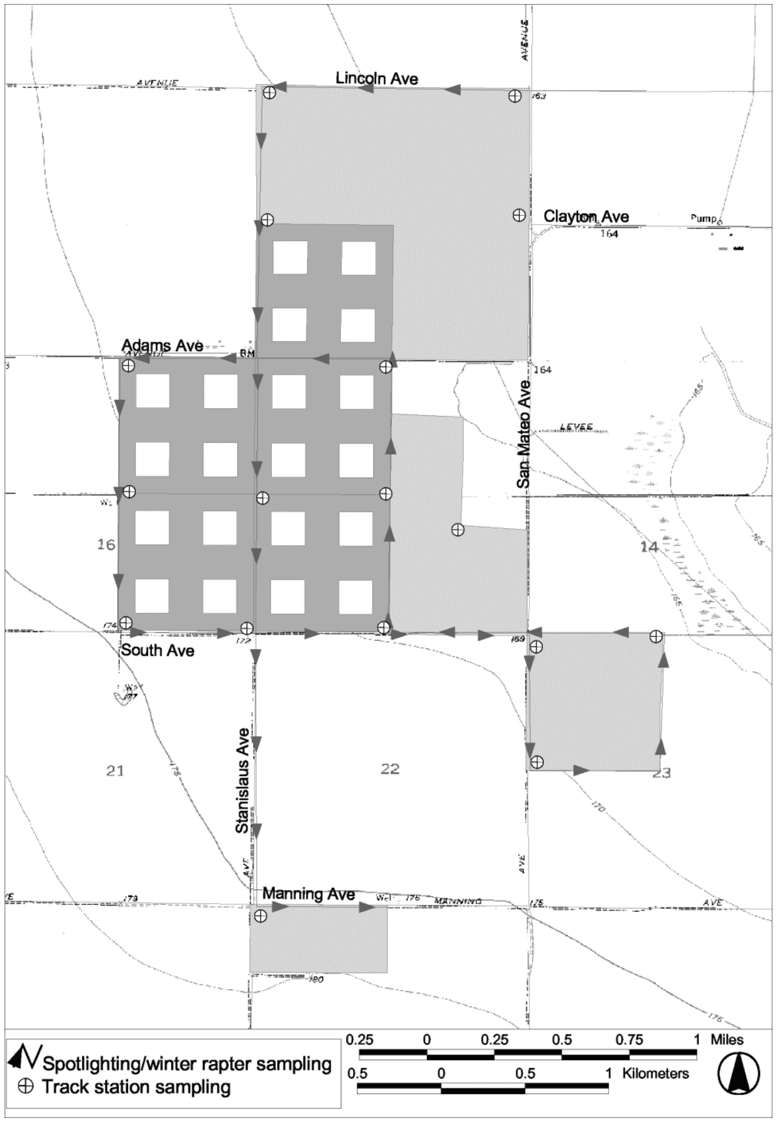

Figure 29. Sampling locations for site-wide biological monitoring at the Tranquillity site.

a. Spotlighting Surveys

i. Methods

Spotlighting surveys at the Tranquillity site were conducted on 29-31May, 17-19 September, and 17-19 December 2001 following methods that have been previously presented (Uptain et al. 2001). The first quarter (spring) spotlighting effort was cancelled due to heavy rains and consequent lack of access to the study site.

ii. Results

There was seasonal variability in species richness during the spotlighting surveys, but there was also a trend of increasing species richness from 1999 to 2001 (Table 33). No single species was present during all census periods, but barn owls (*Tyto alba*), black-tailed jackrabbits (*Lepus californicus*), desert cottontails (*Sylvilagus audubonii*), and short-eared owls were present most seasons. Although seasonal composition of species varied, barn owls, black-tailed hares, desert cottontails and red-tailed hawks (*Buteo jamaicensis*) generally ranked within the top three most abundant species (Table 33). Barn owls were the most abundant species during five of the nine census periods and ranked within the top three most abundant species during seven of the census periods.

Table 33. Rates of species occurrence during 1999 to 2001 spotlighting surveys at the Tranquillity site.

Common name	Rate[1]								
	1999		2000					2001	
	Fall	Winter	Spring	Summ.	Fall	Winter	Summ.	Fall	Winter
western toad	0.09	0	0.20	0.86	0.03	0	0.20	0.17	0
California king snake	0	0	0	0.03	0	0	0	0.03	0
black-crowned night heron	0	0	0	0	0	0	0.66	0	0
burrowing owl	0.09	0.09	0.35	0.14	0	0	0	0	0
duck	0	0	0	0	0	0	0.03	0	0
egret	0	0	0	0	0	0	0.03	0	0
killdeer	0	0	0.09	0.03	0.06	0.40	0	0	0.06
lesser nighthawk	0	0	0	0	0	0	0	0.03	0
red-tailed hawk	0	0.58	0	0	0.26	0.40	0.03	0.29	0.32
western Meadowlark	0	0	0	0	0	0	0	0.09	0
black-tailed hare	0.12	0.20	0.23	0.32	0.12	0.03	0.17	0.26	0
desert cottontail	0.12	0	0.37	0.23	0.06	0.09	0.12	0.35	0.23
coyote	0	0	0.06	0	0	0.09	0.06	0	0
dog	0	0	0	0	0	0.03	0	0	0
kangaroo rat	0	0	0.03	0.23	0	0	0	0.17	0
mouse	0	0	0	0	0.03	0	0.32	0.20	0
California ground squirrel	0	0	0	0	0	0.03	0	0	0
California vole	0.03	0	0	0	0	0	0.06	0.06	0
unknown	0	0	0	0	0	0	0.03	0	0
Species Richness	**7**	**4**	**8**	**9**	**8**	**9**	**13**	**12**	**4**

1. Rate: mean number of observations per mile of survey.

iii. Discussion

As restoration on the Tranquillity site continues, we would expect the species composition and abundance to shift. Greater numbers of kangaroo rats, mice, black-tailed hares, and desert cottontails would be expected. A concomitant increase in predators would also be expected.

b. Track Station Surveys

i. Methods

Track station surveys of the Tranquillity site were conducted on 14-16 March, 30 May-1 June, 9-11 September, and 18-20 December 2001 using methods that have been previously presented (Uptain et al. 2001).

ii. Results

Mean species richness at the track stations was variable throughout the survey duration (Figure 30). The lowest seasonal richness was observed in fall and winter 1999. The highest richness was observed in summer 2000 and spring 2001, although fall 2001 also had relatively high richness values. Similarly, the abundance of tracks at the track stations was quite variable (Figure 31). The lowest seasonal abundance values were in fall and winter 1999 and spring of 2000, whereas the highest seasonal abundance values were in summer 2000. Mammals exhibited the greatest frequency of visitation and the greatest rate of visitation, except in summer and winter 2000, when invertebrates exhibited the greatest rate of visitation (Table 34). Reptiles were conspicuously absent from the track stations.

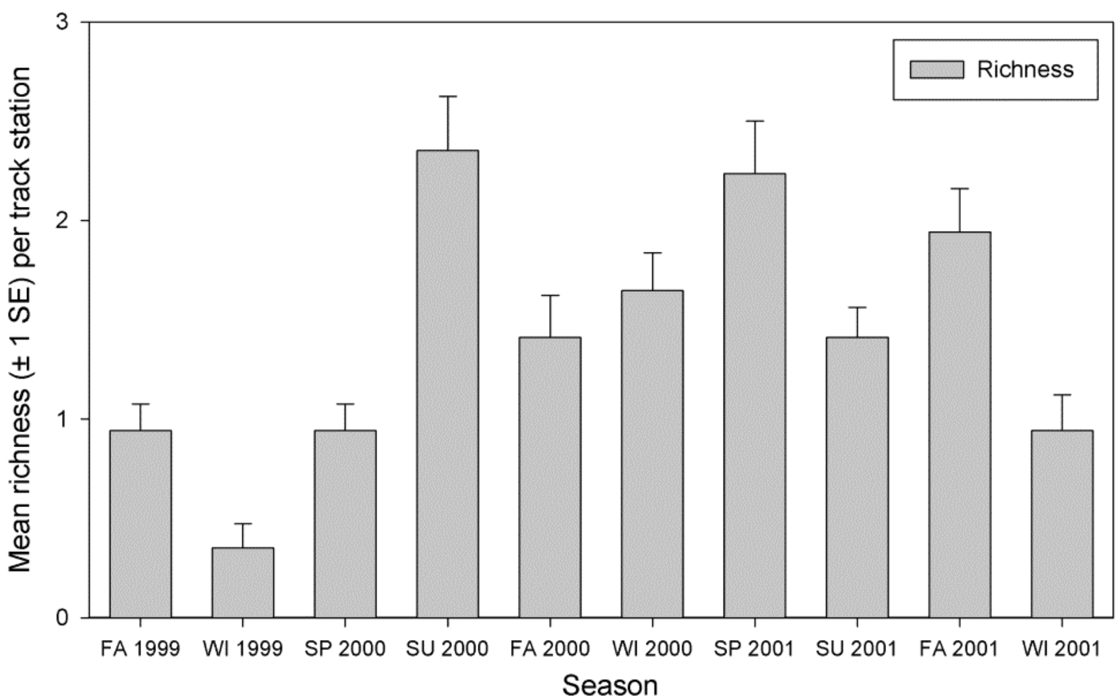

Figure 30. Seasonal richness of tracks observed on the track stations at the Tranquillity site, 1999 through 2001.

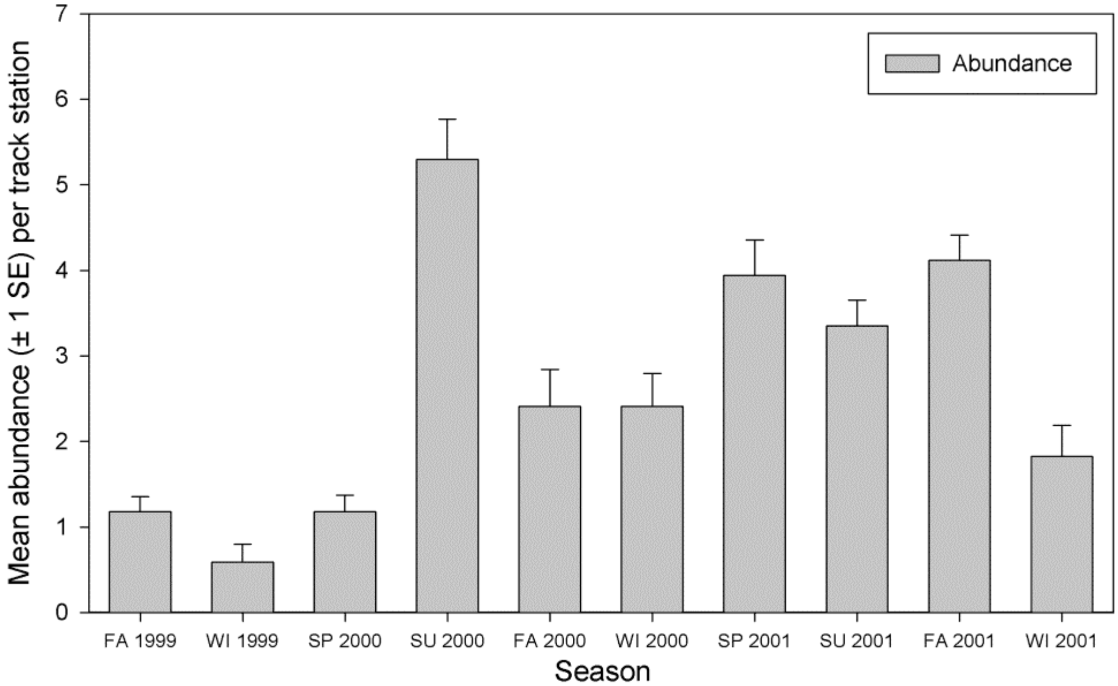

Figure 31. Seasonal abundance of tracks observed on the track stations at the Tranquillity site, 1999 through 2001.

Table 34. Frequency and rate of visitation of wildlife at track stations at the Tranquillity site, 1999 through 2001.

	Invertebrates		Amphibians		Reptiles		Birds		Mammals	
Season	**Freq.[1]**	**Rate[2]**	**Freq.[1]**	**Rate[2]**	**Freq.[1]**	**Rate[2]**	**Freq.[1]**	**Rate[2]**	**Freq.[1]**	**Rate[2]**
Fall 1999	100.0	0.18	0	0	0	0	0	0	100.0	0.14
Winter 1999	0	0	0	0	0	0	0	0	100.0	0.12
Spring 2000	33.3	0.08	0	0	0	0	33.3	0.06	33.3	0.18
Summer 2000	100.0	0.29	100.0	0.10	0	0	100.0	0.18	100.0	0.24
Fall 2000	100.0	0.21	66.7	0.06	0	0	100.0	0.04	100.0	0.16
Winter 2000	66.7	0.25	33.3	0.02	0	0	100.0	0.08	100.0	0.20
Spring 2001	100.0	0.12	66.7	0.04	0	0	100.0	0.14	100.0	0.31
Summer 2001	66.7	0.06	33.3	0.02	0	0	33.3	0.04	100.0	0.31
Fall 2001	66.7	0.16	66.7	0.04	33.3	0.02	100.0	0.06	100.0	0.31
Winter 2001	33.3	0.10	0	0	0	0	33.3	0.10	100.0	0.20

1. Frequency: the percentage of nights that tracks of a taxon were observed during a survey.
2. Rate: the number of track stations visited by a taxon divided by the total number of stations, averaged over the number of survey nights.

iii. Discussion

The high variability of track richness, abundance, frequency, and rate indicates that wildlife populations on the site are not showing a clear trend of steadily increasing numbers and not exhibiting an expansion in distribution. An increasing trend in wildlife numbers and expanding distributions would be expected on a site-wide basis in a response to restoration efforts, or even in response to the establishment of fallow fields. The lack of steadily increasing wildlife numbers or increasing distributions may not reflect responses to restoration, but rather, it may be related to the variability of seasonal and yearly climactic conditions in the San Joaquin Valley.

c. Winter Raptor Survey

i. Methods

The annual winter raptor survey was conducted from 18-20 December 2001 following methods that have been previously presented (Uptain et al. 2001).

ii. Results

Loggerhead shrikes (*Lanius ludovicianus*) and eight species of raptors were observed during the 2001 winter survey (Table 35). American kestrel (*Falco sparverius*) and northern harrier were the most prevalent raptor species observed. Red-tailed hawks, loggerhead shrikes, and white-tailed kites (*Elanus leucurus*) also were frequently observed. One peregrine falcon (*Falco peregrinus*), one rough-legged hawk (*Buteo lagupus*), and two ferruginous hawks (*Buteo regalis*) comprise the uncommon species that were recorded during the census.

Numbers of northern harriers increased slightly since 1999 (Table 35). Loggerhead shrikes were not recorded in 1999, but have increased in rate of occurrence since the 2000 census. The occurrence rates of both American kestrels and white-tailed kites have fluctuated throughout the 3 years of this census.

Table 35. Frequency and rate of occurrence of bird species observed at the Tranquillity site, 1999 - 2001.

Species		1999			2000			2001		
Common name	Scientific name	Total	Freq1	Rate2	Total	Freq1	Rate2	Total	Freq1	Rate2
white-tailed kite	*Elanus caeruleus*	6	66.7	17.1	15	100.0	45.0	7	100.0	18.8
ferruginous hawk	*Buteo regalis*	-	-	-	-	-	-	3	66.7	8.0
prairie falcon	*Falco mexicanus*	1	33.3	2.9	1	33.3	3.0	-	-	-
unidentified falcon	*Falco* sp.	-	-	-	1	33.3	3.0	-	-	-
loggerhead shrike[3]	*Lanius ludovicianus*	-	-	-	11	100.0	33.0	14	100.0	37.5

1. Frequency: Percent of surveys with positive observations.
2. Rate: Mean number observed per mile of survey.
3. Species not counted in 1999

iii. Discussion

This year was the first in which either a peregrine falcon or a ferruginous hawk, both of which are special status species, was seen on the Tranquillity site. The peregrine falcon was observed in pursuit of a small passerine species over one of the study plots. It is possible that both of these species have foraged on the study plots in the past, but were not present during an avian census or noticed while other field work was being conducted. Although the prairie falcon was not recorded during the 2001 winter raptor survey, it was observed during the quarterly avian survey in October 2001.

Home-range size varies among raptor species and generally can be correlated with prey availability, season, and habitat structure. Thus, fluctuations in occurrence rates at the LRDP site for many raptor species are likely attributable to larger landscape-level factors than to plot-level variables.

d. Contaminants Monitoring

i. Methods

Monitoring of selenium contamination of the Tranquillity site followed methods previously presented (Uptain et al. 2001). Vegetation, invertebrate, and small mammal samples were collected from the locations shown in Figure 32. Vegetation sampling was conducted on 10-11 May 2001, invertebrate sampling was conducted on 19-22 June 2001, and small mammal sampling was conducted on 5-6 September 2001. The sampling locations were classified as cultivated areas, uncultivated areas, and experimental areas. Cultivated areas were those where barley is being grown on the site or where other crops are being grown directly adjacent to the LRDP site. Uncultivated areas are those that are fallowed or idled. Samples from experimental areas are those taken directly from the HRS study plots. In previous analyses of contaminant data collected from the Tranquillity site (Selmon et al. 2000, Uptain et al. 2001), geometric means were not calculated for any group of data where one sample or more within a group had a selenium level below the detection limit. This limited our ability to interpret trends in the level of selenium contamination for several groups of data. In this report, when a sample contained less than the detection limit, the value for that sample was set at half the detection limit and a geometric mean was calculated for the data group. Geometric means are used rather than standard means or medians because biota tend to accumulate selenium in a non-linear fashion.

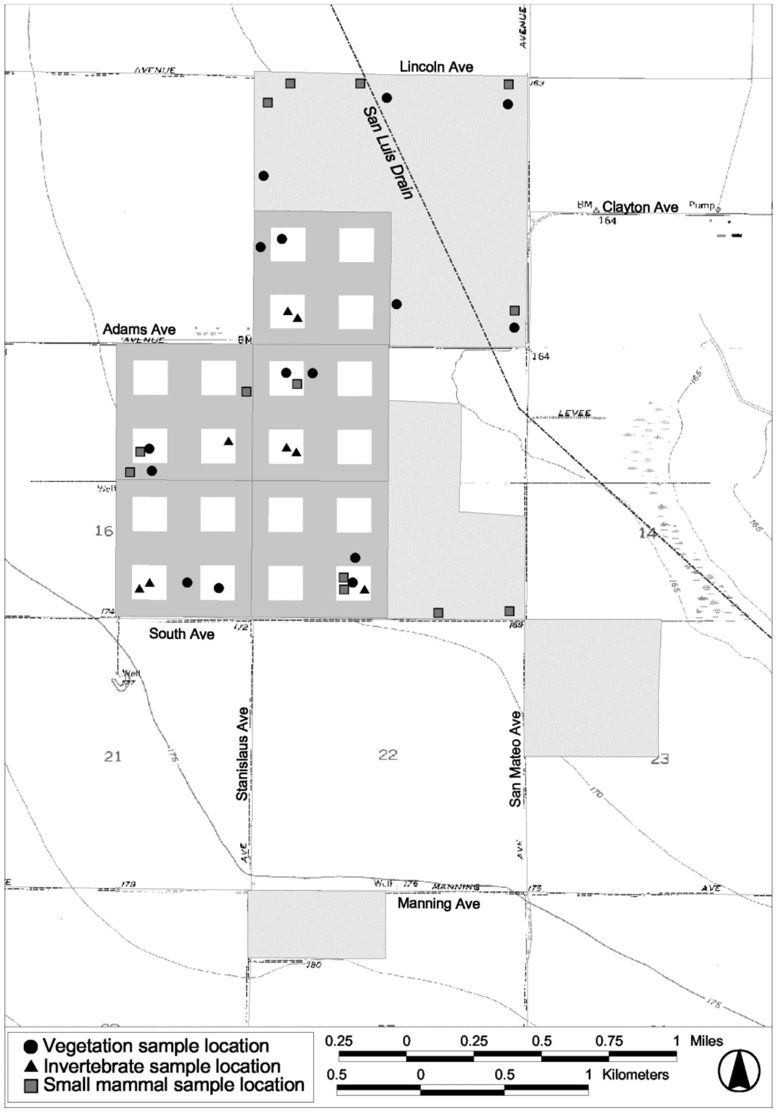

Figure 32. Sampling locations for contaminant monitoring at the Tranquillity site.

ii. Results

Vegetation

There were very few vegetation samples collected from any of the three collection areas (cultivated, uncultivated, and experimental) for selenium analysis in 1999 (Table 36). There were a variety of reasons for this including:

- the project was begun late in the year, when many of the plant species were dead and dried, making collections problematic,
- The cultivated and experimental areas were planted in irrigated barley, which containing a paucity of other species

- Project protocols were being developed, delaying implementation of some sampling, including the collection of contaminant samples.

Selenium concentrations in the four species collected in 1999, regardless of collection area, averaging 0.40 mg/kg or less). Similarly, in 2000 the mean selenium concentrations in most species remained at or below 0.50 mg/kg, except for *Brassica nigra* from cultivated areas, which had mean selenium concentrations of 0.96 and 1.01 mg/kg in seeds and vegetation. Similarly, *Brassica nigra* also had high selenium concentrations relative to other species in the experimental area in both 2000 and 2001. Selenium concentrations of all species sampled did not appreciably increase from 2000 to 2001.

We combined samples from each year into groups representing selenium accumulators (*Brassica nigra*, *Distichlis spicata*, *Heliotropium curassavicum*, and *Sesuvium verrucosum*) and non-accumulators for each of the three areas (cultivated, experimental, and uncultivated). This was done to increase the sample sizes (thus increasing the robustness of the results) and to compare selenium concentrations between accumulators and non-accumulators across sampling areas and years. Selenium concentrations in vegetation (either whole plant or seed) did not increase from 1999 to 2001 in any of the three collection areas at the Tranquillity site (Table 37). The group of accumulator plants did not vary across years or sampling areas to any great degree. Furthermore, the group of accumulator plants did not accumulate selenium at levels considered indicative of selenium accumulators (500 to 1,000 mg/kg).

Table 36. Selenium concentrations in plant species collected from the Tranquillity site

Land use	Taxon code[1]	Part	1999					2000					2001				
			N	Min	Max	Mean	SE	N	Min	Max	Mean	SE	N	Min	Max	Mean	SE
Cultivated	ATAR	Veg	1	0.20	0.20	0.20	0.00										
		Whole						5	0.10	0.63	0.37	0.11					
	AVFA	Whole						5	0.20	0.40	0.33	0.04					
	BRNI	Seeds						4	0.64	1.60	0.96	0.22					
		Veg						4	0.30	1.70	1.01	0.32					
	HOVU	Seeds						5	0.10	0.40	0.24	0.05	5	0.10	0.50	0.20	0.07
		Veg						5	0.10	0.63	0.26	0.09	11	0.30	1.30	0.43	0.09
	MEIN	Veg											3	0.10	0.40	0.16	0.10
	SIIR	Veg	1	0.40	0.40	0.40	0.00										
Experimental	ATAR	Veg	2	0.10	0.50	0.22	0.20	1	0.50	0.50	0.50	0.00	4	0.10	1.10	0.34	0.23
		Whole						4	0.10	0.40	0.26	0.07					
	ATPO	Veg											4	0.10	1.00	0.28	0.20
	AVFA	Whole						5	0.10	0.50	0.25	0.07					
	BEVU	Whole						4	0.10	0.73	0.33	0.13					
	BRMA	Seeds											1	0.10	0.10	0.10	0.00
	BRNI	Seeds						4	0.40	0.50	0.42	0.03	1	0.50	0.50	0.50	0.00
		Veg						4	0.10	0.88	0.44	0.18	1	0.60	0.60	0.60	0.00
	HOMU	Whole						1	0.10	0.10	0.10	0.00					
	HOVU	Seeds	5	0.10	0.30	0.20	0.04	5	0.10	0.40	0.17	0.07					
		Veg	5	0.10	0.40	0.20	0.05	5	0.10	0.50	0.18	0.09					
	SUMO	Veg											5	0.30	2.60	0.51	0.45

Land use	Taxon code[1]	Part	1999					2000					2001				
			N	Min	Max	Mean	SE	N	Min	Max	Mean	SE	N	Min	Max	Mean	SE
Uncultivated	ATAR	Veg	3	0.10	0.50	0.17	0.13						5	0.10	0.30	0.16	0.04
		Whole						5	0.10	0.20	0.11	0.02					
	BRMA	Seeds											5	0.10	0.10	0.10	0.00
		Whole						5	0.10	0.20	0.11	0.02					
	BRNI	Seeds						5	0.10	0.60	0.20	0.09	5	0.10	0.30	0.18	0.04
		Veg						5	0.10	0.40	0.19	0.06	5	0.10	0.50	0.26	0.07
	HECU	Seeds	1	0.10	0.10	0.10	0.00										
		Veg	1	0.10	0.10	0.10	0.00						1	0.40	0.40	0.40	0.00
		Whole						5	0.10	0.40	0.19	0.06					
	HOMU	Whole						3	0.10	0.30	0.14	0.07					
	MEIN	Veg											5	0.10	0.30	0.17	0.05
	PHDI	Seeds											3	0.10	0.20	0.16	0.03
		Veg											3	0.15	0.30	0.21	0.04

1. Vegetation taxonomic codes: ATAR-*Atriplex argentea*, AVFA-*Avena fatua*, BRNI-*Brassica nigra*, HOVU-*Hordeum vulgaris*, MEIN-*Melilotus indica*, SIIR-*Sisymbrium irio*, ATPO-*Atriplex polycarpa*, BEVU-*Beta vulgaris*, BRMA-*Bromus madritensis* var. *rubens*, HOMU-*Hordeum murinum*, SUMO-*Suaeda moquinii*, HECU-*Heliotropium curassavicum*, PHDI-*Phacelia distans.*

Table 37. Selenium concentrations in plant species grouped as selenium accumulators and selenium non-accumulators at the Tranquillity site

Land use	Accum.	Part	1999					2000					2001				
			N	Min	Max	GM	SE	N	Min	Max	GM	SE	N	Min	Max	GM	SE
Cultivated	No	Seeds						5	0.10	0.40	0.24	0.05	5	0.10	0.50	0.20	0.07
		Veg	1	0.20	0.20	0.20	0.00	6	0.10	0.63	0.30	0.09	14	0.10	1.30	0.35	0.08
		Whole	1	0.40	0.40	0.40	0.00	9	0.10	0.63	0.33	0.06					
	Yes	Seeds						4	0.64	1.60	0.96	0.22					
		Veg						4	0.30	1.70	1.01	0.32					
Experimental	No	Seeds	5	0.10	0.30	0.20	0.04	5	0.10	0.40	0.17	0.07	1	0.10	0.10	0.10	0.00
		Veg	7	0.10	0.50	0.21	0.06	6	0.10	0.50	0.22	0.08	13	0.10	2.60	0.37	0.19
		Whole						14	0.10	0.73	0.26	0.05					
	Yes	Seeds						4	0.40	0.50	0.42	0.03	1	0.50	0.50	0.50	0.00
		Veg						4	0.10	0.88	0.44	0.18	1	0.60	0.60	0.60	0.00
Uncultivated	No	Seeds											8	0.10	0.20	0.12	0.02
		Veg	3	0.10	0.50	0.17	0.13	1	0.10	0.10	0.10	0.00	13	0.10	0.30	0.17	0.02
		Whole						12	0.10	0.30	0.12	0.02					
	Yes	Seeds	1	0.10	0.10	0.10	0.00	5	0.10	0.60	0.20	0.09	5	0.10	0.30	0.16	0.05
		Veg	1	0.10	0.10	0.10	0.00	5	0.10	0.10	0.19	0.06	6	0.10	0.50	0.28	0.06
		Whole						3	0.10	3.90	1.12	1.22					

Invertebrates

Selenium concentrations in the four groups of invertebrates sampled (beetles, crickets, isopods, and spiders) did not vary from 1999 to 2001 (Table 38, Figure 33). However, there is a slight trend of increasing selenium levels in all groups except spiders. Isopods exhibited the highest concentrations of selenium levels in all years.

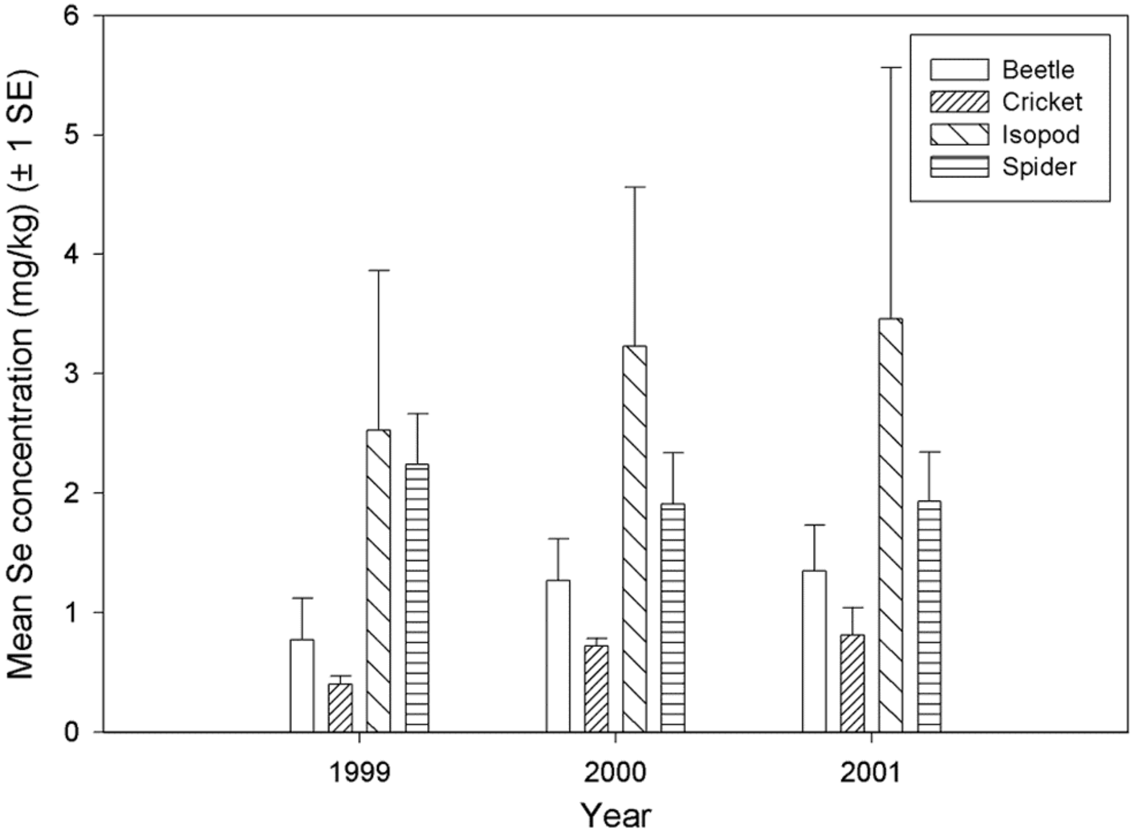

Figure 33. Selenium concentrations in invertebrates sampled from the Tranquillity site.

Table 38. Selenium concentrations in invertebrate species collected from the Tranquillity site

Land use	Taxon group	Part	1999 N	1999 Min	1999 Max	1999 mean	1999 SE	2000 N	2000 Min	2000 Max	2000 mean	2000 SE	2001 N	2001 Min	2001 Max	2001 mean	2001 SE
Experimental	Beetles	Body	2	0.50	1.20	0.77	0.35	5	0.60	2.70	1.27	0.35	5	0.70	2.80	1.35	0.38
	Crickets	Body	4	0.30	0.60	0.40	0.07	5	0.40	1.20	0.72	0.07	5	0.50	1.80	0.81	0.23
	Isopods	Body	3	1.00	5.60	2.53	1.33	5	2.20	4.50	3.23	1.33	5	2.10	13.00	3.46	2.10
	Spiders	Body	5	1.10	3.60	2.24	0.43	5	0.90	2.70	1.91	0.43	5	0.95	3.20	1.93	0.41

Small mammals

Body and liver samples of small mammals collected from all sample locations (cultivated, uncultivated, and experimental) did not vary in selenium concentrations from 1999 to 2001 (Table 39). However, there are trends of decreasing concentrations of selenium in all groups sampled for all sample locations.). The selenium levels in all small mammals captured during all seasons remain below the level considered to be problematic (5 ppm).

Table 39. Selenium concentrations in mammal species collected from the Tranquillity site

Land use	Taxon code[1]	Part	1999 N	1999 Min	1999 Max	1999 mean	1999 SE	2000 N	2000 Min	2000 Max	2000 mean	2000 SE	2001 N	2001 Min	2001 Max	2001 mean	2001 SE
Cultivated	PEMA	Body	5	1.00	1.50	1.21	0.08	5	0.95	1.70	1.42	0.14	6	0.91	1.40	1.19	0.08
		Liver	5	3.30	3.90	3.57	0.10	5	3.10	5.50	3.84	0.42	6	2.30	3.80	3.11	0.20
Experimental	SOOR	Body						13	2.00	4.80	2.51	0.21	6	1.60	2.90	1.95	0.19
		Liver						13	3.40	7.80	4.18	0.34	6	2.90	5.80	3.65	0.45
Uncultivated	PEMA	Body	5	0.75	1.10	0.94	0.07	5	0.73	1.00	0.82	0.05	5	0.50	0.85	0.63	0.06
		Liver	5	2.90	4.40	3.58	0.28	5	1.60	3.90	2.67	0.42	5	0.74	2.30	1.56	0.29

1. Mammal taxonomic codes: PEMA-*Peromyscus maniculatus* (deer mice), SOOR-*Sorex Ornatus* (ornate shrew)

iii. Discussion

The results of our monitoring to date indicate that bio-accumulation of selenium does not appear to be a concern on retired agricultural land at the Tranquillity site. .Selenium levels in most biotic groups sampled on the Tranquillity site generally fall within the range of typical background levels. Typical background levels of selenium in terrestrial plants range from 0.01 - 0.6 mg/kg (USDI 1998). *Brassica nigra* collected from cultivated areas exceeded this range, but *B. nigra* is a known selenium accumulator. Known selenium accumulators can accumulate selenium to levels as high as 500 - 1,000 mg/kg (Rosenfeld and Beath 1964), far exceeding the levels observed in *B. nigra*. Typical background selenium levels of terrestrial invertebrates are 0.1 - 2.5 mg/kg. The mean (geometric mean) selenium level of beetles and crickets fell within this range, but selenium levels in isopods and spiders slightly exceeded this range. Selenium levels in spiders and isopods are expected to exceed those in beetles and crickets because of dietary differences that lead to bio-accumulation of selenium. Beetles and crickets generally feed on vegetation whereas spiders are predatory and isopods feed on detritus. Typical background levels of selenium in small mammals are <1.0 - 4.0 mg/kg for whole body samples and 1.0 - 10.0 mg/kg for liver samples (USDI 1998). The mean selenium levels of body and liver samples from both deer mice and shrews are at the lower end of these ranges.

3. Management

a. Cover Crop Production

In 2001, barley was grown as a cover crop on the 80-acre parcel located along Manning Avenue and in a 40-acre parcel east of the study plots. The barley on both sites was harvested in June. In the winter of 2001-2002, the 80-acre parcel was planted with a restoration mix and the 40-acre parcel was used as a berm trial area, native plant nursery, and barley/seed mix strip trial area (see section III A 1).

b. Grazing

No managed grazing occurred on the LRDP Tranquillity site in 2001. However, trespass grazing did occur in the 160-acre restoration area that is located southeast of the HRS study blocks. The sheep owner had permission to graze sheep south of South Avenue from Westlands Water District and inadvertently encroached upon project lands. Temporary fencing was erected on the parcel and sheep were grazed for a total of 4 days from 8-11 October 2001. The level of grazing was intense enough to virtually denude the parcel of all vegetation. Fortunately, the native plants that germinated from the restoration effort had gone to seed and disarticulated prior to the grazing. Additionally, most of the shrub seedlings that were planted did not survive, although grazing did destroy the few seedlings that persisted. The sheep also trampled and destroyed the majority of the low berms that had been installed in the parcel. Monitoring of the site will occur in spring 2002 to determine if native annual plants remain on the site and to determine the effects of grazing on the non-native weeds (mostly *Sisymbrium* and *Brassica*) that dominated the site.

c. Recreational Uses

The California Department of Fish and Game has annually planted approximately 60 acres of the Tranquillity site in safflower. The safflower field is used for an annual junior dove hunt in September. In 2001, 35 hunters harvested 213 dove during the hunt.

B. Atwell Island

1. Restoration Studies

a. Small Test Plots

During the Fall of 2001 USBLM established a series of 456, 1/1000-acre (6ft 7in x 6ft 7in) test plots in the southwest quarter of Section 23 (Figure 34). 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.

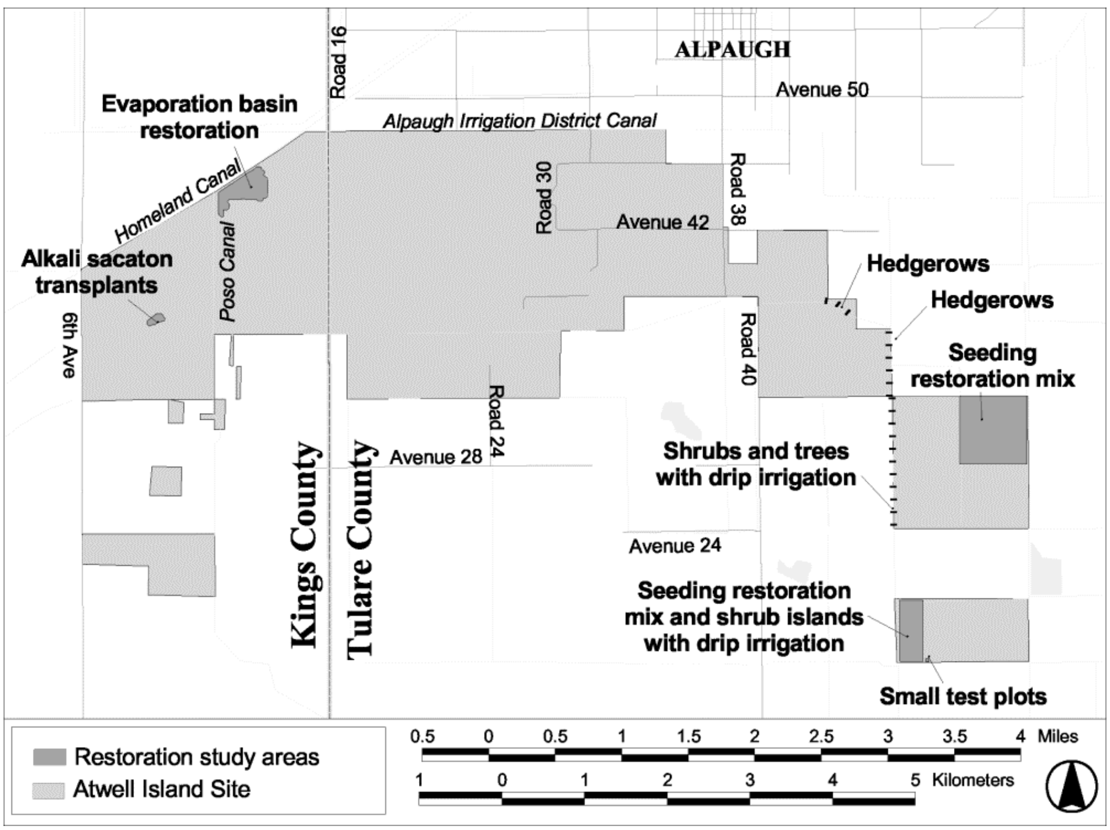

Figure 34. Locations of restoration studies conducted at the Atwell Island site.

A standard seeding rate of 40 pounds/acre was used on these plots for each site preparation. On the scraped area, in addition to the 40 pounds/acre seeding rate, plots with other seeding rates were established: 1) 10 pounds/acre, 2) 80 pounds/acre, and 3) 160 pounds/acre. On the disked area, plots with added 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/ac effectively doubled and tripled the available soil phosphorus and nitrogen in the soil. An additional treatment of 500 lbs/ac of both blood and bone meal was used.

These test plots are being used as a screening technique to look for broad effects and are the first step of a tiered approach. This year's work will be used to search for interesting trends and to help focus future, more in-depth, research. In the second year, if promising species or trends have emerged, USBLM will set up more in-depth trials involving those species and treatments. In this second stage an experimental approach with replicates will be used.

Plots will be monitored by USBLM during the spring of 2002 and in succeeding years. Additional plots will be established in fall of 2002 to look at various weed competition factors and several seed mixes.

b. Hedgerows

During February of 2001, six 0.25-mile long hedgerows were planted in the northeast quarter of Section 10 (Figure 34). This was done using a Rhino plow to dig the ditches and then a Truax range drill to seed over the ditches with a commercial hedgerow mix (60% bran and 40% native seed). The seed mix contained 29% quail bush (*Atriplex lentiformis*), 22% creeping wildrye (*Leymus triticoides*), 14% few-flowered fescue (*Vulpia microstachys*), 14% fiddleneck (*Amsinkia menziesii*), 7% common sunflower (*Helianthus annus*), 7% alkali heath (*Frankenia salina*), 4% turkey mullein (*Eremocarpus setigerus*), 1% bluedicks (*Dichelostemma capitatum*), and 1% spikeweed (*Hemizonia pungens*). The ditches were watered twice, once in May and once in July.

These hedgerows were very successful, with good coverage of sunflower and excellent growth and establishment of quail bush, many of which reached 1.0 m in height by February 2002. As a result of this success, we will establish an additional 38, 0.5-mile long hedgerows in the south east quarter of Section 10 (Figure 34) in 2002. These will be planted in two configurations; a series of four ditches 6 ft apart and single wavy line ditches. Six hedgerows will be seeded with the commercial mix and the remaining ditches will be seeded with a combination of wild-collected quail bush (25%), valley salt bush (25%), sunflower (35%), and alkali sacaton (15%) at a rate of approximately 30 pounds per acre. These hedgerows will be watered two or three times during the season, starting in early March 2002. Approximately 20 acres of this 160 acre quarter section will be planted, but the hedgerows are spread throughout the quarter section.

c. Seeding Restoration Mix

The USBLM seeded a total of 160 acres with restoration mix in January 2001 using a Truax range drill (Figure 34). Only moderate germination was observed, probably due to the lack of spring rain. This site will be monitored in spring 2002.

In late November 2001, 80 acres in Section 23 were seeded. Forty acres were seeded with the restoration mix at approximately 30 pounds/acre and 40 acres with local wild-collected spikeweed seed. The commercial restoration mix was purchased from S&S Seed Company and consisted of 7% *Eremocarpus setigerus*, 3% *Sporobolus airoides*, 2% *Frankenia salina*, 0.3% *Hemizonia pungens*, 1.5% *Lasthenia californica*, 9% *Atriplex* *polycarpa*, 9% *Atriplex spinifera*, 3% *Vulpia microstachys*, 3% *Gilia tricolor diffusa*, 3% *Suaeda moquinii*, 3% *Isocoma acradenia*, and 56% bran. The restoration mix was seeded at a rate of 11.1 pounds of seed/acre. All except four seeding passes were made with the imprinter. The range drill was used on four passes, but was discontinued because the soil was too moist causing the planter to clog. As of mid-February 2002, germination of these plantings has been excellent. The range-drilled areas appear to have better germination than the imprinted areas, primarily because the range drill did a better job at clearing residual vegetation from the soil.

In three areas, approximately 30 by 90 ft in extent, residual and green vegetation was burned off using a hand-held propane torch immediately prior to planting. An inspection in early February 2002 showed germination similar to that of the non-burned areas. By late February 2002, survival and growth of seedlings was much higher on the burned areas than on non-burned plots. Native species observed were *Vulpia* sp., *Gilia* sp., *Lasthenia* sp.(included in seed mix), and California Mustard (*Guillenia lasiophylla*; not in the seed mix).

d. Shrubs and Trees with Drip Irrigation

Approximately 150 cuttings (rooted in supercells—10 in deep plastic containers) of native trees and shrubs were planted along the Alpaugh Irrigation District Canal in Section 14 (Figure 34). Drip irrigation was installed and the plantings were watered with a small portable pump, with the water pumped from the canal. Quail Bush shrubs had high survival and good growth rates, reaching 3 ft in height. The cottonwoods and *Baccharis salicifolia* plantings had zero survival, primarily because of a grasshopper plague in mid-summer. The grasshoppers ate the leaves and the bark of the trees and shrubs. It is likely that this was an aberrant situation and the planting will be re-tried in 2002.

Additional plantings with 8-ft-long poles will be done along the canal in Section 10 using a hydraulic auger in March 2002. This method places the rooting zone of the plant in ground water seepage from the canal, thus avoiding the need for drip irrigation.

e. Shrub Islands with Drip Irrigation

During fall 2001, a drip irrigation system to help establish shrub islands was placed on the 80 acres that were planted with the range drill in Section 23 (Figure 34). Twelve lines, each 1,000 ft long with a total of 1,400 emitters, were installed. The purpose of this irrigation system is to provide supplemental water to help increase survival of shrubs through their first growing season. Seedlings were planted at approximately 300 emitters, while at the other 1,100 emitters seeds were planted. Seedlings were primarily *Atriplex polycarpa*, *Isocoma acradenia*, and *Sporobolus airoides*, with some *Atriplex lentiformis*. Seed was composed of both native and commercial *Atriplex polycarpa* and *Atriplex lentiformis*.

f. Alkali Sacaton Transplants

A patch of 266 alkali sacaton (*Sporobolus airoides*) seedlings was planted along sand ridge in Section 11 in mid-January 2002 (Figure 34). These plants will be watered during the first growing season.

g. Evaporation Basin Restoration

The Evaporation Basin—an approximately 33-acre former evaporation basin located along the western edge of the Atwell Island LRDP property (Figure 34)—was targeted for a cursory restoration trial in late 2001. The evaporation basin is characterized by a flat expanse of highly alkaline, salt-encrusted soil, nearly devoid of vegetation; however, adjacent lands, which are managed by the USBLM, support fair-sized populations of native alkali sink vegetation. The Evaporation Basin was in intermittent closure in 1999, and has had no discharges from tile drains since 1994. Selenium levels were tested in 1994 and were found to be below the detection limit (Interagency Land Retirement Team 1999).

Restoration efforts conducted by ESRP occurred during November and December 2001. Only outer edges of the evaporation basin were accessible, as rainfall at that time had created extremely wet and muddy conditions. Vegetation was introduced to the site by both seeding and transplanting. Areas to be seeded were prepared by loosening the soil with rakes. Native seed from adjacent properties was collected and then broadcast onto the raked seedbeds. Species planted in this manner were: *Allenrolfea occidentalis*, *Distichlis spicata*, *Frankenia salina*, *Heliotropium curassavicum*, and *Suaeda moquinii*. Two of these, *Distichlis spicata* and *Allenrolfea occidentalis*, also were introduced to the site through transplanting. Rhizomes of *D. spicata* that were growing along the perimeter and encroaching onto the salt flat were transplanted onto the restoration area. Plugs of *Allenrolfea occidentalis* were grown by the Southern California Edison Nursery (Auberry) from native seed collected from the Tranquillity area, and were transplanted directly onto the site. At this time, there are no plans to conduct quantitative sampling at the site; rather, the success of the restoration will be monitored non-systematically. Additional planting efforts will be conducted in the evaporation basin as time and resources permit.

h. Native Seed Collection

During 2001 USBLM contracted with four seed collectors to collect native seed in the southern San Joaquin Valley. The spring collection in the Goose Lake area netted 90 pounds of goldfields (*Lasthenia californica*) seed, 0.5 pounds of few-flowered fescue (*Vulpia microstachys*) seed, and 1.5 pounds of slender-hair grass (*Deschampsia danthonioides*) seed. The early fall seed collections yielded 202 pounds of bush seepweed (*Suaeda moquinii*), 778 pounds of spiny saltbush (*Atriplex spinifera*), 78 pounds of alkali heath (*Frankenia salina*), 379 pounds of spikeweed (*Hemizonia pungens*), 1 pound of alkali sacaton (*Sporobolus airoides*), 124 pounds of alkali mallow (*Malvella leprosa*), 3.2 pounds of alkali heliotrope (*Heliotropium curassavicum*), 1 pound of slender-leaf milkweed (*Asclepias fascicularis*), 277 pounds of common sunflower (*Helianthus annuus*), and 5 pounds of goldenbush (*Isocoma acradenia*). The late fall seed collecting yielded 404 pounds of valley saltbush (*Atriplex polycarpa*) and 148 pounds of quail bush (*Atriplex lentiformis*). The weights given above are for cleaned seed, but some chaff and seed husks are included (the amount varies by species).

Nearby natural areas that will serve as reference and seed source sites for restoration efforts include Kern National Wildlife Refuge, Pixley National Wildlife Refuge, Allensworth State Ecological Reserve, and other southern San Joaquin Valley sites managed by California Department of Fish and Game and the Center for Natural Lands Management.

2. Biological Monitoring

ESRP conducted monitoring on a site-wide basis in 2001, which was not directly related to the Atwell Island Habitat Restoration Study. Monitoring consisted of:

- spotlighting surveys;
- track station surveys;
- winter raptor surveys;
- contaminants sampling (vegetation, invertebrates, and small mammals).

Locations of these sampling activities is presented in Figure 35. Additionally, USBLM conducted a winter bird count and constructed a database to record incidental wildlife observations.

Figure 35. Sampling locations for site-wide biological monitoring at the Atwell Island site.

a. Spotlighting Surveys

i. Methods

Spotlighting surveys of the Atwell Island site were conducted on 17-19 September and 10-12 December following methods that have been previously presented (Uptain et al. 2001).

ii. Results

The most commonly observed species during September spotlighting were barn owls, kangaroo rats, western toads, and desert cottontails (Table 40). During December spotlighting, the most common species observed were desert cottontails, barn owls, black-crowned night herons (*Nycticorax nycticorax*), black-tailed jackrabbits, and great egrets (*Ardea alba*). The number of species observed in September (18) was greater than the number observed in December (15) and there were differences in species composition.

Table 40. Frequency and rate of animals observed during spotlighting surveys at the Atwell Island site, 2001.

Taxon	Fall 2001		Winter 2001	
	Frequency[1]	Rate[2]	Frequency[1]	Rate[2]
bats	66.7	0.08	0	0
black-crowned night heron	66.7	0.14	66.7	0.21
black-tailed hare	100.0	0.12	66.7	0.21
burrowing owl	66.7	0.05	100.0	0.12
carp	33.3	0.02	0	0
cat	0	0	33.3	0.02
coyote	100.0	0.05	33.3	0.04
deer mouse	33.3	0.04	0	0
desert cottontail	100.0	0.16	100.0	0.46
dog	66.7	0.05	33.3	0.07
great blue heron	33.3	0.02	33.3	0.02
great egret	66.7	0.04	100.0	0.20
kangaroo rat	100.0	0.25	33.3	0.02
killdeer	33.3	0.02	0	0
prairie falcon	0	0	33.3	0.02
red-tailed hawk	0	0	100.0	0.07
snowy egret	0	0	66.7	0.11
western meadowlark	100.0	0.09	100.0	0.21

1.Frequency: percent of surveys with positive observations.
2.Rate: mean number observed per mile of survey.

iii. Discussion

Rates of observation (an index of abundance), frequency of observation, and species composition are expected to differ seasonally. As expected, each of these indices decreased from September to December. As restoration efforts are expanded, we would expect increases in small mammals, birds, and predators on those species.

b. Track Station surveys

i. Methods

Track station surveys of the Atwell Island site were conducted on 18-20 September and 11-13 December following the methods presented previously (Uptain et al. 2001).

ii. Results

The greatest abundance of tracks and the greatest variety of species were observed during the September survey period. The most abundant tracks observed in September were of mice, insects, kangaroo rats, and toads. The most abundant tracks observed in December were of mice, birds, and dogs. The frequency and rate of visitation of invertebrates, amphibians, and reptiles were higher in fall than in winter (Table 41). Likewise, the rate of visitation (but not frequency) for birds and mammals was higher in the fall.

Table 41. Results of track station surveys at the Atwell Island site, 2001.

	Fall 2001		Winter 2001	
Taxon	**Frequency[1]**	**Rate[2]**	**Frequency[1]**	**Rate[2]**
Invertebrates	100.0	0.17	33.3	0.04
Amphibians	100.0	0.13	0	0
Reptiles	33.3	0.04	0	0
Birds	100.0	0.11	100.0	0.09
Mammals	100.0	0.30	100.0	0.13
Unknown	0	0	66.7	0.04

1. Frequency: the percentage of nights that tracks of a taxon were observed during a survey.
2. Rate: the number of track stations visited by a taxon divided by the total number of stations, averaged over the number of survey nights.

iii. Discussion

We expect that the variety of species and abundance of tracks at the track stations will increase as restoration efforts at the site proceed. Invertebrates, mice, birds, and carnivore visits are especially likely to increase.

c. Winter Raptor Survey

i. Methods

Winter raptor surveys of the Atwell Island site were conducted from 11-13 December 2001 and followed methods presented previously (Uptain et al. 2001).

ii. Results

Eight species of raptors, along with loggerhead shrikes, were documented on the winter raptor survey route (Table 42). Though technically a passerine species, loggerhead shrikes are considered to be an avian predator and are included in this census. The predominant raptors observed were red-tailed hawks and northern harriers (Table 42). American kestrels, white-tailed kites, and loggerhead shrikes were identified each of the three survey dates, but in lower numbers than the former two species. Prairie falcons (*Falco mexicanus*), and ferruginous hawks were observed intermittently throughout the census. A single red-shouldered hawk was detected on the first day of the census. Four species recorded on this census are considered species of special concern in California (CSC) or federal special concern species (FSC): loggerhead shrike (FSC, CSC), ferruginous hawk (FSC, CSC), prairie falcon (CSC), and northern harrier (CSC).

Table 42. Number of observations, frequency, and rate of wintering raptors at the Atwell Island site, 2001.

Species		December			Total[1]	Frequency[2]	Rate[3]
White-tailed Kite	*Elanus caeruleus*	2	4	3	9	100	0.14
Northern harrier	*Circus cyaneus*	12	13	12	37	100	0.56
Ferruginous Hawk	*Buteo regalis*	2	3	0	5	67	0.08
Loggerhead Shrike	*Lanius ludovicianus*	3	9	6	18	100	0.27
Unidentified		2	2	2	6	100	0.09
Total number observed		**44**	**59**	**57**	**160**		

1. Number of observations: total seen per day and total seen during the 3-day survey.
2. Frequency: percent of surveys with positive observations.
3. Rate: mean number seen per mile of survey route.

iii. Discussion

American kestrels, northern harriers, and a single prairie falcon were observed foraging on, or adjacent to, the study plots. All three species are known to feed on small birds along with other prey items. Large flocks of horned larks, which were present on some of the study plots, may be providing a prey source for these three raptors. Red-tailed hawks, white-tailed kites, and northern harriers all were observed performing aerial displays over LRDP lands. White-tailed kites begin courtship behavior and nest building in December and January (Dunk 1995); hence, it is conceivable that these displays represented pair-bonding.

The red-shouldered hawk was an unexpected species considering the open habitat that occurs along the survey route. Red-shouldered hawks typically occur in riparian forests or oak woodlands (Kauffman 1996). This individual was flushed from an open, brushy area along the route that is not representative of its normal habitat. However, a narrow strip of marginal riparian habitat does exist within the vicinity that may support this individual.

The timing of this survey reflects the propensity of numerous raptor species to winter in this region. However, this census is not a complete representation of all raptors using LRDP lands. Species such as Swainson's hawk (*Buteo swainsoni*) may forage over the project site during the breeding season, but migrate south during the winter months. Thus, this species probably would be absent during the census.

d. Mid-winter Bird Count

An 8-hour bird count was conducted by USBLM personnel and volunteers on 26 December 2001. A total of 71 bird species were found during the day and 4,190 individual birds were recorded. The most common species were: red-winged blackbird (1,408), house finch (362), white-crowned sparrow (314), savannah sparrow (291), horned lark (184), and European starling (176). This count will be repeated yearly. In the future, two or three groups will be recruited to help with the count in order to get better coverage of the area.

e. Incidental Wildlife Sighting Database

Beginning in August 2001, USBLM started a database to keep track of incidental wildlife sightings. As of February 2002, 681 observations have been made, recording 102 species of birds, 5 species of mammals, 2 species of reptiles, and 5 species of butterflies on the Atwell Island Project Area. Noteworthy sightings include merlin, Swainson's hawk, prairie falcon, white-tailed kite, white pelican (*Pelecanus erythrorhynchos*), white-faced ibis (*Plegadis chihi*), Virginia rail (*Rallus limicola*), sandhill crane (*Grus canadensis*), redhead (*Aythya americana*), long-billed curlew (*Numenius americanus*), herring gull (*Larus argentatus*), yellow warbler (*Dendroica petechia*), chestnut-collared longspur (*Calcarius ornatus*), and coast horned lizard.

f. Contaminants Monitoring

i. Methods

Monitoring of selenium contamination of the Atwell Island site was conducted on 16 May (vegetation) and 12-13 June 2001 (invertebrates). Methods were previously presented (Uptain et al. 2001). Vegetation, invertebrate, and small mammal samples were collected from the locations shown in Figure 36. Sampling locations were classified as cultivated areas, uncultivated areas, and experimental areas. Samples were collected in both 2000 and 2001 to provide information on baseline conditions. For analysis, plants were grouped as selenium accumulators (those plant species known to accumulate selenium in their tissues), and non accumulators. Small mammal tissues that were collected in 2001 spoiled prior to being frozen in the lab. Therefore, a representation of baseline conditions of selenium contamination in small mammals at the Atwell Island site was derived solely from data collected in 2000 during the pre-project inventory (see Appendix A in Uptain et al. 2001). In previous reports (Selmon et al. 2000, Uptain et al. 2001), geometric means of contaminant samples were not calculated on a group of data whenever one or more samples within the group had a selenium level below the detection limit. In this report, when a sample contained less than the detection limit, the value for that sample was set at half of the detection limit and the geometric mean was calculated for the data group.

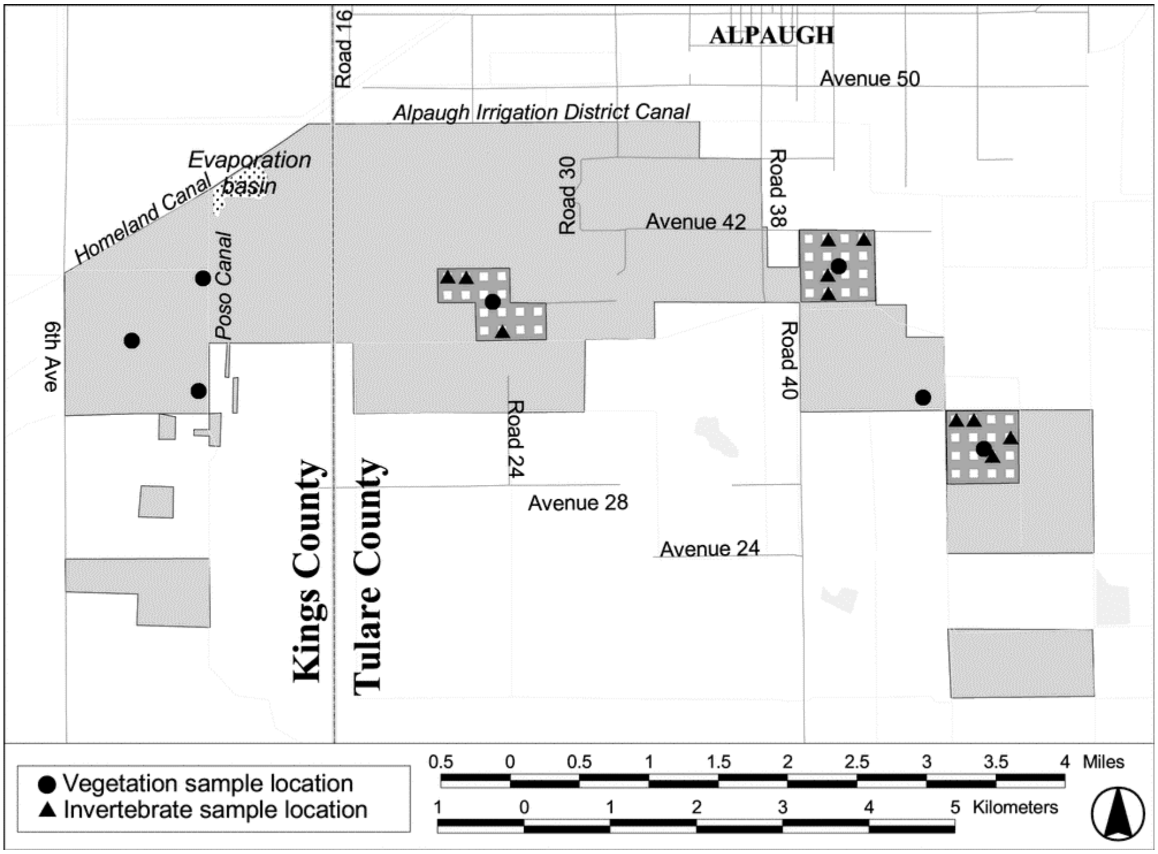

Figure 36. Locations of selenium sampling at the Atwell Island site.

ii. Results

The geometric means of the samples collected for all taxa had selenium concentrations within the range of typical background levels (see Table 43, Table 44, Table 45 and section III A d iii of this report). Furthermore, all taxa exhibited trends of declining selenium levels between 2000 and 2001 (except small mammal data because no data were available for 2001).

Table 43. Selenium levels in samples of vegetation collected from the Atwell Island site during baseline surveys in 2000 and 2001.

Land use	Taxon code	Part	2000					2001				
			N	Min	Max	Mean	SE	N	Min	Max	Mean	SE
Cultivated	ATAR	Veg						3	0.1	0.1	0.1	0.000
	HOMU	Seeds						3	0.1	0.1	0.1	0.000
	HOVU	Seeds						3	0.1	0.1	0.1	0.000
		Veg						3	0.1	0.1	0.1	0.000
	MEIN	Veg						3	0.1	0.1	0.1	0.000
Uncultivated	ATAR	Whole	10	0.1	0.4	0.11	0.030	3	0.1	0.3	0.14	0.067
	BRMA	Seeds						3	0.1	0.2	0.13	0.033
		Veg	1	0.1	0.1	0.1	0.000					
	BRNI	Seeds	5	0.1	0.1	0.1	0.000					
		Veg	4	0.2	0.5	0.3	0.075					
		Whole	1	0.1	0.1	0.1	0.000					
	CRTR	Whole	9	0.1	0.3	0.13	0.029					
	DISP	Whole	5	0.05	1.4	0.17	0.259					
	HECU	Veg						3	0.1	0.1	0.1	0.000
	HEPU	Veg						3	0.1	0.2	0.13	0.033
		Whole	8	0.05	0.2	0.08	0.018					
	HOMU	Seeds						3	0.1	0.3	0.14	0.067
		Whole	10	0.05	0.1	0.09	0.005					
	MEIN	Veg						1	0.1	0.1	0.1	0.000
		Whole	10	0.05	0.15	0.09	0.009					
	SIIR	Whole	4	0.05	0.1	0.08	0.013					

1. Vegetation taxonomic codes: ATAR-*Atriplex argentea*, HOMU-*Hordeum murinum*, HOVU-*Hordeum vulgaris*, MEIN-*Melilotus indica*, BRMA-*Bromus madritensis* var. *rubens*, BRNI-*Brassica nigra*, CRTR-*Cressa truxillensis*, DISP-*Distichlis spicatum*, HECU-*Heliotropium curassavicum*, SIIR-*Sisymbrium irio*.

Table 44. Selenium levels in samples of invertebrates collected from the Atwell Island site during baseline surveys in 2000 and 2001.

Land use	Taxon group	Part	2000 N	2000 Min	2000 Max	2000 mean	2000 SE	2001 N	2001 Min	2001 Max	2001 mean	2001 SE
Uncultivated	Beetles	Body						8	0.04	0.4	0.13	0.051
	Crickets	Body						9	0.1	0.45	0.18	0.037
	Isopods	Body						9	0.07	0.6	0.33	0.067
	Spiders	Body						9	0.29	1	0.55	0.075
Experimental	Beetles	Body	10	0.1	1	0.49	0.125					
	Crickets	Body	3	0.2	1	0.39	0.252					
	Isopods	Body	12	0.1	1.5	0.38	0.104					
	Spiders	Body	11	0.35	2.5	0.81	0.227					

Table 45. Selenium levels in samples of small mammals collected from the Atwell Island site during baseline surveys in 2000 and 2001.

Land use	Taxon group	Part	2000 N	2000 Min	2000 Max	2000 mean	2000 SE
Uncultivated	*Peromyscus maniculatus (deer mice)*	Body	10	0.5	0.82	0.68	0.034
		Liver	10	1.9	3.4	2.37	0.151

iii. Discussion

Data for the Atwell Island site will be collected in 2002 and compared to the baseline data presented here. It is expected that selenium levels will continue to decline, as has occurred on the Tranquillity site.

3. Management

a. Controlled Burning

The USBLM completed an Environmental Assessment (USBLM 2001) for controlled burning on the project area. A controlled burn was conducted by a USBLM fire crew along a canal on the south side of Section 23 in mid-November 2001.

b. Game Bird Heritage Program Dove Hunt

During the summer of 2001, safflower was planted on 60 acres and barley was planted on 10 acres of Section 10 (see Figure 34). This was a cooperative project between USBLM and California Department of Fish and Game, with USBLM furnishing the water and labor and CDFG purchasing the seed. The safflower was grown with approximately 0.5 acre-feet of water applied in pre-planting irrigation. The lack of spring rain was responsible for poor seed production of the safflower. The plants grew to normal size and produced abundant seed heads, but most heads had only one or two seeds and most seeds were "blanks" (i.e. only the shell had formed and there was no seed inside). The hunt was conducted on opening day of dove hunting season in early September. Twenty seven hunters attended the hunt and harvested only 13 doves. This cooperative project will be repeated during 2002, but the site will be moved to a location with better soil and closer to roosting sites along the Alpaugh Irrigation District Canal in Section 5.

IV. PHYSICAL IMPACTS

A. Tranquillity Site

1. Tranquillity Site 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 (in Section 10), 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 (in Sections 15 and 16), 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. Tranquillity Site Soils

Soils in the Tranquillity Demonstration Project area consist of clays and loams, which formed in alluvium, derived from igneous and sedimentary rock. Individual soil mapping units in order of abundance in the project area include the Tranquility clay, Lillis Clay, and the 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 37). 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 a test pit located in the NW 1/4 of Section 16 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 soil water 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 37). 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 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 soil water 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 37). 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).

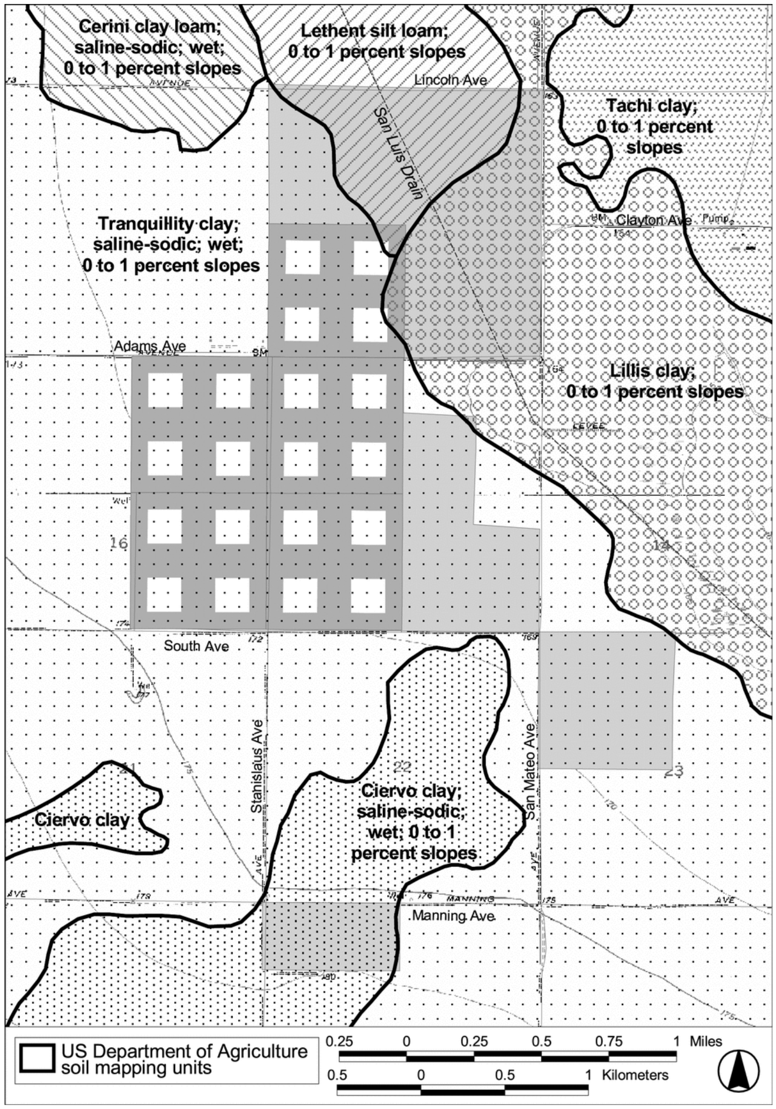

Figure 37. U.S. Department of Agriculture soil mapping units, Tranquillity site.

a. Soil Sampling: Tranquillity Site

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. This report is available on the USBR website at http://www.mp.usbr.gov/regional/landret/2000annrpt/html/index.html or by request from Mr. Robert May, the USBR Land Retirement Program Manager.

3. Weather: Tranquillity Site

Hourly precipitation, temperature, wind and relative humidity data are 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 8.9 inches of rainfall was recorded at the CIMIS station, with most of the rainfall occurring between January and June (Table 46).

Table 46. Monthly CIMIS weather data and estimated barley crop water use at the Tranquillity site for calendar Year 2001.

Month (2001)	Reference evapotranspiration (inches)	Barley crop coefficient	Estimated evapotranspiration barley (inches)	Measured precipitation (inches)
January	1.46	0.3	0.44	1.69
February	1.98	1.18	2.34	1.06
March	4.00	1.18	4.72	0.40
April	5.30	1.18	6.25	0
May	9.69	0.40	3.88	2.26
June	9.84	0.20	1.97	0.78
July	8.46	Not applicable	0	0
August	8.26	Not applicable	0	0
September	6.39	Not applicable	0	0.02
October	4.56	Not applicable	0	0
November	1.98	Not applicable	0	1.39
December	1.01	Not applicable	0	1.28
Total	**62.93**			**8.88**

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 the DWR. 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 (DWR 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 UC 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 (DWR 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 (DWR 2000).

Monthly barley crop consumptive water use exceeded precipitation at the site during the calendar year 2001 in all months except January (-1.25 inches), November (-1.39 inches), and December (-1.28 inches; Figure 38, Table 46). 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 level trends observed in the shallow monitor wells and sumps at the site during calendar year 2001 support this inference.

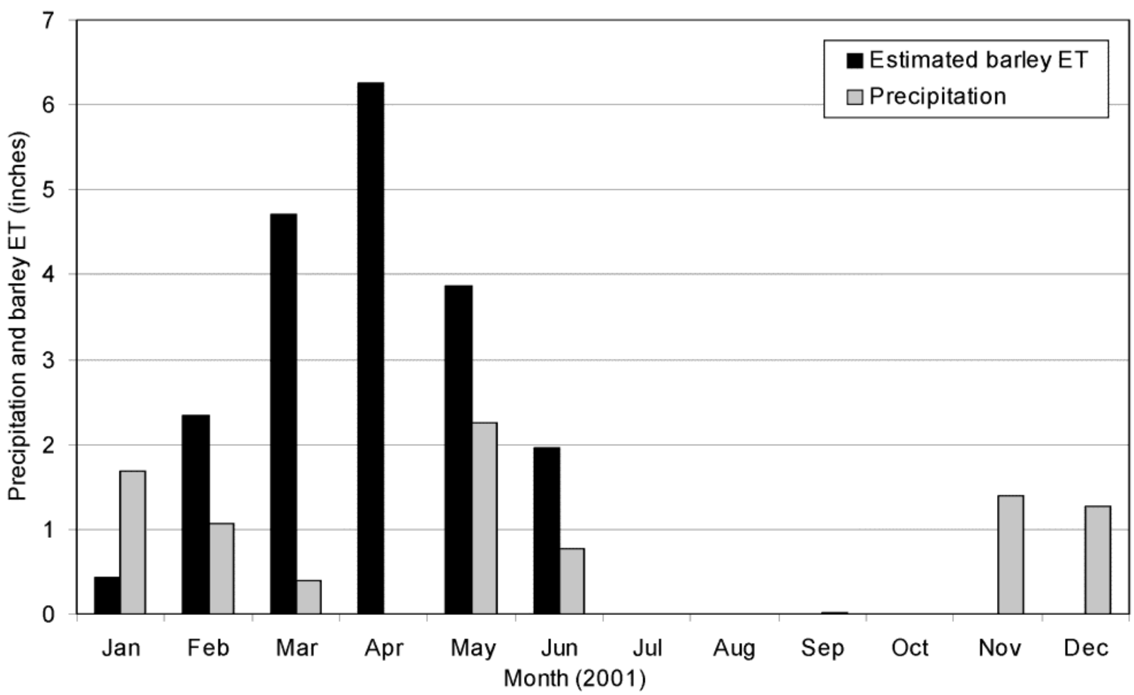

Figure 38. Monthly precipitation and estimated barley crop consumptive water use for calendar year 2001 at the Tranquillity site.

4. Irrigation: Tranquillity Site

A cover crop of barley was planted at the Tranquillity site to provide weed and dust control and to isolate the experimental plots from each other. Approximately 367 acre feet of water was applied to 960 acres of the barley crop in 2001, resulting in an average of approximately 4.6 inches of water applied per acre. Water was applied to the 960 acres of barley using a hand moved sprinkler irrigation system in 12 hour sets during the time period from March 15 to April 30, 2001. The barley crop consumptive water use exceeded precipitation and applied irrigation water during the irrigation period (Table 47), thus it is unlikely that the irrigation application contributed to recharge to the perched water table. Continued declining groundwater level trends observed in the shallow monitor wells and sumps at the site during calendar year 2001 support this inference. Approximately 0.25 acre foot of water was also applied to a linear hedgerow planting located on the west side of Section 23.

Table 47. Estimated barley crop consumptive water use as compared with precipitation and applied irrigation water at the Tranquillity site.

Month	Estimated barley ET (inches)	Precipitation (inches)	Applied irrigation (inches)	Irrigation deficit (inches)
March	4.7	0.4	2.3	2.0
April	6.3	0	2.3	4.0

5. Hydrology and Surface Water Monitoring: Tranquillity Site

No surface water ponding was observed at the site during the calendar year 2001, and 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 AMSL 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 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. 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.

6. Groundwater Level Monitoring: Tranquillity Site

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 39. 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 are18 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 39).

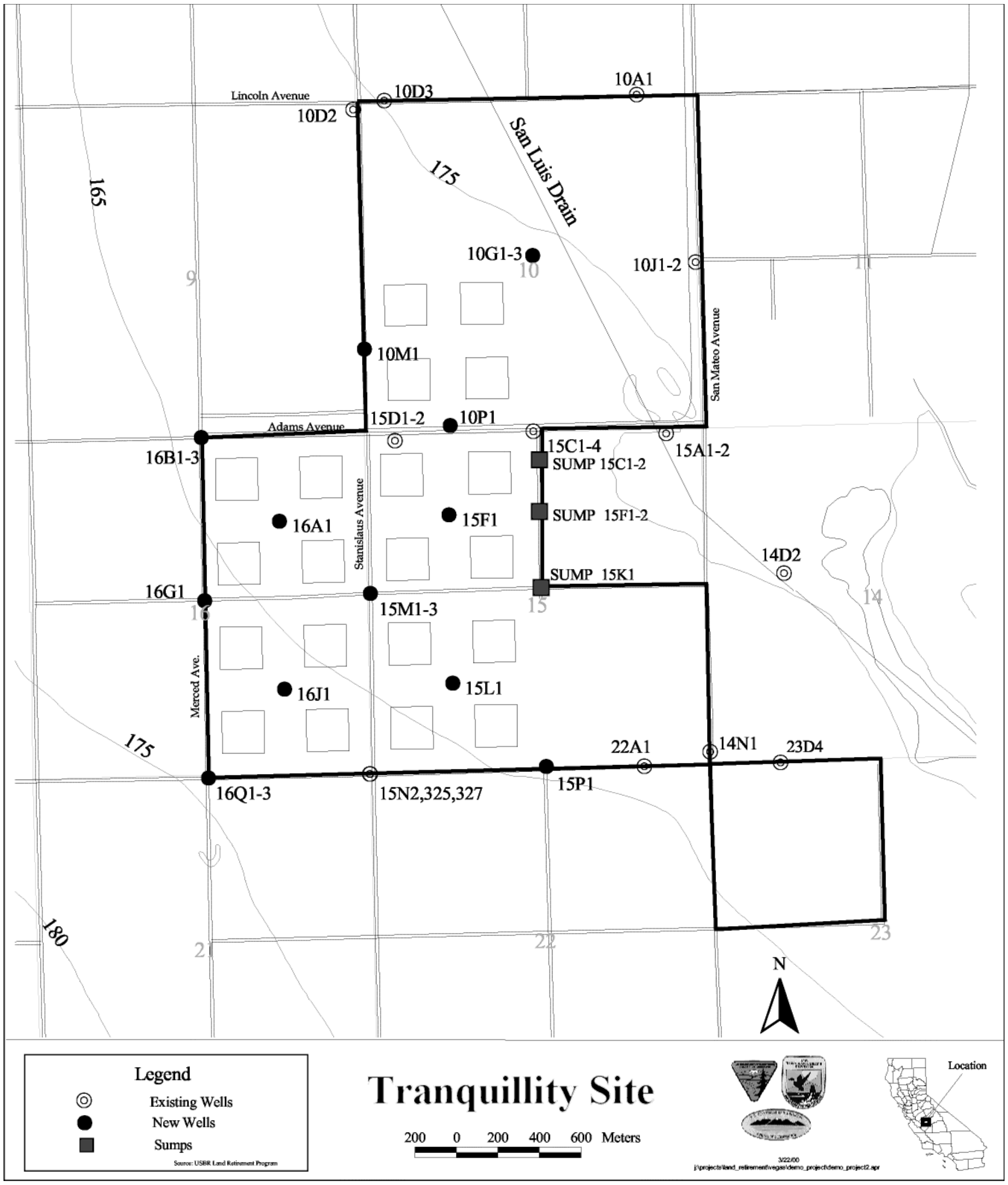

Figure 39. Monitor well and sump location map, Tranquillity site.

7. Groundwater Response to Land Retirement: Tranquillity Site

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 monitoring the shallow perched groundwater system at the site since the land was retired from irrigated agriculture in August, 1998. A hydrograph is a commonly used method to graphically display groundwater level trends observed in monitor wells. 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 40. 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 on Figure 39. 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.

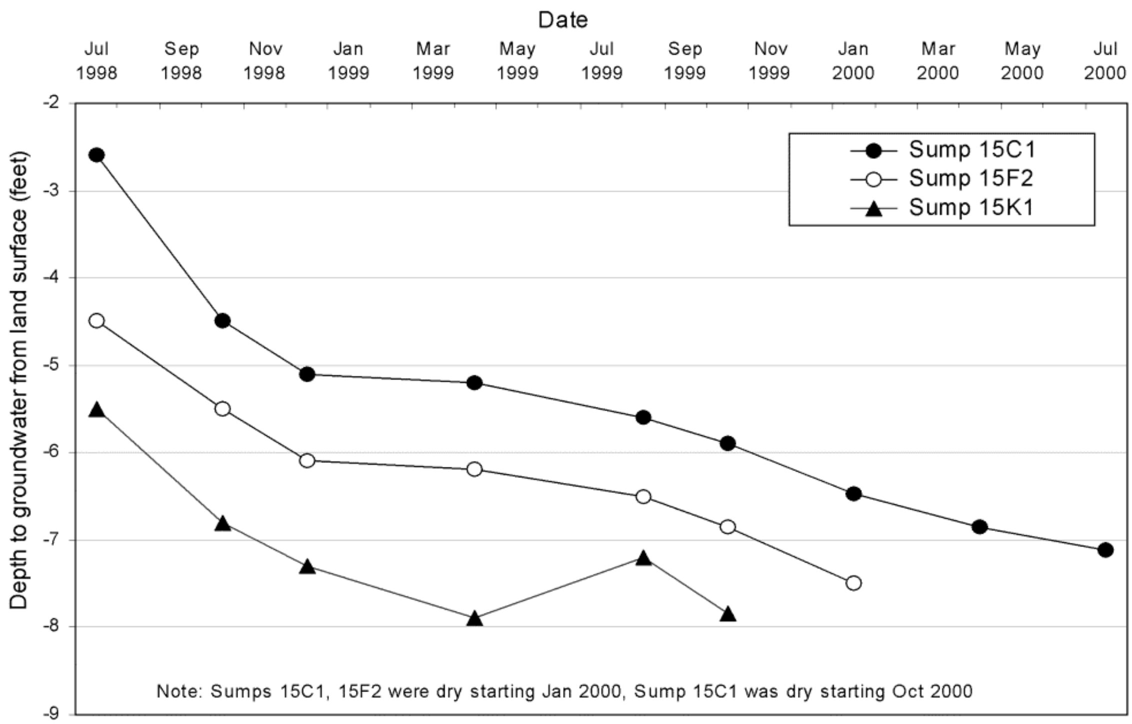

Figure 40. Hydrographs for three agricultural drain sumps at the Tranquillity site showing a declining shallow groundwater trend

A declining water level trend 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 Figures 41 and 39, 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 42). The total water-level declines observed in wells 15M1 and 16A1 were 5.2 and 6.1 ft, respectively.

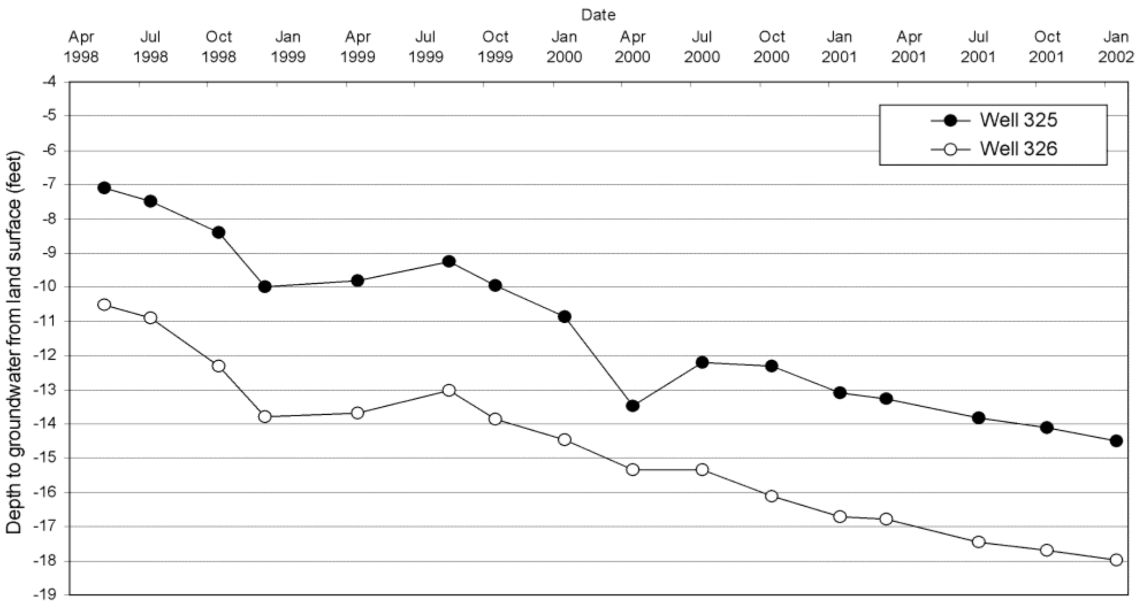

Figure 41. Hydrographs for monitor wells 325 and 326 at the Tranquillity site showing a declining shallow groundwater trend.

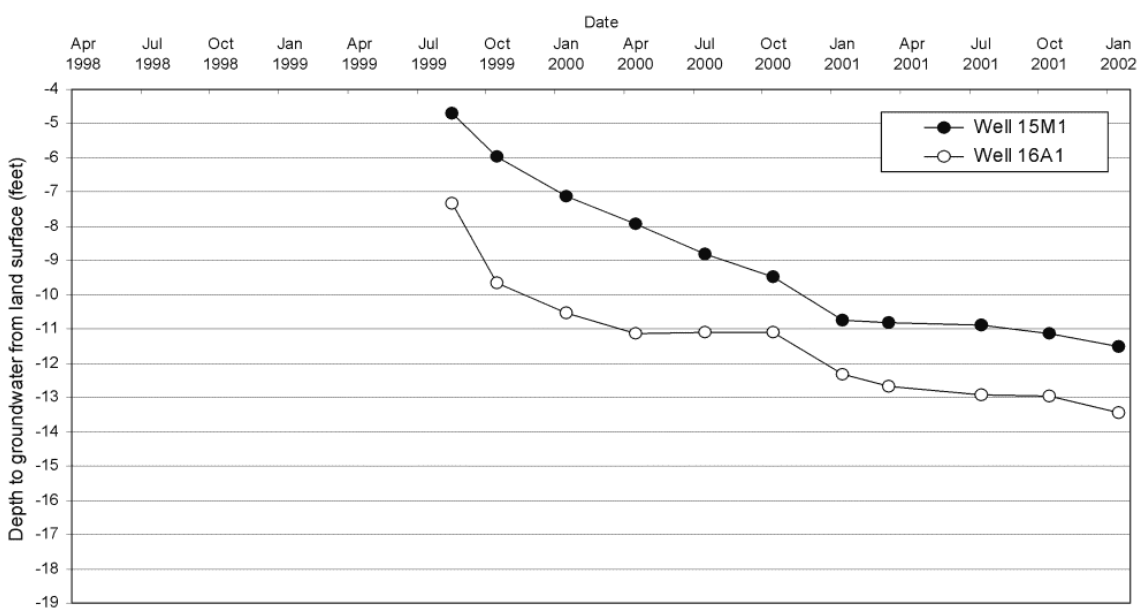

Figure 42. Hydrographs for monitor wells 15M1 and 16A1 at the Tranquillity site showing a declining shallow groundwater trend.

Synoptic depth to groundwater maps are another useful way to portray the decline of the shallow water-table beneath the Tranquillity site. Figures 43-45 show the depth to groundwater from the land surface as measured in monitor wells at the site in October, 1999, October, 2000, and October 2001, respectively. 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). Another aspect of the site hydrogeology shown by the synoptic maps is the fact that the site can be divided into two distinct areas based on the depth to groundwater observations. The depth to the water-table north of Adams Avenue (Section 10) is 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.

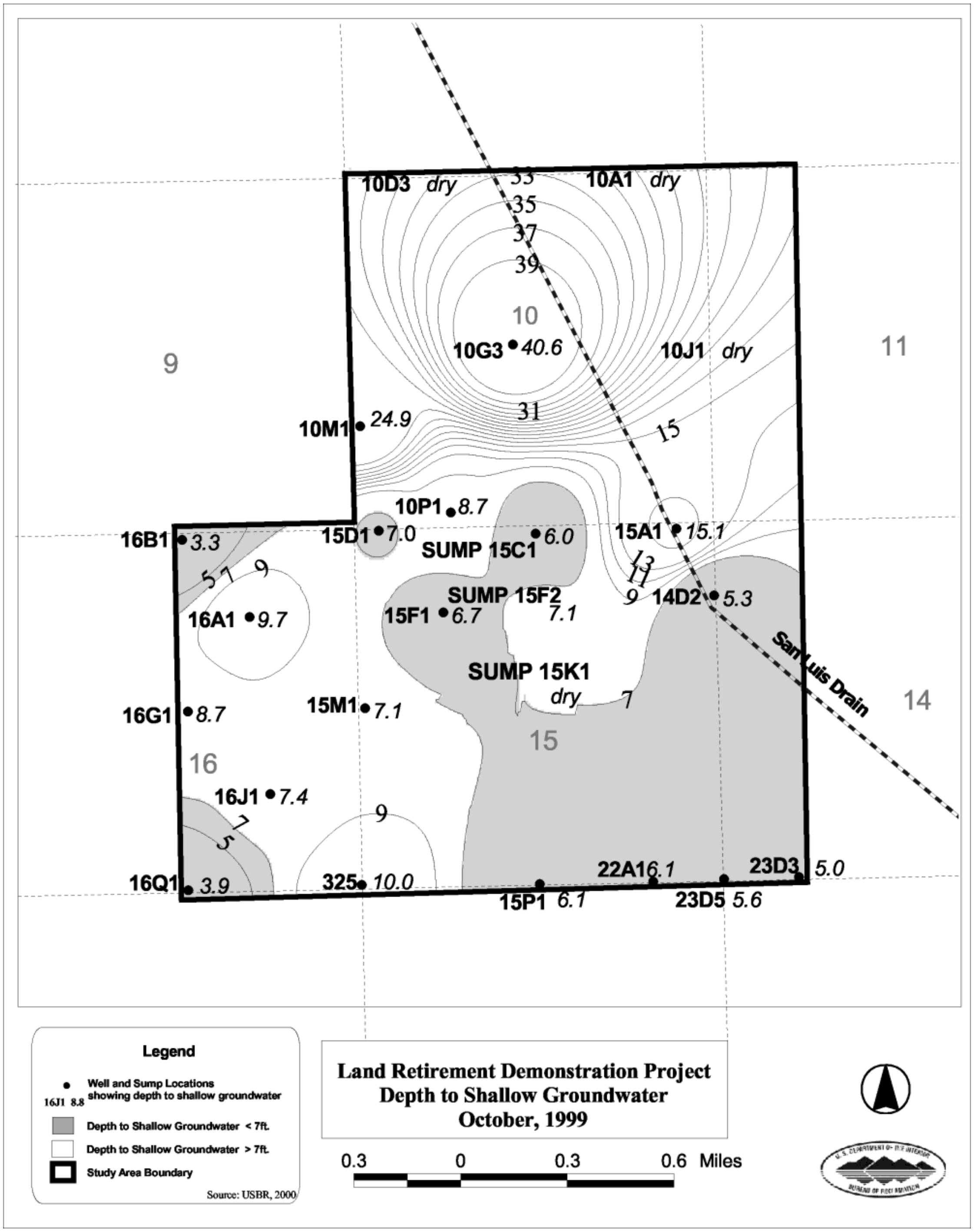

Figure 43. Depth to shallow groundwater, October, 1999. The project area underlain by shallow groundwater within 7 ft of the land surface is approximately 600 acres.

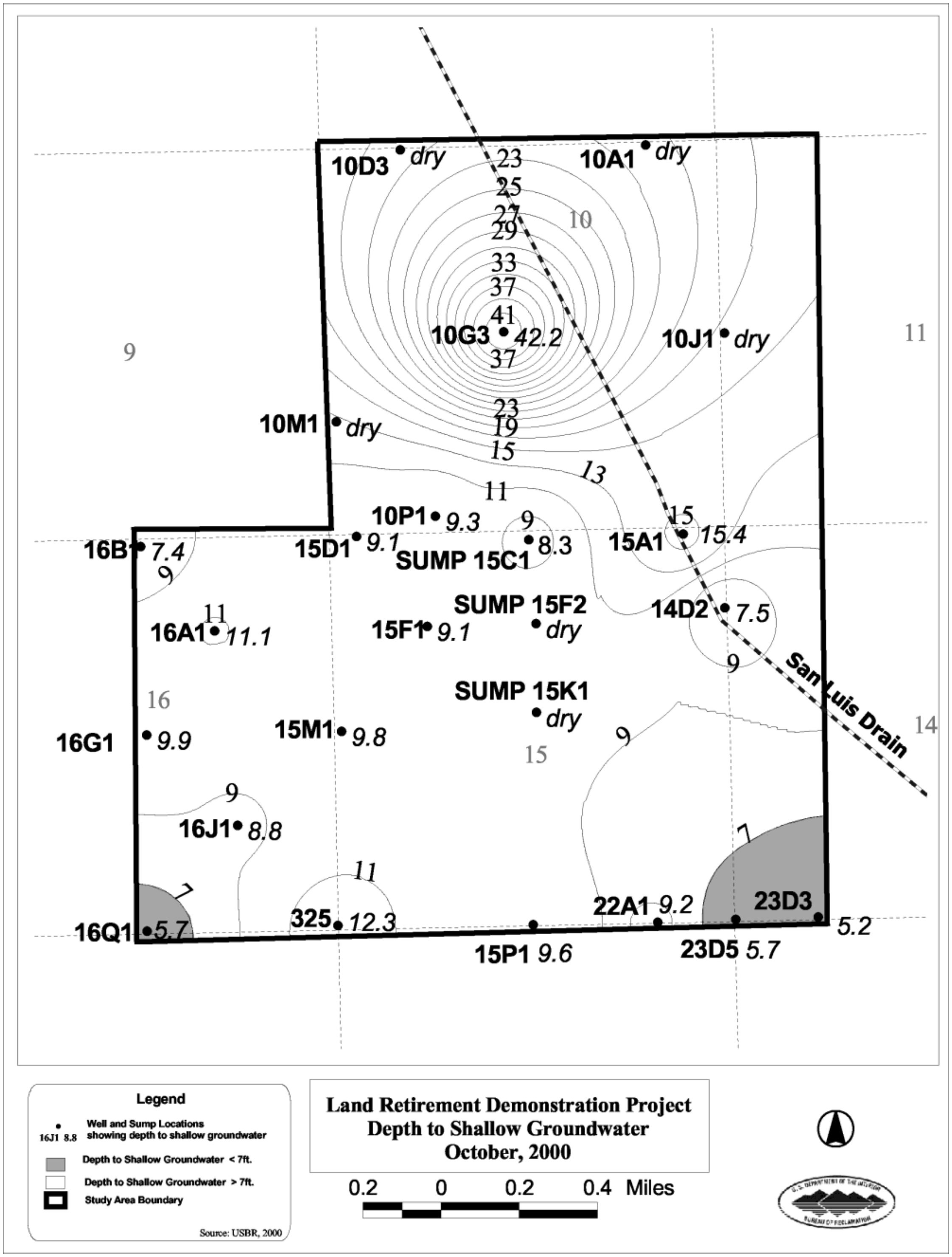

Figure 44. Depth to shallow groundwater, October, 2000. The project area underlain by shallow groundwater within 7 ft of the land surface is approximately 55 acres.

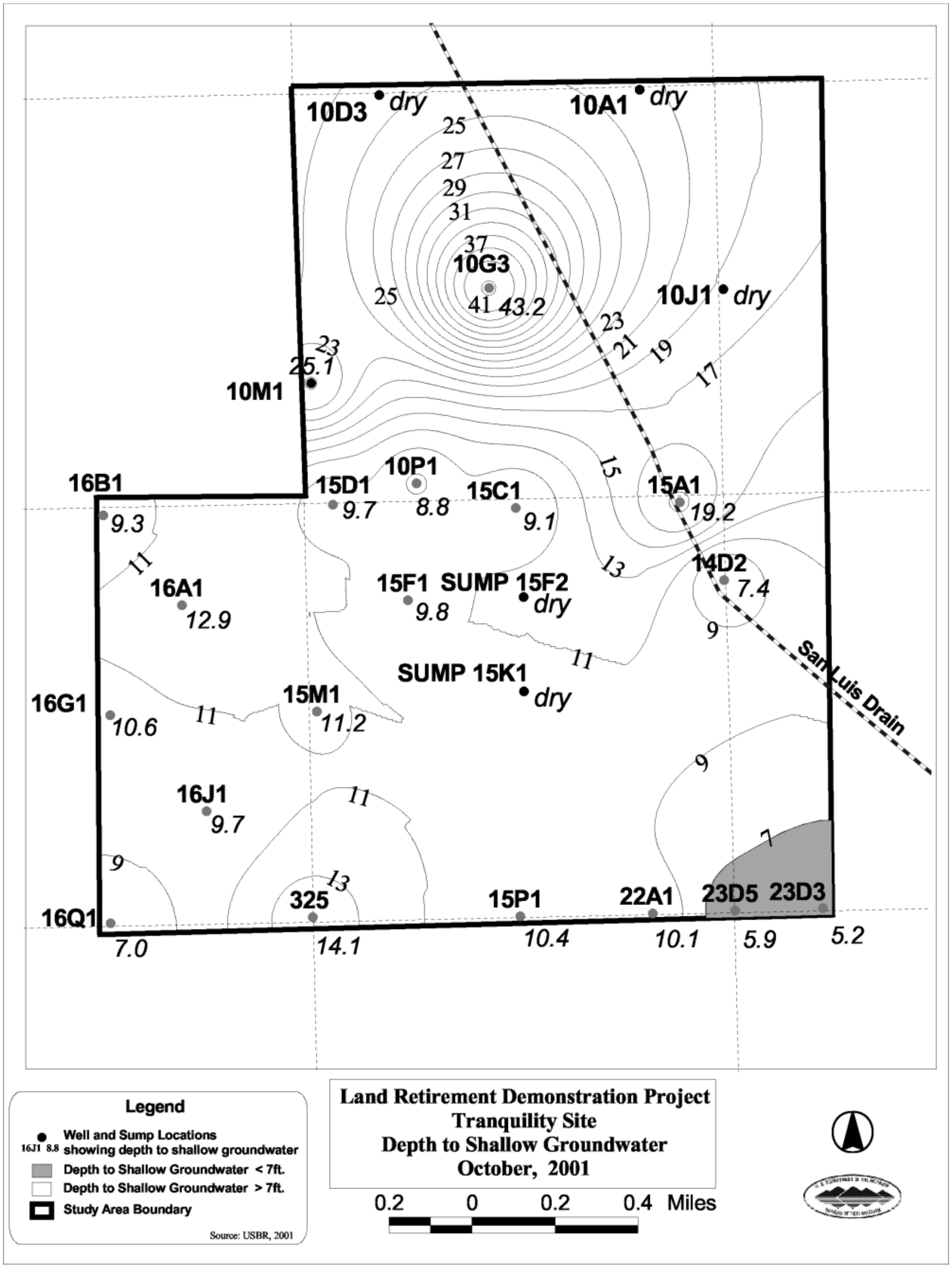

Figure 45. Depth to shallow groundwater, October, 2001. The project area underlain by shallow groundwater within 7 ft of the land surface is approximately 34 acres.

The combinations of dry climatic conditions and greatly reduced irrigation applications associated with land retirement have resulted in significant shallow water-table declines 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 2 years of monitoring is approximately 4 ft (Table 48). To conclusively demonstrate the cause and effect relationship between the declining shallow groundwater levels observed on site and land retirement, comparison with background or reference wells is warranted. Ideal background wells would be located in the project vicinity, with similar soils and geology, but in an area with active ongoing irrigation. An effort will be made to obtain data from appropriate offsite "background" wells for comparison with observed demonstration project groundwater levels.

Table 48. Groundwater level decline observed in ten wells at the Tranquillity site for the time period from August, 1999 to October, 2001.

Well	Water level decline (feet)
15P1	5.6
15L1	1.0
15M1	4.8
15F1	3.3
16G1	3.7
16Q1	4.4
16A1	5.6
16B1	5.8
15N1	4.9
15C1	2.7
Minimum	**1.0**
Maximum	**5.8**
Average	**4.1**

8. Groundwater Quality Monitoring: Tranquillity Site

The purposes for selenium 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 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. 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 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).

a. Groundwater Salinity: Tranquillity Site

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 Tables 37 and 38. 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.

b. Groundwater Major Ion Chemistry—Tranquillity Site

Baseline major ion chemistry for the groundwater samples collected during year 1 of monitoring are presented in Tables 37 and 38 The groundwater comprising the shallow, 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 49. Groundwater quality data for shallow wells at the Tranquillity site - major ions and field parameters.

Statistic	Minimum	25th percentile	Median	75th percentile	Maximum	Mean
Number of Samples	44	44	44	44	44	44
EC(field) (µS/cm)	11500	32620	43260	52350	76980	41987
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)	2300	8725	13000	16500	25000	13009
Potassium (mg/l)	7	20	30	42	94	32
Total Alkalinity (mg/l)	150	260	330	423	610	351
Chloride (mg/l)	380	1150	2700	3200	4100	2332
Sulfate (mg/l)	4300		24500	31000	62000	26330

Table 50. Groundwater quality data for deep wells at the Tranquillity site - major ions and field parameters.

Statistic	Minimum	25th percentile	Median	75th percentile	Maximum	Mean
Number of Samples	12	12	12	12	12	12
EC(field) (µS/cm)	5630	6763	7675	17315	18580	10633
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	1100	2425	3800	1714
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	1700	1900	924
Sulfate (mg/l)	2100	2750	3100	5525	7300	4067

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 (greater than 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 46).

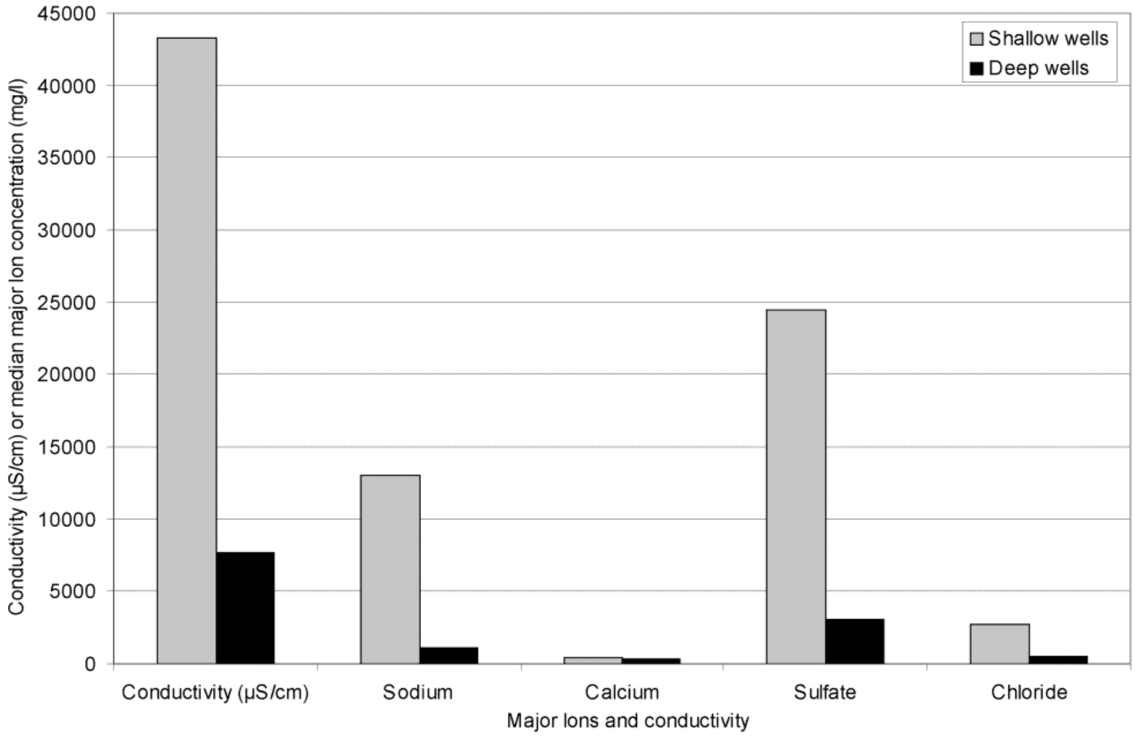

Figure 46. Comparison of dominant major ion concentrations and electrical conductivity for groundwater samples from shallow and deep wells.

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) have 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.

c. Trace Elements in Groundwater - Tranquillity Site

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 below.

Table 51. Groundwater quality data for shallow wells at the Tranquillity site - trace elements and tritium.

Statistic	Minimum	25th percentile	Median	75th percentile	Maximum	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 52. Groundwater quality data for deep wells at the Tranquillity site - trace elements and tritium.

Statistic	Minimum	25th percentile	Median	75th percentile	Maximum	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

d. Selenium in Groundwater - Tranquillity Site

Selenium concentrations measured in the shallow groundwater wells and sumps (less than 50 feet deep) at the site during the first year of monitoring show considerable spatial variation. In general, selenium concentrations in the shallow groundwater system are 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 USEPA water-quality criteria for long-term exposure in aquatic environments is 5 µg/l (USEPA 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 show considerable spatial variation. 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) range from the analytical limit of detection (less than 0.0004) to 0.0005 µg/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 Ranges 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 ($Se\ O_4^{2-}$) and selenite (SeO_3^{2-}) 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 47). 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. Reducing geochemical conditions in the Sierran deposits probably play a significant role in the extremely low selenium concentrations observed in wells 15C3 and 10G3.

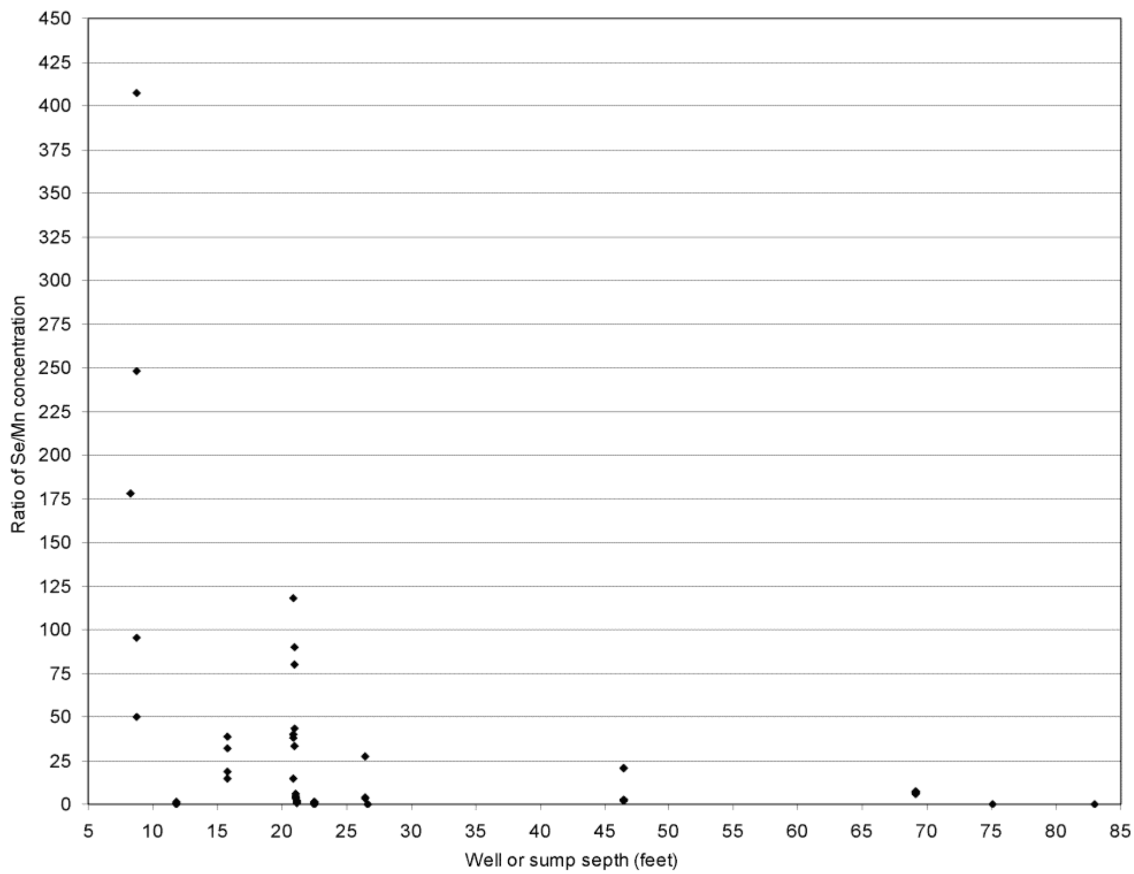

Figure 47. Ratio of Selenium to Manganese (Se/Mn) concentration in groundwater samples plotted verses well depth. The Se/Mn ratio shows a decreasing trend with depth indicating oxidizing geochemical conditions in the shallow wells and reducing conditions in the deep wells.

e. Selenium Trends in Shallow Groundwater—Tranquillity Site

The US Fish and Wildlife Service (USFWS) established performance standards for retired lands in the Recovery Plan for Upland Species of the San Joaquin Valley (USFWS 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 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 due to the limited sample size. 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 53). 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 53. 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

f. Boron in Groundwater—Tranquillity Site

The presence of high concentrations of boron in the shallow groundwater are 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 51). No water-quality criteria for boron exist for aquatic life or human health. There is an irrigation water criterion of 750 micrograms/liter (µg/l) of boron sensitive crops (US EPA 1986). Perry et al. (1994) have 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 52). 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.

g. Origin and Isotopic Composition of Groundwater - Tranquillity Site

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 Tables 39 and 40. The oxygen and hydrogen isotope data 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.

h. Groundwater Age - Tranquillity Site

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.

i. Evaporative concentration of shallow groundwater—Tranquillity Site

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 data 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 48 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.

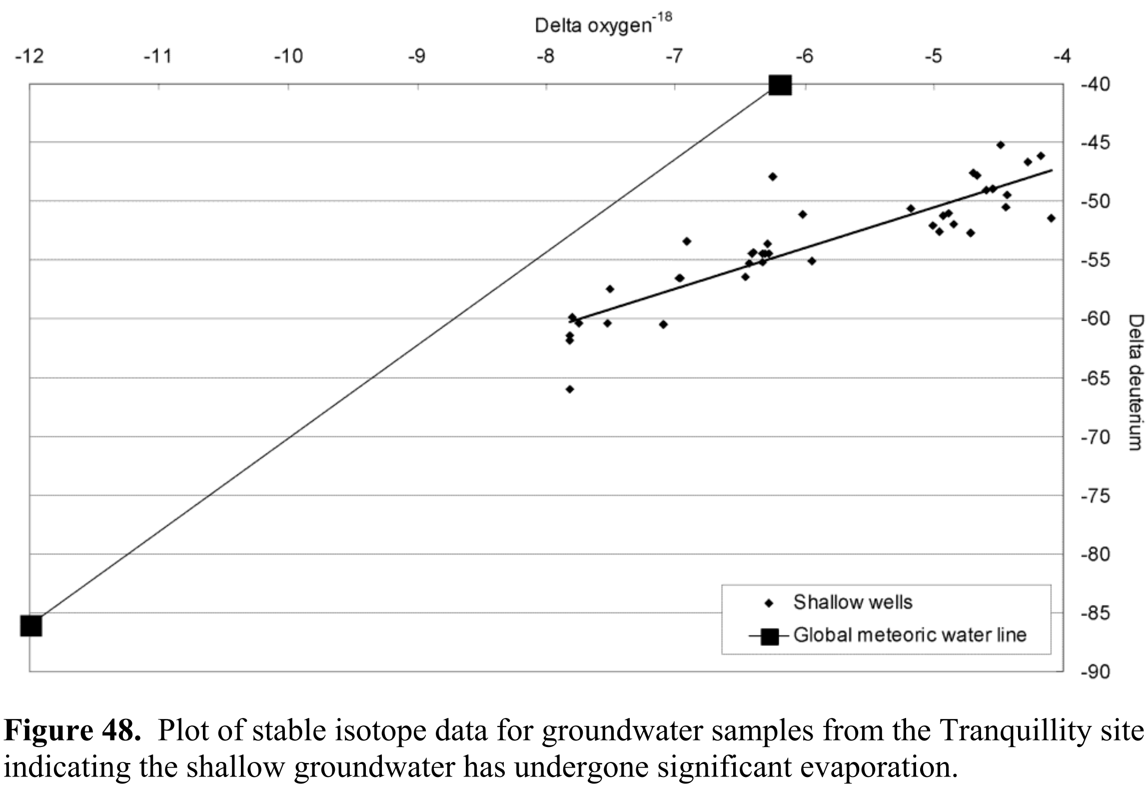

Figure 48. Plot of stable isotope data for groundwater samples from the Tranquillity site indicating the shallow groundwater has undergone significant evaporation.

B. Atwell Island Site

1. Atwell Island Site 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 lakebed 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 lakebed 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 lakebed traverses the western boundary of the site from southwest to northeast.

2. Atwell Island Site Soils

Soils in the Atwell Island study area consist of silt and sand loams that are formed in alluvium derived from igneous and sedimentary rocks. Individual soil mapping units found in the study area in the order of abundance include the Posochanet silt loam, Nahrumb silt loam, the Westcamp silt loam, Excelsior find sandy loam, and Lethent fine sandy loam (Figure 49). 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. 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. Nahrumb silt loam occurs on basin rims and consists of mixed alluvium from granitic rocks. Nahrumb 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 high 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.

a. Soil Sampling: Atwell Island Site

Baseline soil sampling will be conducted at the Atwell Island site during spring of 2002. Sixteen sites will be sampled within each experimental block. Each site will be located at the approximate center of the 2-acre plots (Figure 49). Three soil samples will be collected from each site. A 0-12 inch sample consisting of a four increment composite soil samples collected within a 2-meter radius of the central boring. A single soil sample will be collected from the 12-30-inch depth interval. This sample represents the active root zone of irrigated soils. A single soil sample will also be collected from the 30-60-inch substrata zone. This zone represents the lower root zone just above the vadose zone. All soil material will be sampled in the 12-30 and 30-60-inch samples. Sampling in this manner will result in 48 soil samples collected on each 160 acre block. Two field replicate (QC) samples will be collected from each quarter section. Field replicate samples will be done using the fractional shoveling method. All sample sites will be located and georeferenced using a GPS receiver set on the North American 1927 datum.

Soil samples will be analyzed for total and water soluble selenium, sulfate, chloride, electrical conductivity, and moisture. All surface soil samples will be analyzed for boron, magnesium, potassium, sodium, carbonate, and nitrate. 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 soil data quality (CH2M Hill 1999). The soils analyses will be performed by the U.S. Geological Survey and the U.S. Bureau of Reclamation analytical laboratories in Denver, Colorado.

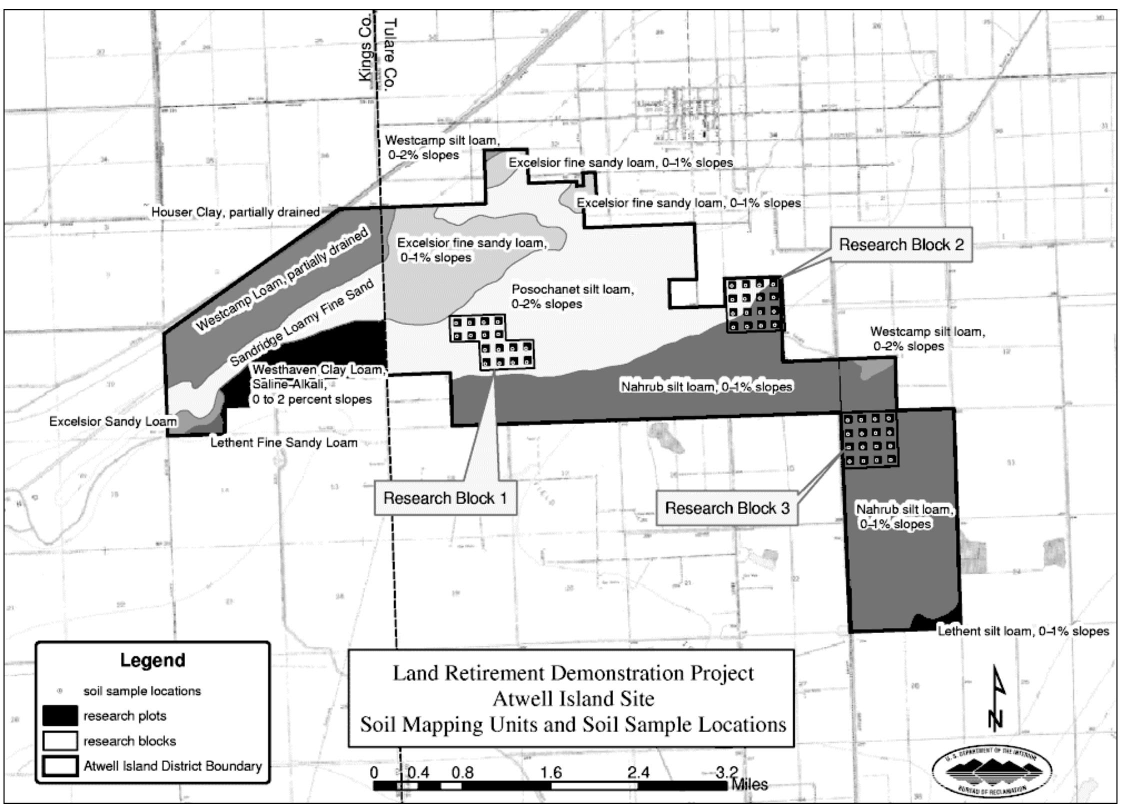

Figure 49. U.S. Department of Agriculture soil mapping units and soil sample locations at the Atwell Island site.

3. Weather: Atwell Island Site

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 CDWR, and can be used to guide crop irrigation scheduling and estimate consumptive water use for various crops. A total of 7.99 inches of rainfall was recorded at the CIMIS station, with most of the rainfall occurring between January, April, and October-December.

4. Irrigation: Atwell Island Site

A cover crop of barley was planted on the three habitat restoration study blocks at the Atwell Island site to provide weed and dust control and to equilibrate the soil conditions on the study plots prior to installation of the experimental treatments. Accordingly, both the buffer areas and the study plots were planted in barley. Approximately 164 acre-feet of water was applied to 480 acres, resulting in an application rate of approximately 4.1 inches of water per acre. However, water was not applied in equal amounts to each study block. On block 1 (see Figure 49), 64.7 acre-feet of water was applied by flood irrigation during the time period from 24-31 March 2001. On block 2, 48.8 acre-feet was applied by sprinkler irrigation during the time period from 30 March through 5 April, 2001 and on block 3, 50.7 acre-feet of water was applied using sprinkler irrigation.

The largest volume of irrigation water applied at the site during calendar year 2001 was from ongoing farming operations. Farming operations continued on approximately 2,800 acres of the Atwell Island site as negotiations for land acquisition with the current landowners proceeded. 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 from the current landowners. 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 is shown in Table 54 (Smith 2001).

Table 54. Estimated 2001 net crop water requirement and deep percolation losses at the Atwell Island site.

Crop	Acreage	Total crop water requirement (acre-feet)	Irrigation water application requirement (acre-feet)	Estimated deep percolation (acre-feet)
Alfalfa	1,142	4,568	7,028	2,460
Barley	160	211	325	114
Oats	1,001	821	1,263	442
Safflower	490	1,269	1,952	683
Total	**2,793**	**6,869**	**10,568**	**3,699**

5. Hydrology and Surface Water Monitoring: Atwell Island Site

Monitoring of surface water at the Atwell Island site will commence in calendar year 2002. 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, although 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 in the vicinity of 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.

6. Groundwater Level Monitoring: Atwell Island Site

There are approximately 20 monitor wells in the project vicinity that will be used to measure groundwater levels beneath the site on a quarterly basis. The well locations are shown on Figure 50 . Existing wells constructed prior to the purchase of the demonstration project lands were installed by the U.S. Geological Survey, the CDWR 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 inches 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).

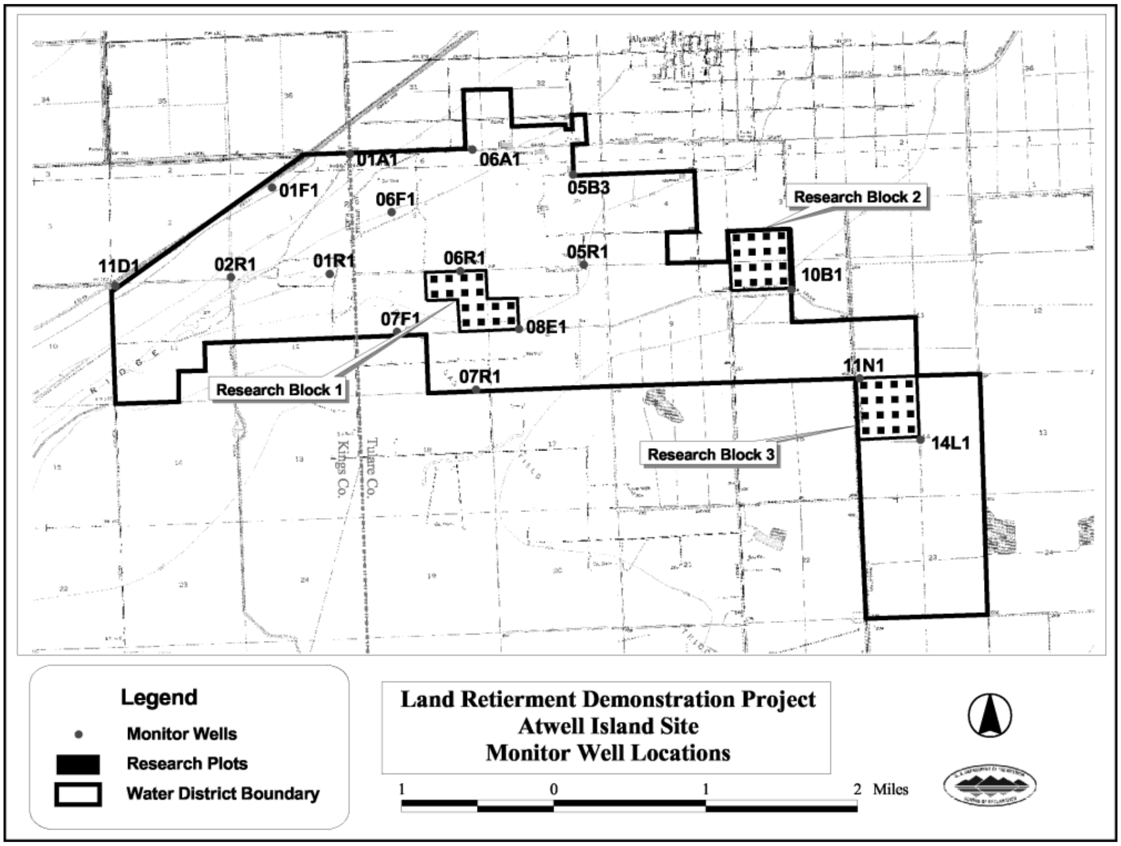

Figure 50. Monitor well locations at the Atwell Island site.

7. Groundwater Levels: Atwell Island Site

Calendar year 2002 will serve as the baseline year for establishing groundwater levels and groundwater quality at the Atwell Island site. Groundwater levels measured in 20 wells during January 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). Water levels will be measured quarterly in the monitor wells over the life of the demonstration project in order to track the water-table response to land retirement. An attempt will be made to identify and collect water level data from appropriate reference wells in the project vicinity.

8. Groundwater Quality Monitoring: Atwell Island Site

Baseline groundwater quality samples will be taken on a quarterly basis during the first year of monitoring at the Atwell Island site. The first round of groundwater samples were taken from 20 wells at the Atwell Island site in January 2002. The same sampling and analysis protocols that were used at the Tranquillity site will be used on groundwater samples at the Atwell Island site.

V. TOURS, PRESENTATIONS, CONFERENCES, AND WORKSHOPS

The Land Retirement Team gave an annual site tour to interested agency personnel and private parties on 18 April 2001.

In January 2001, a presentation was given at The Wildlife Society's Western Section annual conference in Sacramento, CA. The title of the presentation was "Restoration of native plant and animal communities on retired agricultural lands". Two presentations were given at the Society for Ecological Restoration, California Chapter at a conference held in San Diego, CA. on 1-2 November 2001. The title of the presentations were "Habitat restoration on retired agricultural lands in the San Joaquin Valley, Part I: Successes and failures of native plant restoration" and "Habitat restoration on retired agricultural lands in the San Joaquin Valley, Part II: Responses of wildlife to restoration". A 1-hour long lecture was given in May 2001 to biology students and faculty at California State University, Stanislaus as part of a symposium series. The LRT also presented a PowerPoint presentation of the Land Retirement Demonstration project to the Westlands Resource Conservation District on 18 September 2001.

Several Land Retirement Team members attended a one-day workshop on restoration techniques on 13 August 2001. That workshop was sponsored by the United States Bureau of Land Management, was presented by Craig Dremann of The Reveg Edge, and was held at the Kern National Wildlife Refuge in Tulare County, CA. A number of Land Retirement Team staff also attended the national conference of The Wildlife Society held in Reno, NV. in September 2001. The Point Reyes Bird Observatory Landbird Monitoring Training Workshop held 4-8 June 2001 and the Central Valley Birding Symposium held 15-8 November 2001 were also attended by an LRT staff member.

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VII. APPENDICES

A. Additional Vegetation Tables

Table A1. Overview of species encountered during all vegetation sampling at the Tranquillity HRS site.

				Pre-project inventory[4]				HRS sampling[6]		
Family	Binomial[1]	Life history[2]	Origin[3]	Sec. 10	Sec. 15	Sec. 16	Apnd E[5]	1999	2000	2001
Amaranthaceae	*Amaranthus* sp.	AH	N.A.	-	-	+	+	-	-	-
Asclepiadaceae	*Asclepias fascicularis*	PH	N	-	-	-	-	-	+[7]	-
Asteraceae	*Carthamus tinctorius*	AH	I	+	-	-	+	-	-	-
	Centaurea solstitialis	AH	I	+	-	+	+	-	-	-
	Conyza canadensis	AH	N	+	+	-	+	-	-	-
	Helianthus annuus	AH	N	+	+	-	+	-	-	-
	*Hemizonia pungens**	AH	N	-	-	-	-	-	-	+
	*Isocoma acradenia**	S	N	-	-	-	-	-	+	-
	Lactuca serriola	AH	I	+	+	-	+	+	+	+
	*Lasthenia californica**	AH	N	-	-	-	-	-	+	+
	Microseris sp.	AH (?)	N	-	-	+	-	-	-	-
	Picris echioides	A/PH	I	-	-	-	-	-	-	-
	Senecio vulgaris	AH	I	-	-	+	+	+	+	-
	Sonchus asper	AH	I	+	-	-	+	+	-	-
	Sonchus oleraceus	AH	I	+	+	+	+	+	+	+
	Xanthium strumarium	AH	N	-	-	+	+	-	-	-
Boraginaceae	*Amsinckia menziesii*	AH	N	-	-	-	-	-	-	+
	*Heliotropium curassavicum**	PH	N	-	-	-	+	-	-	-
Brassicaceae	*Brassica nigra*	AH	I	-	-	-	+	+	+	+
	Capsella bursa-pastoris	AH	I	-	+	-	+	+	+	+
	Hirschfeldia incana	PH	I	+	-	+	+	-	-	-
	Raphanus sativus	A/BH	I	+	-	-	+	-	-	-
	Sisymbrium irio	AH	I	-	-	-	+	+	+	+
Chenopodiaceae	*Atriplex argentea*	AH	N	+	+	-	-	+	+	+
	Atriplex patula	AH	N	-	-	-	-	-	-	-
	*Atriplex polycarpa**	S	N	-	-	-	-	-	-	-
	Beta vulgaris	PH	I	-	-	-	+	+	+	+
	Chenopodium album	AH	I	-	-	+	+	+	+	-
	Monolepis nuttalliana	AH	N	-	-	-	-	-	+	-

				Pre-project inventory[4]				HRS sampling[6]		
Family	Binomial[1]	Life history[2]	Origin[3]	Sec. 10	Sec. 15	Sec. 16	Apnd E[5]	1999	2000	2001
Chenopodiaceae	*Salsola tragus*	AH	I	+	-	-	+	-	-	+
	*Suaeda moquinii**	PH	N	-	-	-	-	-	+	+
Convolvulaceae	*Calystegia* sp.	V (?)	N	-	-	+	-	-	-	-
	Convolvulus arvensis	PH/V	I	-	-	-	+	+	+	-
Fabaceae	*Medicago sativa*	PH	I	-	-	-	-	-	-	+
	Melilotus indica	AH	I	+	+	+	+	+	+	+
Frankeniaceae	*Frankenia salina**	PH	N	-	-	-	-	-	+	-
Geraniaceae	*Erodium cicutarium*	AH	I	-	-	-	+	+	+	+
Hydrophyllaceae	*Phacelia distans*	AH	N	-	-	-	+	+	+	+
Juncaceae	*Juncus* sp.	N.A.	N.A.	-	-	-	+	-	-	-
Malvaceae	*Eremalche parryi*	AH	N	-	-	-	+	+	+[7]	-
	Malva parviflora	AH	I	-	-	-	-	+	+	-
	Malvella leprosa	PH	N	-	-	+	+	-	+	-
Onagraceae	*Epilobium brachycarpum*	AH	N	+	-	-	+	-	-	-
Poaceae	*Avena fatua*	AH	I	+	-	+	+	+	+	+
	*Bromus carinatus**	AH	N	-	-	-	-	-	+	+
	Bromus diandrus	AH	I	-	-	-	-	-	-	+
	Bromus hordeaceus	AH	I	+	-	-	+	-	-	-
	Bromus madritensis	AH	I	+	-	+	+	+	+	+
	Crypsis schoenoides	AH	I	-	-	+	+	-	-	-
	Cynodon dactylon	PH	I	-	-	-	-	-	-	-
	Distichlis spicata	PH	N	+	-	-	+	-	-	-
	Hordeum depressum	AH	N	-	-	-	+	+	+	-
	Hordeum marinum	AH	I	+	-	+	+	-	-	-
	Hordeum murinum	AH	I	+	-	-	+	+	+	+
	Hordeum vulgare	AH	C	-	-	-	+	+	+	+
	Leptochloa uninervia	AH	N	-	-	+	+	-	-	-
	*Leymus triticoides**	PH	N	-	-	-	-	-	-	+
	Phalaris minor	AH	I	+	+	+	+	-	+	+[8]
	Polypogon monspeliensis	AH	I	-	+	-	+	-	-	-
	*Vulpia microstachys**	AH	N	-	-	-	-	-	+	+
Polemoniaceae	*Gilia tricolor*	AH	N	-	-	-	-	-	-	-
Polygonaceae	*Polygonum* sp.	N.A.	N.A.	-	-	-	-	-	-	-
	Rumex crispus	PH	I	+	-	+	+	-	-	-
Sapotaceae	*Bassia hyssopifolia*	AH	I	-	-	-	-	-	-	+
Solanaceae	*Physalis lanceifolia*	AH	I	+	-	+	+	-	-	-
	Solanum americanum	A/PH	N	-	-	-	-	-	+	-
Tamaricaceae	*Tamarix ramosissima*	T or S	I	-	-	-	+	-	-	-

Table A2. Overview of species encountered in Tranquillity HRS vegetation sampling, 2001. Species marked with an asterisk are imprinted species. Roman numerals indicate study Block. Numerical values in cells indicate mean percent cover for that particular species in that plot.

Taxon code	O[2]	Contoured/imprinted					Not contoured/ imprinted					Contoured/not imprinted					Not contoured/not Imprinted				
		I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
AMME	N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13	-	-	-	-
ATAR	N	0.19	-	18.90	0.15	0.02	1.54	-	3.23	6.29	-	0.13	-	0.25	0.63	-	-	0.02	3.56	4.29	0.02
AVFA	I	0.13	2.00	-	-	-	-	1.69	4.46	-	0.13	0.19	3.19	6.19	-	1.25	-	14.10	21.04	-	-
BAHY	I	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-
BEVU	I	7.15	-	-	-	0.13	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-
BRCA*	N	-	-	0.02	-	-	-	-	-	0.13	-	-	-	-	-	-	-	-	-	-	-
BRDI	I	0.02	-	-	-	-	-	-	0.13	-	-	-	-	-	-	-	-	-	-	-	-
BRMA	I	11.65	-	-	-	-	25.31	0.02	0.02	-	-	18.46	-	-	3.23	-	66.67	-	-	-	0.25
BRNI	I	0.90	-	-	-	16.19	0.79	-	0.02	3.54	4.94	0.02	-	-	-	38.23	0.58	0.71	-	0.13	-
CABU	I	-	2.63	-	0.13	0.21	-	8.19	0.50	-	0.13	-	1.35	-	-	0.25	-	1.15	4.31	-	0.04
ERCI	I	1.19	-	-	-	-	0.33	-	-	-	-	0.52	-	-	-	-	1.00	-	-	-	-
HEPU*	N	-	-	-	-	-	-	-	0.02	-	-	-	-	-	-	-	-	-	-	-	-
HOMU	I	5.13	-	-	-	0.13	21.73	-	0.02	-	0.75	33.75	-	-	2.56	3.54	1.04	-	-	-	0.63
HOVU	C	0.56	16.31	1.94	0.02	0.15	0.19	13.58	4.48	0.81	-	0.19	6.46	6.19	0.15	-	0.56	17.60	1.31	0.15	-
LACA*	N	-	0.15	0.02	-	-	0.06	0.21	0.04	0.04	-	-	-	-	-	-	-	-	-	-	-
LASE	I	0.04	0.56	1.46	1.02	-	0.04	0.17	0.90	0.21	-	0.06	0.27	1.40	-	-	-	1.83	2.19	4.63	-
LETR	N	0.02	0.02	-	-	-	-	0.06	0.15	-	-	-	-	-	-	-	-	-	-	-	-
MEIN	I	3.94	0.15	0.69	-	-	5.88	0.02	2.98	-	-	7.17	0.02	6.44	-	-	9.13	1.52	2.77	-	-
MESA	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02	-
PHSP	NA	0.08	-	-	-	-	0.02	-	-	-	-	0.13	-	-	-	-	-	0.02	-	-	0.13
PHDI	N	1.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SATR	I	-	-	4.33	0.65	-	-	-	-	-	-	-	-	0.75	-	-	0.13	-	1.71	-	-
SIIR	I	-	9.04	7.50	1.44	19.42	-	11.92	6.35	13.96	19.06	-	15.77	0.88	16.54	27.69	-	4.94	5.85	9.08	53.33
SOOL	I	0.10	0.63	1.92	0.13	-	0.02	0.23	1.65	-	-	0.02	0.02	0.13	-	-	0.02	0.15	1.00	1.31	-
SUMO*	N	-	0.63	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
VUMI*	N	-	0.94	-	-	-	0.02	0.71	0.13	-	-	-	-	-	-	-	-	-	-	-	-
Spp. Rich.[3]:		**15**	**11**	**10**	**7**	**7**	**12**	**11**	**16**	**7**	**5**	**12**	**7**	**8**	**6**	**5**	**9**	**10**	**9**	**7**	**6**

1. Taxon Code: AMME, Amsinckia menziesii; ATAR, Atriplex argentea; AVFA, Avena fatua; BAHY, Bassia hyssopifolia; BEVU, Beta vulgaris; BRCA, Bromus carinatus; BRDI, Bromus diandrus; BRMA, Bromus madritensis subsp. rubens; BRNI, Brassica nigra; CABU, Capsella bursa-pastoris; ERCI, Erodium cicutarium; HEPU, Hemizonia pungens; HOMU, Hordeum murinum; HOVU, Hordeum vulgaris (Barley); LACA, Lasthenia californica; LASE, Lactuca serriola; LETR, Leymus triticoides; MEIN, Melilotus indica; MESA, Medicago sativa ; PHSP, Phalaris sp.; PHDI, Phacelia distans; SATR, Salsola tragus; SIIR, Sisymbrium irio; SOOL, Sonchus oleraceus; SUMO, Suaeda moquinii; VUMI, Vulpia microstachys.
2. Origin: N, Native; I, Introduced; C, Cultivar (Barley); NA, not known.
3. Species Richness: number of species observed in a particular plot.

Table A3. Frequency of species noted during vegetation sampling, 2001. Species marked with an asterisk are those included in the seed mix.

Species	Origin	Plot[1]	Quadrat[2]
Amsinckia menziesii	Native	1	1
Atriplex argentea	Native	14	50
Avena fatua	Introduced	11	82
Bassia hyssopifolia	Introduced	1	1
Beta vulgaris	Introduced	3	13
*Bromus carinatus**	Native	2	2
Bromus diandrus	Introduced	2	2
Bromus madritensis subsp. *rubens*	Introduced	8	94
Brassica nigra	Introduced	11	72
Capsella bursa-pastoris	Introduced	11	70
Erodium cicutarium	Introduced	4	28
*Hemizonia pungens**	Native	1	1
Hordeum murinum	Introduced	10	82
Hordeum vulgare (Barley)	Introduced	17	159
*Lasthenia californica**	Native	6	15
Lactuca serriola	Introduced	14	76
*Leymus triticoides**	Native	4	7
Melilotus indica	Introduced	12	98
Medicago sativa	Introduced	1	1
Phalaris sp.	Introduced	5	13
Phacelia distans	Native	1	5
Salsola tragus	Introduced	5	13
Sisymbrium irio	Introduced	16	264
Sonchus oleraceus	Introduced	14	40
Suaeda moquinii	Native	2	2
Vulpia microstachys	Native	4	18
Summed Frequency of Introduced Species:			**1,108**
Summed Frequency of Native Species:			**101**

1. Frequency of plots in which a particular species was noted.
2. Frequency of quadrats in which a particular species was noted.

Table A4. Overview of species encountered during the pre-project inventory of the Atwell Island site and baseline vegetation sampling of the Atwell Island HRS plots.

Freq.[1]	Cover[2]	Site cover[3]	Species/morpho-species	Family	Origin[4]	Life history[5]	A[6]	B[7]	C[8]
381	30.96	31.120	*Hordeum vulgare* {Barley}	Poaceae	B	AH	-	-	-
208	4.52	2.497	*Hordeum murinum*	Poaceae	I	AH	+	+	+
168	5.20	2.289	*Melilotus indica*	Fabaceae	I	AH	+	+	+
124	1.75	0.565	*Amsinckia menziesii*	Boraginaceae	N	AH	+	+	+
124	6.42	2.107	*Phalaris minor*	Poaceae	I	AH	-	+	+
114	10.14	3.089	*Avena sativa*	Poaceae	I	A/P	-	-	-
111	3.63	1.059	*Erodium cicutarium*	Geraniaceae	I	AH	+	+	+
77	5.31	1.065	*Medicago polymorpha*	Fabaceae	I	AH	-	-	-
52	1.21	0.164	*Chenopodium* sp.	Chenopodiaceae	N.A.	H	-	-	-
51	1.65	0.219	*Sisymbrium irio*	Brassicaceae	I	AH	+	+	+
50	0.80	0.104	*Bromus m.* subsp. *rubens*	Poaceae	I	AH	+	+	+
49	0.86	0.109	*Capsella bursa-pastoris*	Brassicaceae	I	AH	-	-	-
38	0.62	0.061	Unknown Cordate Leaved	N.A.	N.A.	N.A.	-	-	-
36	1.88	0.176	*Atriplex argentea*	Chenopodiaceae	N	AH	+	+	+
36	0.71	0.066	*Vulpia myuros*	Poaceae	I	AH	-	-	-
24	0.92	0.057	Narrow Leaf Grass	Poaceae	N.A.	H	-	-	-
24	0.71	0.044	*Sonchus oleraceus*	Asteraceae	I	AH	-	+	-
24	4.29	0.268	*Spergularia* sp.	Caryophyllaceae	N.A.	H	-	-	-
22	1.07	0.061	*Poa annua*	Poaceae	I	AH	-	-	-
21	7.50	0.410	*Polygonum* sp.	Polygonaceae	N.A.	H	-	-	-
18	3.61	0.169	*Polypogon monspeliensis*	Poaceae	I	AH	-	+	-
14	1.21	0.044	*Lactuca serriola*	Asteraceae	I	AH	+	+	-
12	26.88	0.840	*Bassia hyssopifolia*	Chenopodiaceae	I	AH	+	+	+
11	2.09	0.060	*Bromus diandrus*	Poaceae	I	AH	-	+	+
11	0.73	0.021	*Lolium* sp.	Poaceae	I	H	-	-	-
10	0.75	0.020	Shiny Grass	Poaceae	N.A.	H	-	-	-
10	0.50	0.013	*Sonchus* sp.	Asteraceae	I	H	-	-	-
8	4.19	0.087	*Brassica nigra*	Brassicaceae	I	AH	-	+	-
7	2.57	0.047	*Atriplex* sp.	Chenopodiaceae	N.A.	S (?)	-	-	-
6	0.50	0.008	*Cressa truxillensis*	Convolvulaceae	N	PH	+	+	+
5	0.50	0.007	*Malva parviflora*	Malvaceae	I	AH	-	+	+
4	4.75	0.050	*Carthamus tinctorius*	Asteraceae	I	AH	-	-	-
4	1.13	0.012	Unknown Narrow Leaved	N.A.	N.A.	N.A.	-	-	-
4	2.38	0.025	Unknown Shiny Leaf	N.A.	N.A.	N.A.	-	-	-
2	1.75	0.009	Annual *Atriplex*	Chenopodiaceae	N.A.	S (?)	-	-	-
2	1.75	0.009	Unknown toothed leaf.	N.A.	N.A.	N.A.	-	-	-
2	0.50	0.003	Unknown w/ red cotyledons	N.A.	N.A.	N.A.	-	-	-
2	0.50	0.003	Unknown with Fleshy Leaf	N.A.	N.A.	N.A.	-	-	-
1	3.00	0.008	*Digitaria* sp.	Poaceae	I	H	-	-	-
1	0.50	0.001	*Hemizonia pungens*	Asteraceae	N	AH	+	+	+
1	15.00	0.039	*Hordeum* sp.	Poaceae	N.A.	H	-	-	-
1	0.50	0.001	*Monolepis nuttalliana*	Chenopodiaceae	N	AH	-	+	-
1	0.50	0.001	*Senecio vulgaris*	Asteraceae	N.A.	AH	-	-	-
1	0.50	0.001	Unknown Grass	Poaceae	N.A.	H	-	-	-
1	0.50	0.001	Unknown Hairy Leaved	N.A.	N.A.	N.A.	-	-	-
1	0.50	0.001	Unknown Hairy Ovate Leaved	N.A.	N.A.	N.A.	-	-	-
1	0.50	0.001	Unknown Lanceolate	N.A.	N.A.	N.A.	-	-	-

Freq.[1]	Cover[2]	Site cover[3]	Species/morpho-species	Family	Origin[4]	Life history[5]	A[6]	B[7]	C[8]
			Leaved						
1	0.50	0.001	Unknown Mustard	Brassicaceae	N.A.	H	-	-	-
1	0.50	0.001	Unknown species	N.A.	N.A.	N.A.	-	-	-
-	-	-	*Acroptilon repens*	Asteraceae	I	PH	-	+	-
-	-	-	*Allenrolfea occidentalis*	Chenopodiaceae	N	S	+	-	-
-	-	-	*Distichlis spicata*	Poaceae	N	PH	+	+	+
-	-	-	*Helianthus annuus*	Asteraceae	N	AH	+	+	-
-	-	-	*Heliotropium curassavicum*	Boraginaceae	N	PH	+	+	-
-	-	-	*Isocoma acradenia*	Asteraceae	N	S	+	+	-
-	-	-	*Malvella leprosa*	Malvaceae	N	PH	-	+	-
-	-	-	*Medicago sativa*	Fabaceae	I	PH	-	+	-
-	-	-	*Rumex crispus*	Polygonaceae	I	PH	-	+	+
-	-	-	*Salsola tragus*	Chenopodiaceae	I	AH	+	+	-
-	-	-	*Scirpus acutus*	Cyperaceae	N	PH	-	-	+
-	-	-	*Sesuvium verrucosum*	Aizoaceae	N	PH	+	+	+
-	-	-	*Tamarix parviflora*	Tamaricaceae	I	T or S	+	-	-

1. Frequency: the number of quadrats in which the taxon was noted. Species with no values listed were those encountered during the pre-project Inventory (2000) that were not observed in sampling quadrats during the baseline survey (2001).
2. Estimated mean percent cover of the taxon calculated from only those quadrats in which the species was noted. Percent cover values were estimated from midpoints of the cover class (e.g., a species with an estimated cover of 5-25% was evaluated as having a cover of 15%).
3. Estimated site-wide mean percent cover calculated from the summed cover data divided by the total number (384) of quadrats.
4. Key to Origins: B, Barley; I, Introduced; N, Native; N.A., Not Known.
5. Key to Life History: ,H, Herb; AH, Annual Herb; PH, Perennial Herb; APH, Annual or Perennial Herb; S, Shrub; T, Tree; N.A., Not Known.
6. Species encountered in Area A during the pre-project Inventory (see Figure 19).
7. Species encountered in Area B during the pre-project Inventory (see Figure 19).
8. Species encountered in Area C during the pre-project Inventory (see Figure 19).

B. Rank-abundance Graphs Generated from Vegetation Sampling on the Tranquillity Habitat Restoration Study Plots, 1999-2001

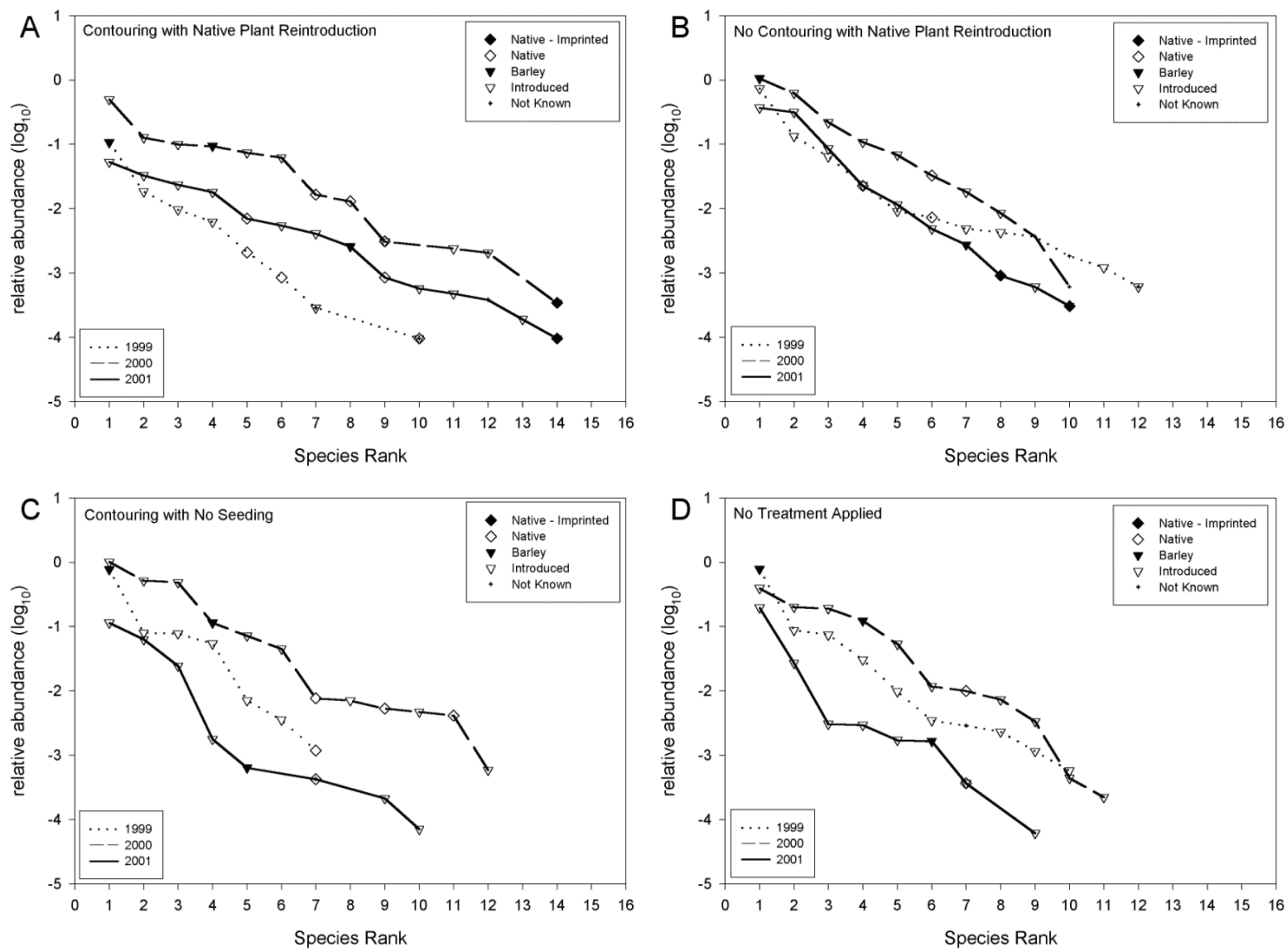

Figure B1. Rank-abundance curves for the Block 1 study plots, Tranquillity HRS.

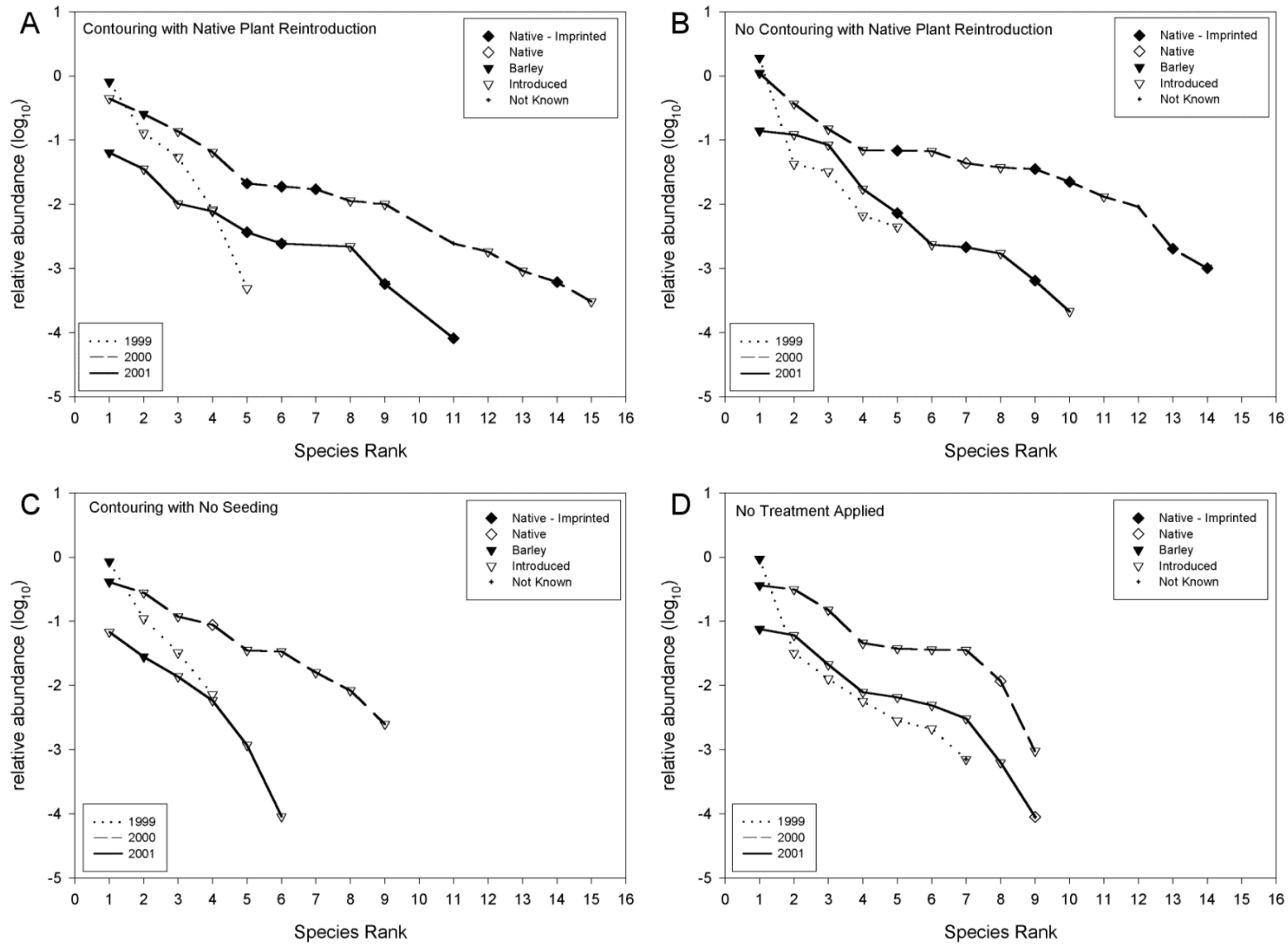

Figure B2. Rank-abundance curves for the Block 2 study plots, Tranquillity HRS.

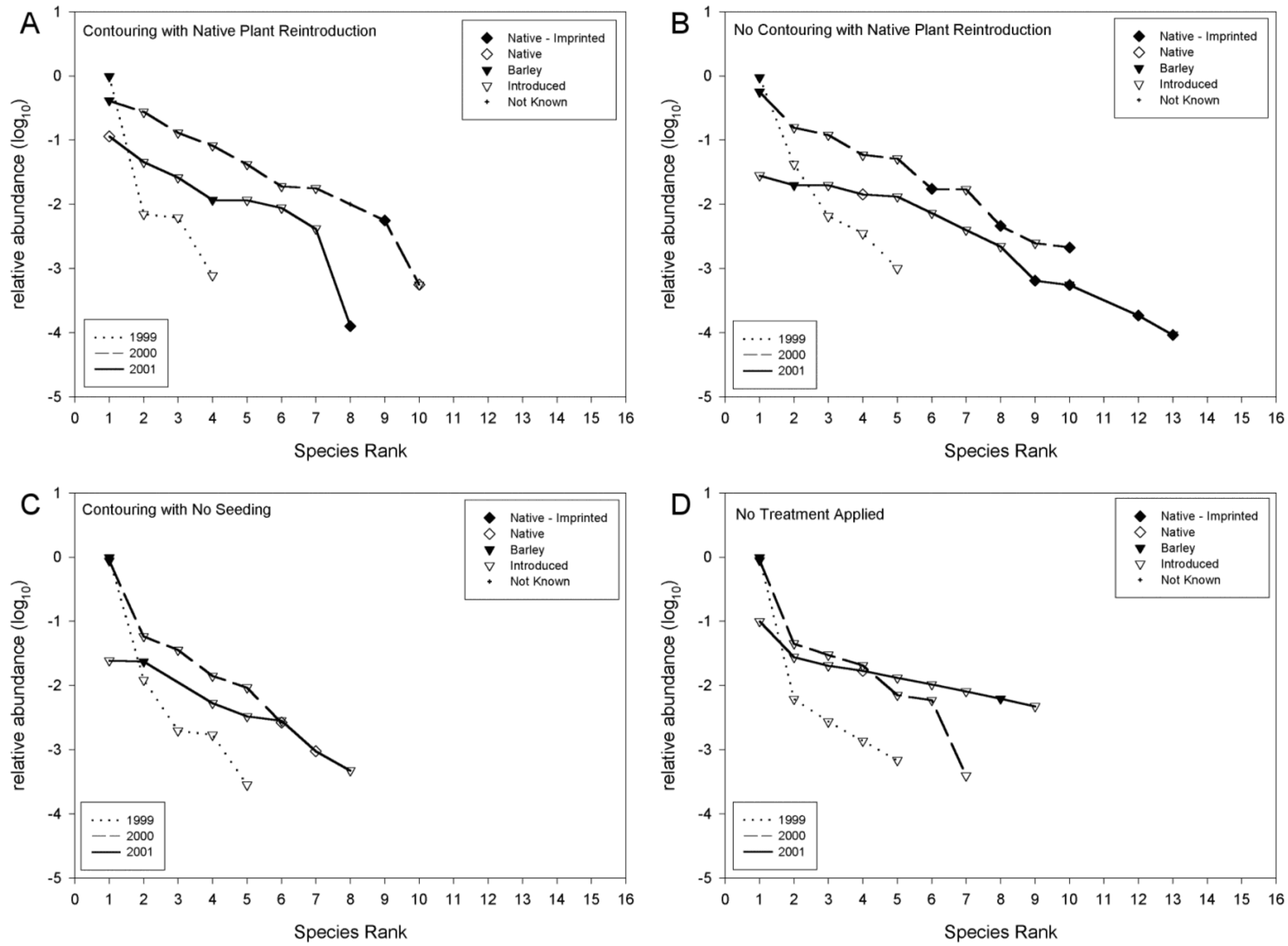

Figure B3. Rank-abundance curves for the Block 3 study plots, Tranquillity HRS.

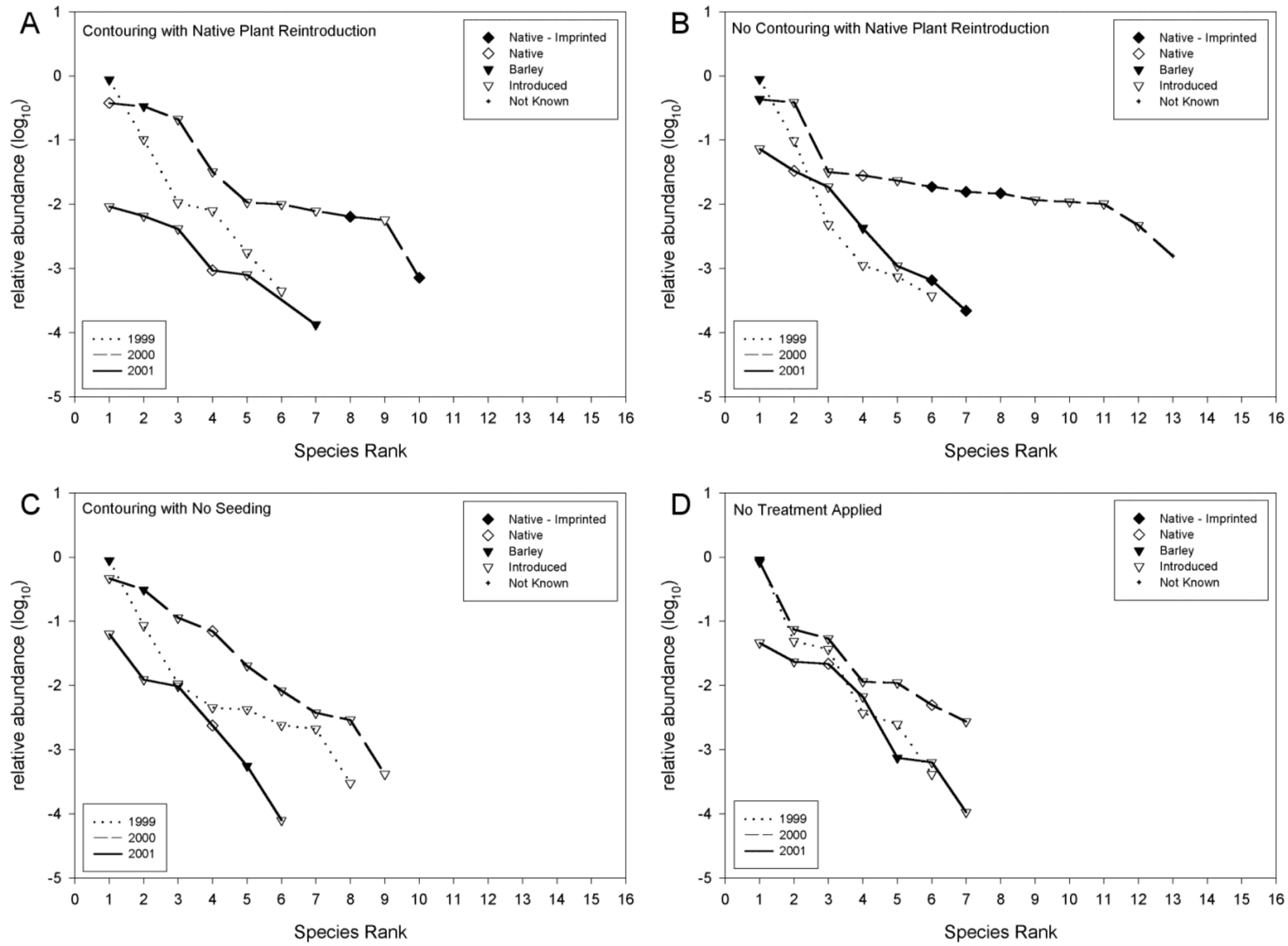

Figure B4. Rank-abundance curves for the Block 4 study plots, Tranquillity HRS.

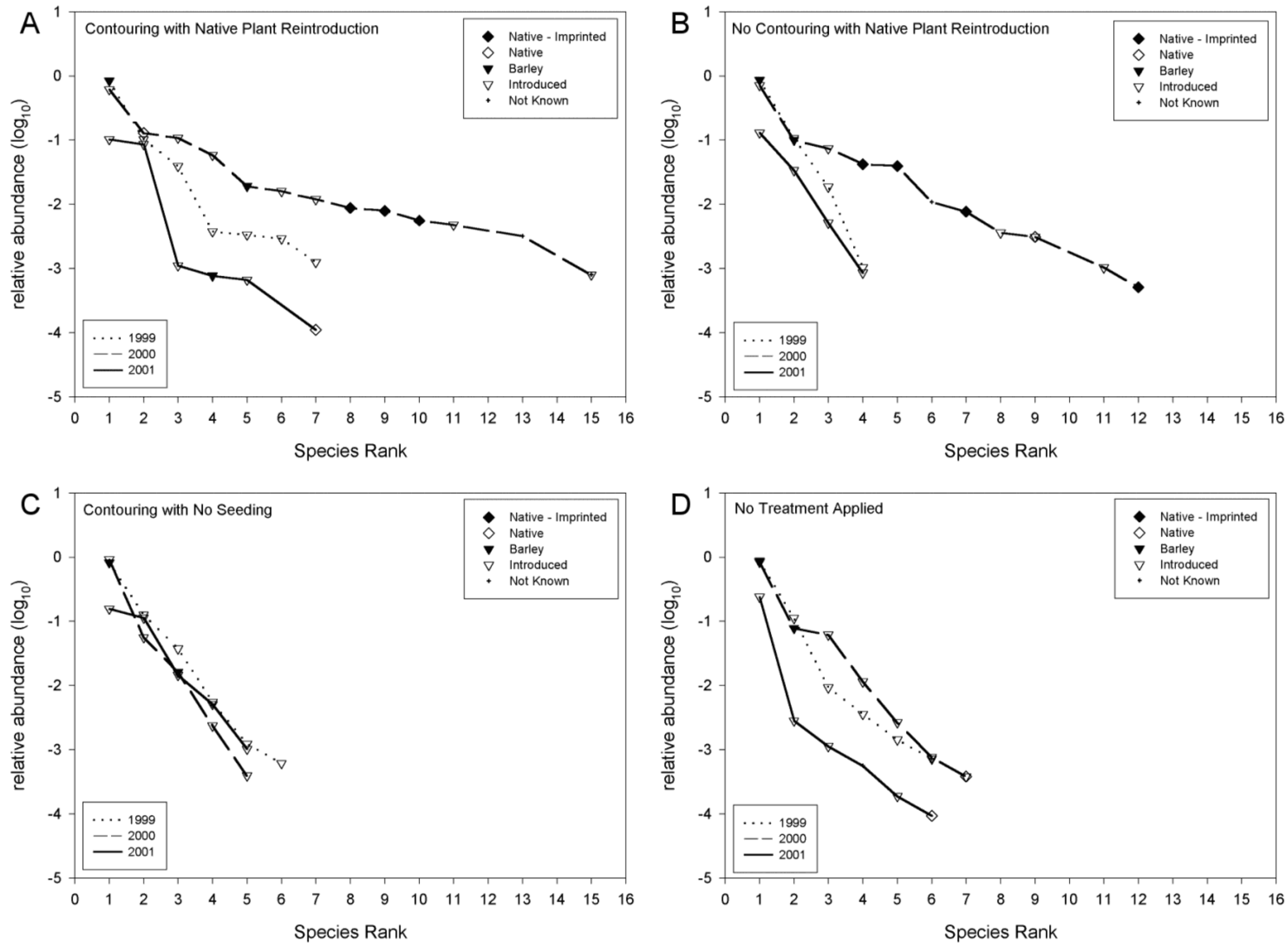

Figure B5. Rank-abundance curves for the Block 5 study plots, Tranquillity HRS.

C. Avian Species Observed on the Tranquillity Habitat Restoration Study Plots, 1999-2001

Table C1. Avian species observed on the Tranquillity HRS plots, 1999-2001.

Avian code	Common name[1]	Scientific name	Status[2]	1999	2000	2001
AMCR	American Crow	*Corvus brachyrhynchos*		+	+	+
AMKE	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*		+	+	-
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*	CSC	+	+	+
NOMO	Northern Mockingbird	*Mimus polyglottos*		+	-	+
PRFA	Prairie Falcon*	*Falco mexicanus*	CSC	-	+	-
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*		+	+	+

Avian code	Common name[1]	Scientific name	Status[2]	1999	2000	2001
SEOW	Short-eared Owl**	*Asio flammeus*	CSC	-	+	+
SOSP	Song Sparrow	*Melospiza melodia*		-	+	+
WCSP	White-crowned Sparrow	*Zonotrichia leucophrys*		+	+	+
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	*Dendroica coronata*		-	-	+

1 * = Facultative grassland specialist; **, Obligate grassland specialist as in Vickery et al. 1999.

3 Key to status: FSC, Federal Special Concern species; CSC, CA Special Concern Species; FPT, Federally proposed for listing as Threatened.