Chapter 4. Results of a Habitat Restoration Study on Retired Agricultural Lands in the San Joaquin Valley, California

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4.1. Introduction

Land retirement without habitat restoration would likely lead to large fields infested with weeds and pests which would affect neighboring agriculture and require extensive and continuous management. Appropriate habitat restoration must accompany land retirement to minimize weeds and pests and to maximize benefits for wildlife. Although land retirement has the potential to enhance wildlife values and improve ecological systems in the San Joaquin Valley, it is recognized that land uses other than wildlife habitat may take precedence on some lands. Some land uses, particularly grazing and, in some cases, dryland farming can be compatible with and may even contribute to habitat values for wildlife. Land retirement could provide wildlife habitat and contribute to the recovery of endangered and threatened plant and animal species (FWS 1998). Retired agricultural lands could provide connecting linkages and corridors between existing habitat areas or large areas of contiguous blocks of land that would provide habitat for new core populations of sensitive species.

The Biological Opinion for the Land Retirement Demonstration Project (LRDP) (FWS 1999) required that a 5-year Habitat Restoration Study (HRS) be conducted focusing on determining the responses of wildlife to land retirement and restoration efforts. Specific objectives of the HRS were to:

- Determine the efficacy of revegetation with native plants as a means to facilitate upland habitat restoration.
- Determine the efficacy of microtopographic contouring as a means to facilitate upland habitat restoration.
- Examine the responses of plants and wildlife to land retirement and restoration.

To accomplish these goals, a large-scale (323.75 ha; 800 ac) study was initiated at the Tranquillity site in 1999. Twenty long-term study plots were established and a broad range of data were collected over a 5-year period (see Section 4.2.1 for a description of the experimental design). At the plot-scale, vegetation, invertebrates, amphibians, reptiles, birds, and small mammals were all monitored throughout the duration of the project. Avian nesting success on the study plots also was studied in 2002 and 2003. Site-wide monitoring included track station surveys, windshield surveys, and spotlighting. The results of these monitoring efforts provide information on wildlife use of retired agricultural lands over a 5-year period. The results also allowed an evaluation of the effectiveness of the restoration efforts and the relative value of those restoration efforts to wildlife.

4.2. Methods

4.2.1. Study Design

A 323.75 ha (800 ac) Habitat Restoration Study (HRS) was established on retired agricultural lands in 1999 to examine the responses of wildlife to restoration efforts. The study incorporated a complete randomized block design and consisted of twenty, 4.05 ha (10 ac) study plots arrayed in 5 blocks (Figure 4-1). The size of the HRS was determined by that which could be reasonably manipulated and monitored with a high degree of experimental rigor, but which was sufficient to yield significant results in a relatively short amount of time (5 years or less). Two restoration factors were studied: (1) the introduction of native plants through seeding (imprinting) and transplanting; and (2) the re-establishment of surface contouring (i.e., microtography). Four combinations of these treatment factors were applied (Figure 4-1).

4.2.2. Restoration Methods

Plots were arranged in a randomized block design to control variation caused by the heterogeneous physical characteristics of the site. Four treatments were randomly assigned to plots within each block; plots were established in April of 1999. Plot corners were permanently marked with 0.91 m (3 ft) sections of reinforcing bar (rebar) and pin flags were added to help locate plot corners. Plot corners were located with a Global Positioning System (GPS) receiver, and data points were archived.

To minimize interactions between plots and to reduce weeds and soil erosion, each plot was surrounded by a 12.14 ha (30 ac) buffer that was maintained with a barley cover crop. During the first year of the Demonstration Project (1999), all HRS experimental plots and associated buffer regions were planted in barley. To grow a healthy cover crop the soil was disked and leveled and the soil was prepared until it was of uniform texture. Barley was drilled at approximately 77.11 kg per 0.40 ha (170 lbs per ac).

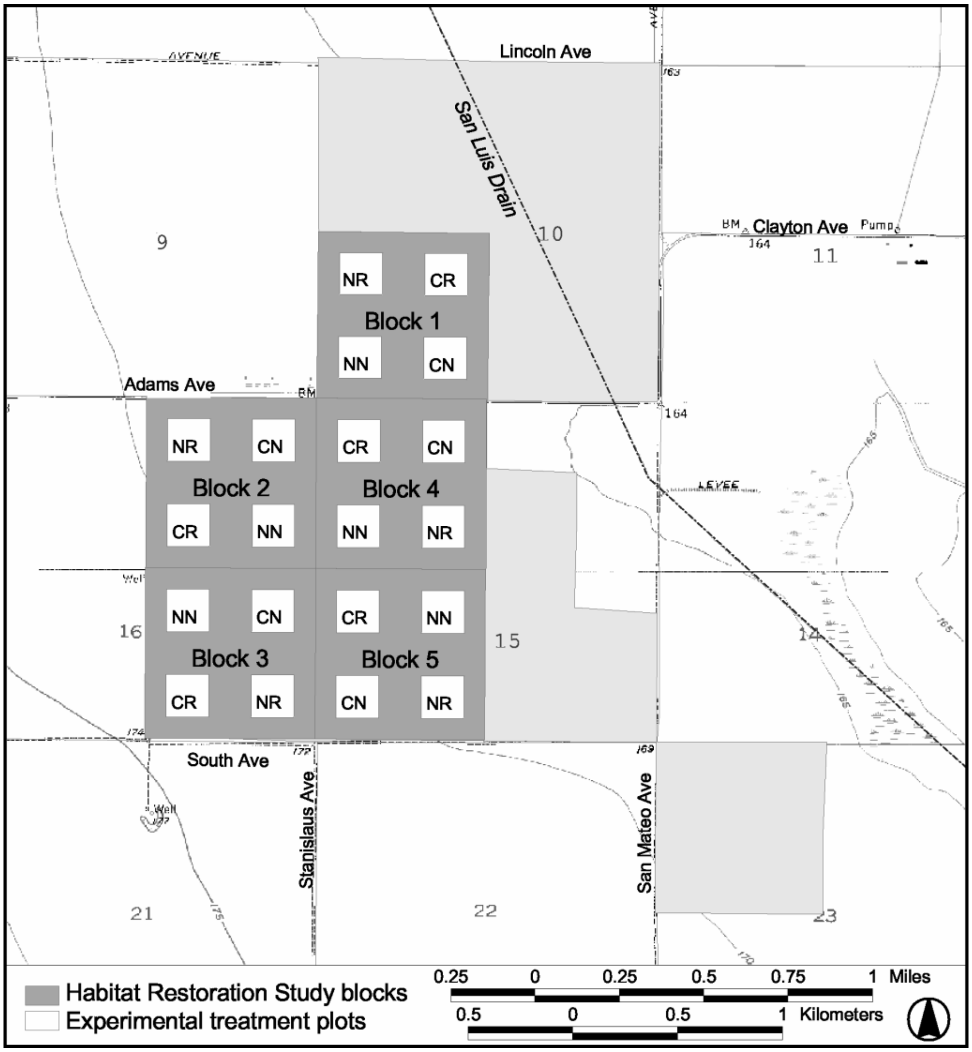


Figure 4-1. Map of the Tranquillity HRS plots showing treatments and blocks. Key to Treatments: CR = contouring and seeding; NR = seeding and no contouring; CN = contouring and no seeding, and NN = no contouring and no seeding.

Due to the effectiveness of the 1999 crop at controlling weeds and providing vegetative cover on retired lands, barley was used as the cover crop for all subsequent years. The seed was inexpensive ($0.10-$0.15 per .45 kilo) and was planted without extensive ground preparation. Irrigation was applied to give the barley a competitive advantage over weeds and with the hopes of obtaining a profitable crop. The barley was irrigated with approximately 7.6 cm (3 in) of water (an amount which would not contribute to deep percolation) in spring of 1999, 2000, and 2001. The barley was not irrigated in subsequent years to reduce costs and, although this precluded production of a harvestable crop, the barley was flailed and replanted to reduce the need to purchase seed.

Imprinting is an experimental seeding method that creates small impressions in the soil and deposits seed directly in the indentation (Dixon 1988). This method of seeding promotes seed-soil contact while protecting the seed from wind and predators. Native seed was imprinted evenly across the plots receiving the reintroduction prescription in March 2000. Plant species were selected based on representative species from nearby ecological reserves and known species composition of the desired plant communities. Further information on rates of applications, costs and mix preparation can be found in Selmon et al. (2000).

Microtopographic contours (berms) were created to reintroduce minor vertical variation across the landscape. Such heterogeneity may create microhabitat suitable for plant germination and animal burrows. Berms were established on experimental plots in January 2000 using a modified agricultural implement commonly used to create "checks" in flood-irrigated agricultural fields. The 240, 12 m (39.3 ft) long berms were installed on each plot. Prior to installation of the HRS plots, it was found that berms were compacted by imprinting. Accordingly, the berms in the seeded plots were initially installed at about twice standard height. The resulting berms on all plots after seeding were consistent in height.

Native plants also were introduced onto the experimental plots via direct transplanting in March and April of 2000. Seedlings were grown from seed in local nurseries from commercial and local seed sources. Transplanted seedlings were closely grouped in "shrub islands" (i.e., closely-grouped planting) to maximize the potential for "nurse plant" effects. Two types of shrub islands were created (Table 4-1). Twenty-five islands (13 Type A and 12 Type B) were installed on each plot. In fall 2000, all shrub islands were inventoried. Wherever necessary, additional seedlings were transplanted into the existing shrub islands such that each island had the minimum number of species as shown in Table 4-1. Transplanting in the Type B islands was augmented by broadcast seed of *Isocoma acradenia*.

Table 4-1. Overview of shrub island planting, Tranquillity HRS. Figures in the Initial Planting columns indicate the number of individuals that were initially transplanted to each island. Figures in the Fall Replanting columns indicate the target number (i.e., minimum number of living individuals) for each species following replanting in fall 2000.

	"Type A"		"Type B"	
	Initial Planting	Fall Replanting	Initial Planting	Fall Replanting
Allenrolfea occidentalis	14	4	-	-
Atriplex polycarpa	-	-	12	8
Isocoma acradenia	-	-	2	seeding
Leymus triticoides	4	0	-	-
Sporobolus airoides	22	8	-	-

Nursery stock generally needs ample rain or irrigation after planting for establishment in native soils. The Tranquillity study site rarely receives sufficient rainfall to support transplanted nursery stock, so DriWater™, a time-release water product, was installed adjacent to seedlings when planting the shrub islands. To facilitate establishment, additional water was applied 2-3 times with a backpack sprayer within 2 weeks of planting.

4.2.3. Plot-Level Monitoring

4.2.3.1. Vegetation Survey Methods

Vegetation monitoring was timed (as much as possible) to coincide with the period when the majority of the annual species had begun to senesce. Monitoring dates for all years are presented in Table 4-2. Sampling methodologies were consistent throughout the 4 years of monitoring on the plots. Data were collected from 24 quadrats (35 x 70 cm) on each plot. A stratified random sampling approach was employed, with plots divided into sixth-sections and four sampling points randomly selected within each section. All species were noted and the percent cover for each species estimated using a modified Daubenmire cover scale (0-1 percent; 1-5 percent; 5-25 percent; 25-50 percent; 50-75 percent; 75-95 percent; 95-100 percent; Bonham 1989). The total percent cover of all species within the quadrat was also estimated using the same scale. Whenever possible, species were identified completely; failing this, species were assigned morpho-species names (e.g., “Unknown Compositae”).

In addition to cover data, qualitative data were entered for each quadrat (e.g., whether or not the percent cover of vegetation in the quadrat was representative of the general area), and for individual species (e.g., flowering condition). Qualitative assessments were also made at the plot-wide scale. To document that portion of the flora that was not represented in the quadrats, a running list was compiled of all species noted on the plot. However, estimates of species richness were based solely on the species that occurred in the quadrats.

In fall of 2002, a census of shrubs and shrub-like annuals was conducted on the HRS plots; however, this survey was not repeated in 2003. A complete account of the 2002 survey was presented in Uptain et al. (2004).

Photographic vouchers were taken on the HRS plots to document post-treatment conditions and to provide a permanent record of changes in vegetation structure and composition. Photographs (one 35 millimeter [mm] and one digital) were taken from each of two standard locations along the southern boundary of each plot (43 meters [m] from each of the corners), with the cameras oriented northwards. Copies of the photos are archived at Endangered Species Recovery Program (ESRP) and Reclamation offices in Fresno, with the 35 mm photos stored in binders and the digital photos archived on compact disk. Photographs were taken quarterly, except in 2003 when three photographic surveys were made (March 21; June 18, 24-25; September 16-18).

Table 4-2. Plot-level survey dates for the various biotic groups, 1999 to 2003. Monitoring in 1999 (baseline monitoring) preceded the installation of the HRS plots but was conducted on the 323.75 ha (800 ac) area on which the plots were subsequently cited.

Biotic group	Year	Survey Dates
Vegetation	1999	23, 26, 27, 29 Apr
	2000	25-27 Apr; 1 May
	2001	7-9 May
	2002	11, 12, 15, 20 Mar
	2003	8-11, 15-16, 21-22 Apr
Invertebrates	1999	8-10 June
	2000	6-7, 13-14 June
	2001	19-22 June
	2002	16-19 April
	2003	20-23 May
Amphibians and Reptiles	1999	8-10 June
	2000	6-7, 13-14 June
	2001	11-13 July
	2002	8-10 June, 29 April, 2-3 May, 9-11 July, 8-10 Jan(pitfall)
	2003	14-16 Jan, 7-9 May, 8-10 July, 21-23 Oct, 3-4 Dec (just amphib)
Birds	1999	12-14 May, 21-23 July, 20-22 Oct
	2000	12-14 Jan, 8-10 May, 26-28 July, 17-19 Oct
	2001	17-19 Jan, 18-20 April, 18-20 July, 2-4 Oct
	2002	16-18 Jan, 2-4 April, 22-24 July, 8-10 Oct
	2003	14-16 Jan, 7-9 May, 8-10 July, 21-23 Oct
Small Mammals	1999	11-14 Oct
	2000	15-18 May, 8-11Aug, 6-9 Nov
	2001	27 Feb-2 Mar, 30 April-3 May, 6-9 Aug, 5-8 Nov
	2002	29 Jan-1 Feb, 6-9 May, 15-18 July, 28-31 Oct
	2003	4-7March, 28-30 April-1 May, 21-24 July, 6-9 Oct

4.2.3.2. Invertebrates

Invertebrates were collected over a 5-year period (Table 4-2) from five pitfall arrays (Figure 4-2) that were established on each of the 20 study plots. Each array consisted of four, 11.36 liters (3 gal) buckets sunk into the ground to the rim. The buckets were connected by 6.1 m by 30 cm (20 ft by 1 ft) sections of galvanized steel flashing used to guide invertebrates into the buckets. During the four consecutive survey days, bucket lids were removed and supported approximately 2.5 cm (1 in) above the rim by wooden stakes. Buckets were opened for approximately 24 hours between each survey day.

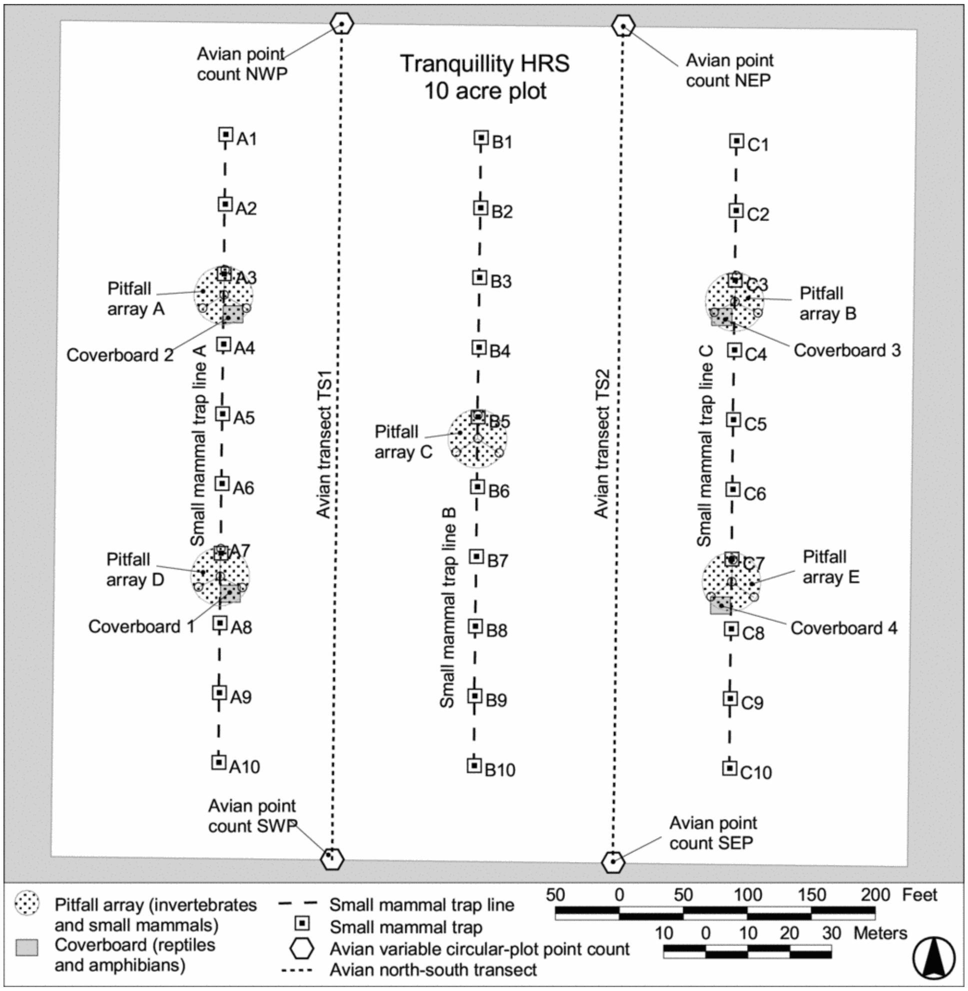


Figure 4-2. Locations of pitfall arrays, amphibian and reptile coverboards, avian transects and point-count locations, and small mammal trapping lines on a study plot at the Tranquillity site.

All invertebrates found within the pitfalls were identified to order and counted. A voucher specimen was collected of each invertebrate type that was present on each plot. These were later identified to the family level whenever possible. The numbers of orders found on each plot over the 4-day survey period were tallied to obtain richness. The abundance of invertebrates present on each plot was determined by tallying the numbers of invertebrates found in each bucket over the 4-day sampling period, then adding the tallies of all buckets on a plot, then dividing the total by four to obtain an average number per day. Richness and abundance values are based upon the ordinal level because consistent and accurate invertebrate field identification beyond that level was not possible.

Once the identification process was complete, invertebrate orders and families were classified into one of four functional groups; herbivores, predators, pollinators, and parasites. Although this process is not complete, the classification has enabled us to identify agriculturally beneficial and harmful invertebrates which occur on the study plots and assess the potential impacts of land retirement in promoting populations of these invertebrates.

4.2.3.3. Amphibians and Reptiles

Reptile and amphibian surveys were typically conducted concurrently with avian surveys (Table 4-2). On occasion, asynchronous surveys were conducted because of time constraints imposed by the avian surveys and the need to conduct amphibian surveys during periods of rain. Visual encounter surveys (Heyer et al. 1994) were conducted along the small mammal trapping transects, and four 0.37 m by 0.37 m (4 ft by 4 ft) coverboards per plot (Figure 4-2) were inspected for the presence and/or sign of amphibians and reptiles. Additionally, incidental sightings of amphibians and reptiles were recorded during other surveys and other site visits.

4.2.3.4. Birds

Bird diversity and abundance surveys Avian surveys were conducted quarterly over a 5-year period (Table 4-2) on the study plots. Four point counts on variable circular plots (Verner 1985) and two parallel north-south transects (Figure 4-2) were censused for four consecutive mornings. Surveys began within 30 minutes of sunrise (Ralph et al. 1993). All five blocks were concurrently sampled by 5 biologists synchronizing starting times between blocks to within 5 minutes of each other. Each circular-plot was censused for 5 minutes and each transect was censused for 5 minutes, resulting in 30 minutes of observations per plot. The direction of the survey route was alternated on each subsequent survey day. All species recorded on experimental plots were included in data analyses; fly-over and species not on experimental plots were incidentally noted but excluded from analyses. Avian species observed on experimental plots were identified to species and all detected birds were documented as either a visual or a vocal account. Location, activity, and distances from observer also were recorded.

Nest survey We searched for nests from the first week of March through the first week of April in 2002 and 2003 to identify nests, determine nesting success, and the causes of nest failure. Rope dragging, the standard method used to search for ground nesting birds and their nests (Labisky 1957), was conducted using a 60 m (200 ft) long, 0.95 cm (0.38 inch) thick nylon rope. Each plot was surveyed once each week for 4 consecutive weeks. Three sweeps of the rope were necessary to completely cover each plot. When a bird flushed, the surrounding area was searched for active nests. Nest locations were mapped on a site map, their positions were recorded using a hand-held global positioning system unit, and they were marked in the field using a pin-flag placed 5 m (16.5 ft) south of the nest. Active nests were checked at 3- to 4-day intervals until nesting ended. Precautions described by Ralph et al. (1993) were used to minimize nest disturbance and the risk of predation. Data recorded included nest height, nest dimensions, nest orientation, the presence or absence of adults, the number of eggs or nestlings present, and a brief description of nestlings (e.g., number, size, presence of pin feathers, etc.). Clutch initiation was estimated by backdating (Alisauskas and Ankney 1992) and mean clutch size and median fledge date were calculated for all monitored nests. Photographs of nests and nestlings were taken. Vegetation at each nest site was characterized once nests were vacated. Each site was characterized using four 35 cm by 70 cm (14 - 28 inch) sampling quadrats placed immediately adjacent to the nest in each cardinal direction. Within each quadrat, we estimated percent cover (total vegetative cover, cover of shrubs, grasses, forbs, litter, and bare ground), the total cover of each plant species present, and the average height of plants.

4.2.3.5. Small Mammals

Small mammal trapping was conducted quarterly over a 5-year period (Table 4-2). On each study plot, 30 Sherman live-traps were placed in three lines of 10 traps each with an inter-trap spacing of 15m (50 ft) (Jones 1996, Figure 4-2). Traps were baited with a small handful of millet, opened approximately an hour before sunset, and checked and closed starting 2 hours after dark. All five blocks were checked simultaneously by one biologist per block. Each night, the starting point was moved to the ending point of the previous night so that the traps were open for approximately the same amount of time over the survey period. Captured mammals were identified, sexed, weighed, and reproductive status and trap location noted. Kangaroo rats (*Dipodomys heermanni*) were marked with passive integrated transponders (PIT tags) and other species were marked by clipping a patch of fur from the rump or hindquarters.

Pitfall traps also were used to capture small mammals. Data from the pitfall traps were used to augment the assessment of species richness and some small mammals captured in the pitfalls were sacrificed for selenium analysis. The 4-day pitfall survey was conducted concurrently with the invertebrate surveys (Table 4-2). Pitfall traps were checked after sunrise for small mammals and closed, prior to processing invertebrates. The tip of the tail was removed from shrews (*Sorex ornatus*) and pocket mice (*Perognathus inornatus*) to be used in a genetics study.

4.2.4. Site-Wide Surveys

4.2.4.1. Spotlighting Surveys

Spotlight surveys were conducted quarterly from fall 1999 to fall 2003 (Table 4-3) to evaluate the site-wide richness and abundance of wildlife at the Tranquillity site. In spring 2001, heavy rains and flooding of the site precluded a survey. Two biologists illuminated the landscape along a 25.07 km (15.58 mi.) route (Figure 4-3) using 1,000,000 candlepower spotlights. Surveys were conducted for 3 consecutive days, except in spring of 2002 when flooding of the site required the survey to be conducted during two, 2-day periods. Each survey began at sunset and was completed in approximately 2 hours. The vehicle was driven at 15 to 25 kph (10 to 15 mph), and species observed were identified with the aid of 10 x 50 power binoculars. Data recorded included species, number of individuals, location (odometer reading and/or GPS waypoint) and additional notes. The start and end times, temperature, mileage, environmental conditions (wind speed and direction, cloud cover and moon phase), and additional notes (e.g., flooded areas, unusual activity etc.) were recorded. The richness and abundance of amphibians, reptiles, avian, and mammals were generated for each survey period.

Table 4-3. Dates of spotlighting surveys, track station surveys, and winter raptor surveys conducted from 1999 to 2003.

Survey	Year	Dates
Spotlighting	1999	14-16 Sep; 20-22 Dec
	2000	27-29 March; 19-21 June; 11-13 Sep; 27-29 Nov
	2001	29-31 May; 17-19 Sep; 17-19 Dec
	2002	4-5, 11-12 March; 24-26 June; 9-11 Sep; 9-11 Dec
	2003	24-26 March; 16-18 June; 15-17 Sep
Track stations	1999	15-17 Sep; 21-23 Dec
	2000	28-30 March; 20-22 June; 12-14 Sep; 28-30 Nov
	2001	14-16 March; 30-31May, 1 June; 11-13 Sep; 18-20 Dec
	2002	5, 12-13 March; 25-27 June; 11-13 Sep; 10-12 Dec
	2003	25-27 March; 17-19 June; 16-18 Sep
Winter raptor	1999	21-23 Dec
	2000	3-5 Jan (2001)
	2001	18-20 Dec
	2002	10-12 Dec
	2003	6-8 Jan (2004)

4.2.4.2. Track Station Surveys

Seventeen track stations (Figure 4-3) were checked for 3 consecutive days each quarter from 1999 to 2003 (Table 4-3). Surveys were not conducted in spring or summer 1999 because the project had not yet been initiated. Each station consisted of a 1 m (3.3 ft) square galvanized steel plate covered with a 5 to 8 cm (2 to 3 in) layer of equal parts of dolomite and fine sand. A can of wet cat food was set in the center of the plate as an attractant. The substrate and cat food were replaced as needed. Each track station was checked for tracks between 0600 and 1000 hours. We attempted to identify tracks to the species level, but sometimes only identifications to family or order were possible. Data are reported as richness and rate of visitation.

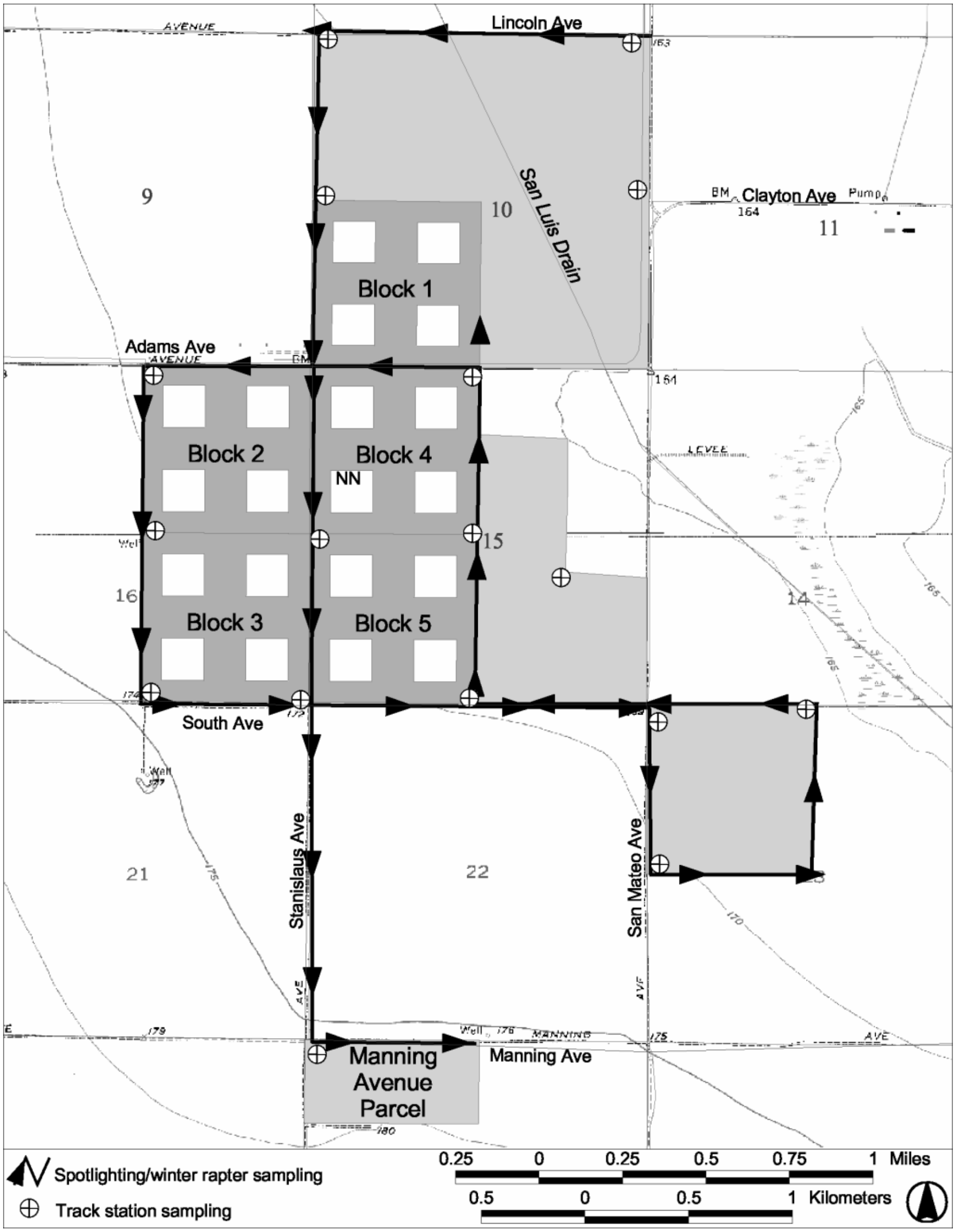


Figure 4-3. Locations of the spotlight survey route, track stations, and winter raptor survey route, 1999 to 2003.

4.2.4.3. Winter Raptor Surveys

Windshield surveys were conducted in December or January from 1999 to 2003 (Table 4-3) to determine raptor abundance and distribution. Surveys generally began 1 hour after sunrise, but start times were delayed if fog hindered visual observations. The 25.07 km (15 mi) survey route was located adjacent to the demonstration site (Figure 4-3). The route was surveyed for 3 consecutive days each survey period by driving the route slowly (approximately 5 to 10 miles per hour or 8 to16 kilometers per hour). Raptors were identified using binoculars and a spotting scope. Data recorded included species, sex, age (when possible), activity at time of first observation, and location. The start location, weather conditions (cloud cover, wind, moon phase, and temperature), start and end times, and start and end odometer readings were recorded. Loggerhead shrikes (*Lanius ludovicianus*), mountain plovers (*Charadrius montanus*), and other sensitive bird species also were recorded and reported to the California Natural Diversity Database (CNDDB). Raptor abundance was calculated as the average number observed per day over each 3-day census.

4.2.4.4. Statistical Analysis of Vegetation Data

Species were grouped by "origin" (e.g., introduced, native, etc.) for some analyses. One category, the "tumbling saltweeds" is a modification of what had been referred to in previous annual reports as the "Native–Undesirable" category. The tumbling saltweeds are composed of two species, *Atriplex argentea* (silverscale saltbush) an undesirable native species, and the non-native *Atriplex rosea* (tumbling oracle). These annual herbs, which possess a shrub-like form, have demonstrated the capacity to quickly become established and to dominate large areas of the study plots.

The remaining categories are self-explanatory (e.g., "Native"); however, the "Imprinted and Introduced" category merits a brief explanation. This category was created to integrate the contribution of species that could be ascribed to genera that were represented in both the "Native - Imprinted" and "Introduced" categories, but which were frequently not identifiable to the level of species. In the 2003-04 growing season, the "Imprinted and Introduced" category was represented at the Tranquillity HRS by a single pair of species: the grasses *Vulpia microstachys* (imprinted) and *V. myuros* (introduced). Fertile individuals of both species were frequently encountered; nevertheless, quadrats would often contain only infertile material, and it was not possible to confidently ascribe this material to a particular species. It was assumed that both species were present on any plot in which *Vulpia* was noted; hence, the Imprinted and Introduced category contributed two species to estimates of species richness. For analyses of abundance, one-half of the percent cover value from the Imprinted and Introduced species was applied to the Native – Imprinted category and one-half to the Introduced category.

Descriptive statistics, t-tests, and Analysis of Variance (ANOVA) procedures were conducted using the software package STATISTICA (StatSoft, Inc. 2002). 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 analyzed by Detrended Correspondence Analysis

(DCA, Hill and Gauch Jr. 1980). Ordinations were conducted using the software package PC-Ord (McCune and Mefford 1999).

4.2.4.5. Analysis of Data for the Other Biotic Groups

The effects of restoration treatments on the richness and abundance of invertebrates, amphibians and reptiles, birds, and small mammals were analyzed using Analysis of Variance applied to log-transformed data. If warranted, post-hoc analyses using Fisher LSD tests were performed. Statistical analyses were accomplished using Statistica 6 (Statsoft, Inc. 2002). The geometric means (hereafter referred to as means) of the data sets were graphed using Sigma Plot (SPSS Inc. 2002).

In addition to evaluating the affects of restoration on richness and abundance of invertebrates as a group, we separately evaluated the abundance of the beetles (*Coleoptera*) and spiders (*Araneae*). These two orders are commonly used as indicators of restoration effects because they are sensitive to environmental change, taxonomically well known, and biologically diverse (Perner and Malt 2003, Rykken et al. 1997). Additionally, we separated invertebrate orders into three groups—herbivores, pollinators, and predators—to evaluate the abundance of these groups in response to restoration treatments. Similarly, we grouped birds into one of three categories—obligate grassland species (those birds that require grassland habitats), facultative grassland species (those birds that benefit from grassland habitats), and other species—to evaluate the abundance of birds based upon ecological roles.

Nesting data were analyzed using the Mayfield method (Mayfield 1961, 1975) to calculate various parameters associated with nesting survival. The relationship between the presence of plants and nest success was statistically evaluated. Chi-square tests were used to determine if nest success or failure was influenced by the presence of individual plant species and student's *t*-tests were used to evaluate nest success relative to nest height and the mean number of plant species present. Spearman rank correlation was used to evaluate the correlation between the number of successful nests and the number of plant species present at the nest site. All statistical tests were performed in Statistica 6 (Statsoft, Inc. 2002).

Data from spotlight and track station surveys were log transformed and analyzed using single-factor or multifactor Analysis of Variance in Statistica 6 (StatSoft, Inc. 2002). Data from winter raptor surveys were log transformed and analyzed using repeated measures Analysis of Variance and Spearman rank correlation.

4.3. Results

4.3.1. Plot-Level Monitoring

4.3.1.1. Vegetation

Results are initially considered with reference to site-wide patterns. Subsequently, patterns among treatments and blocks (i.e., replicates) are considered.

Site-level At the site level, species richness initially increased after imprinting (i.e., from 1999 to 2000; Table 4-4). Nevertheless, site-level richness decreased during the following 2 years, reaching levels that were approximately equivalent to that of the baseline year (i.e., 1999).

Table 4-4. Overall vegetation species richness in the Tranquillity HRS study plots. Included data are solely those species which occurred within the quadrats.

Species Category	1999	2000	2001	2002	2003
Native - Imprinted	0	5	5	4	3
Native	3	5	2	2	2
'Tumbling Saltweeds'	1	1	1	1	1
Imprinted & Introduced	0	2	2	2	0
Barley	1	1	1	1	1
Introduced	15	16	15	12	17
Not Known	6	5	1	4	0
Total	26	35	27	26	24

Thirteen native species were imprinted into the plots in 2000 (Table 4-5); see Selmon 2000 for an overview of the experimental design and plot installation). Of these imprinted species, only six (46.2 percent) were noted during vegetation monitoring in 2000 and 2001, and only five (38.5 percent) in 2002. By 2003, only three of the imprinted species occurred in the spring monitoring quadrats (Table 4-5). Less than half of the species that were imprinted were observed during any particular year's monitoring; however, approximately two-thirds (9) of the imprinted species have been observed at some point during monitoring (i.e., during at least 1 year's monitoring).

Table 4-5. Species imprinted in the Tranquillity HRS Plots (1999), and an overview of those imprinted species noted in the quadrats during spring vegetation monitoring, 2000-2003.

Species	Family	Common Name	2000	2001	2002	2003
Allenrolfea occidentalis[A]	Chenopodiaceae	iodinebush	-	-	-	-
Atriplex polycarpa	Chenopodiaceae	allscale saltbush	-	-	+	+
Atriplex spinifera	Chenopodiaceae	spinescale saltbush	-	-	-	-
Bromus carinatus	Poaceae	California brome	+	+	+	-
Frankenia salina	Frankeniaceae	alkali heath	+	-	+[B]	-
Heliotropium curassavicum	Boraginaceae	seaside heliotrope	-	-	-	-
Hemizonia pungens	Asteraceae	common spikeweed	-	+	-	-
Isocoma acradenia	Asteraceae	goldenbush	+	-	-	-
Lasthenia californica	Asteraceae	California goldfields	+	+	+	+
Leymus triticoides	Poaceae	creeping wild-rye	-	+	-	-
Sporobolus airoides	Poaceae	alkali sacaton	-	-	-	-
Suaeda moquinii	Chenopodiaceae	bush seepweed	+	+	-	-
Vulpia microstachys	Poaceae	small fescue	+	+	+	+

A. A few, transplanted individuals are still alive on Block 1; however, none of these occurred within the quadrats.

B. Noted in a single, non-imprinted plot.

In addition to species that are actively introduced to restoration sites through imprinting and direct planting, it is hoped that native species would become established on retired lands without human intervention. It is expected that these species would become established either through existing seed banks or through colonization from other areas and, indeed, at the Tranquillity HRS, a number of non-imprinted natives have been noted on the plots (Table 4-6). As discussed in the Methods section, the native *Atriplex argentea* (the native component of the 'tumbling saltweeds') is considered to have an overall negative impact on restoration and, hence, is non-desirable. Therefore, that species is not included in the tally of "naturally established" native species. Discounting *A. argentea*, eight non-imprinted native species have been noted on the HRS plots (Table 4-6).

Non-imprinted native species were best represented during the first year of restoration (i.e., 2000), with five species noted during monitoring (Table 4-6). However, only two such species were noted during each of the subsequent year's monitoring. As will be discussed later, none of these species were well-represented on the HRS plots.

Table 4-6. Non-imprinted, native species (excluding Atriplex argentea) noted in the quadrats during spring vegetation monitoring in the Tranquillity HRS, 1999-2003.

Species	1999	2000	2001	2002	2003
Amsinckia menziesii	-	-	+	+	-
Eremalche parryi	+	-	-	-	-
Hordeum depressum	+	+	-	-	+
Malacothrix coulteri	-	-	-	+	-
Malvella leprosa	-	+	-	-	-
Monolepis nuttalliana	-	+	-	-	-
Phacelia ciliata	+	+	+	-	+
Solanum americanum	-	+	-	-	-
Total:	**3**	**5**	**2**	**2**	**2**

The dominance by non-native species that was suggested by the site-level richness patterns was even more evident when species' abundances were considered (Table 4-7). The eleven most abundant species were non-native, with three species (*Sisymbrium irio*, *Bromus madritensis*, and *Capsella bursa-pastoris*) providing more than three-quarters (77.0 percent) of the vegetative cover.

In general, vegetation on the HRS plots tended towards dominance by one or the other of two most abundant species: *Sisymbrium irio* (London rocket) and *Bromus madritensis* (red brome). To examine the spatial partitioning of these two species, we developed a spatial analysis in which the plots were divided into sixths and the mean abundances of selected species represented graphically (Figure 4-4 and Figure 4-5).

As was noted, vegetation monitoring employed stratified random sampling, with the plots divided into sixth-sections (sextants) and four quadrats situated within each section. For this analysis, the mean percent cover for each 'sextant' was calculated from the cover values from the four quadrats. Although this type of representation does not allow for statistical analyses, it is well-suited to show spatial variations in species abundances.

This approach was employed, because there was an evident partitioning of the two dominant weeds, with *Bromus madritensis* dominant on the northernmost plots (Block 1) and *Sisymbrium irio* the more abundant species on most areas of the remaining 16 plots (Blocks 2-4). This partitioning is clearly represented in the graphs (Figure 4-4 and Figure 4-5). Although not included here, a graph of the sextant abundance data for *Capsella bursa-pastoris* (the third most abundant species) showed a similar pattern to that of *S. irio*.

Table 4-7. All species noted in the quadrats during spring vegetation monitoring in the Tranquillity HRS, 2003, including species code, common name, life-form, origin, mean percent cover, and relative abundance. Species codes are used to identify species in subsequent figures. Relative abundance represents the percent contribution of a particular species to the total cover. Key to Origins: C = Cultivar; I = Introduced, N = Native (non-imprinted): N-I = Imprinted Native; T = Tumbling Saltweeds; U = Unknown.

Taxon	Code	Common Name	Life-form	'Origin'	% Cov.	Rel. Abd.
Sisymbrium irio	A	London rocket	annual herb	I	42.048	47.889
Bromus madritensis	B	red brome	annual herb	I	15.190	17.299
Capsella bursa-pastoris	C	shepherd's purse	annual herb	I	10.335	11.771
Melilotus indica	D	sourclover	annual herb	I	5.962	6.791
Brassica nigra	E	black mustard	annual herb	I	3.329	3.792
Senecio vulgaris	F	old-man-in-the-Spring	annual herb	I	3.184	3.627
Erodium cicutarium	G	redstem filaree	annual herb	I	2.775	3.160
Hordeum murinum	H	foxtail barley	annual herb	I	2.690	3.063
Sonchus sp.	I	prickly lettuce	annual herb	I	0.341	0.388
Vulpia myuros	J	rattail fescue	annual herb	I	0.311	0.355
Avena sp.	K	oats	annual herb	I	0.289	0.329
Atriplex polycarpa	L	allscale saltbush	shrub	N-I	0.286	0.326
Lactuca serriola	M	prickly lettuce	annual herb	I	0.272	0.310
Beta vulgaris	N	beet	annual herb	I	0.194	0.221
Hordeum vulgare	O	barley	annual herb	C	0.158	0.180
Vulpia microstachys	P	small fescue	annual herb	N-I	0.149	0.170
Atriplex argentea	Q	silverscale saltbush	annual herb	T	0.079	0.090
Hordeum depressum	R	alkali barley	annual herb	N	0.040	0.045
Bromus diandrus	S	ripgut brome	annual herb	I	0.031	0.036
Bromus sp.	T	brome	annual herb	I	0.031	0.036
Malacothrix coulteri	U	snake's head	annual herb	N	0.031	0.036
Lasthenia californica	V	California goldfields	annual herb	N-I	0.030	0.034
Malva parviflora	W	cheeseweed	annual herb	I	0.023	0.026
Phacelia ciliata	X	Great Valley phacelia	annual herb	N	0.009	0.011
Bromus carinatus	Y	California brome	perennial herb	N-I	0.006	0.007
Lolium perenne	Z	perennial ryegrass	perennial herb	I	0.006	0.007
Bromus hordeaceus	a	soft brome	annual herb	I	0.001	0.001
Chenopodium sp.	b	N.A.	not known	U	0.001	0.001
Phalaris minor	c	littleseed canarygrass	annual herb	I	0.001	0.001

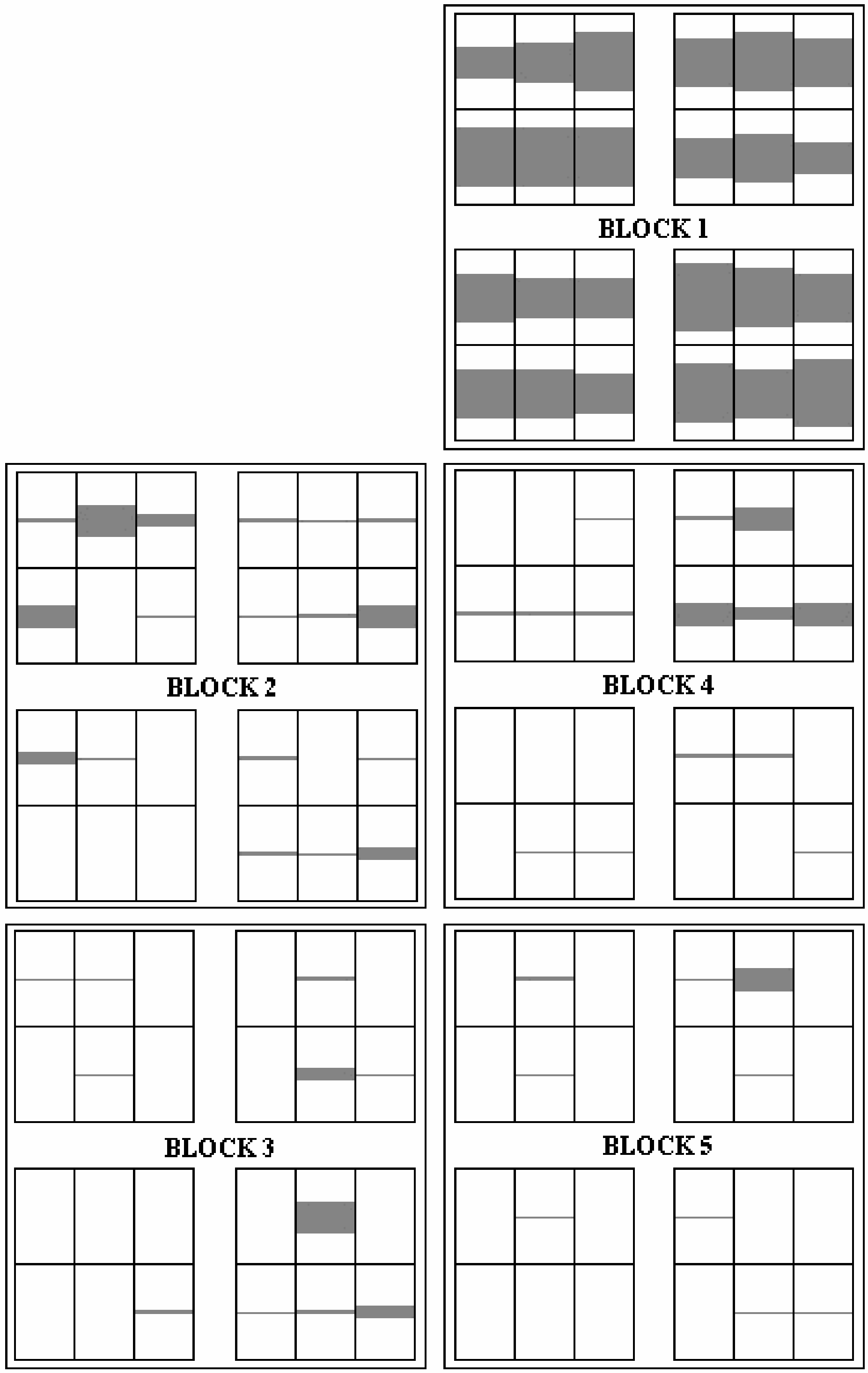


Figure 4-4. Distribution of Bromus madritensis (red brome) at the Tranquillity HRS, 2003. Each small rectangle represents a 'sextant'; i.e., the portion of the plot in which a particular group of four sampling quadrats was located. The shading represents the mean percent cover of red brome in that particular sextant.

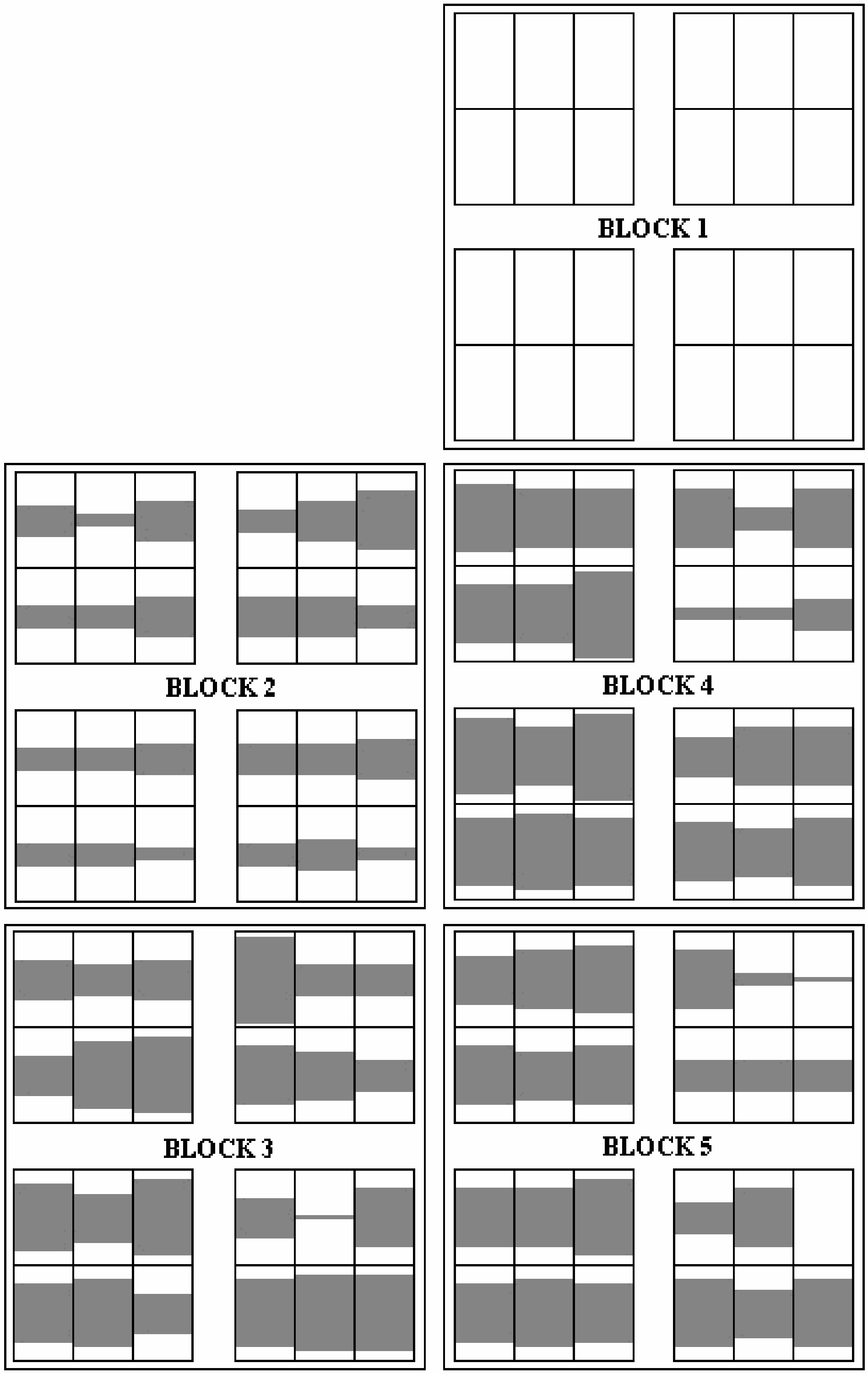


Figure 4-5. Distribution of Sisymbrium irio (London rocket) at the Tranquillity HRS. Each small rectangle represents a 'sextant', i.e., the portion of the plot in which a particular group of four sampling quadrats was located. The shading represents the mean percent cover of London Rocket in that particular sextant.

Generally, the areas dominated by *Bromus madritensis* were those with soils characterized by high electrical conductivity readings and high levels of soluble boron. These areas were the only part of the HRS in which the salt-tolerant *Allenrolfea occidentalis* survived. The buffers of the red brome-dominated plots also tended to have a large component of brome. This pattern was increasingly evident in the later years of the project, and was apparent throughout Block 1 and in the northern half of Block 4. Although *Sisymbrium irio* was an obvious component in buffers of the London rocket-dominated plots, it was not nearly as abundant as was red brome in the northernmost buffers.

A few additional, site-wide patterns should be noted. First, the relative absence of non-imprinted, native species was particularly troubling. With the exception of the tumbling saltweed *Atriplex argentea,* few non-imprinted native species have been observed on the study Plots. To date, only two 'desirable' native species, *Malacothrix coulteri* (snakes head) and *Phacelia ciliata* (valley Phacelia), have shown any sign of becoming established on the study site. Throughout the course of the project, abundances of both these species have been low (Table 4-7; Figure 4-6; Figure 4-7).

Also of note was the difference in appearance between the herbaceous vegetation on the plots and in the buffer areas (excluding those buffers dominated by red brome). Generally, species (both introduced and adventitious natives) in the buffer were more robust and showed less stress with the onset of the dry season than did the same species on the plots. In part, this pattern may be attributable to the barley ameliorating conditions to some degree (i.e., by functioning as a nurse crop). This difference in vegetation may also be a function of the different delivery techniques, as the plots were imprinted and the buffers drilled. Specifically, the depressions created by the imprinter appear to facilitate erosion of the clay soils at the Tranquillity site.

Treatments and blocks The predominance of non-native species that was evidenced in the site-wide abundance data (Table 4-7) was also clear when considering treatment-level vegetation patterns. To graphically represent the contribution of the various species and species classes to the site's vegetation, a series of rank-abundance curves were plotted (Figure 4-6; Figure 4-7).
Plots were ordered sequentially by Block number within each graph; hence, the leftmost curve represents the Plot from Block 1, the second to the left, Block 2, etc. Rank-abundance curves were plotted along the x-axis in such a way as to minimize overlap. Thus, no ordinal scale is presented along the x-axis; rather, the curves are interpreted such that the leftmost data point represents the highest (first) ranked species, with subsequent data points representing the second highest ranked species, etc.

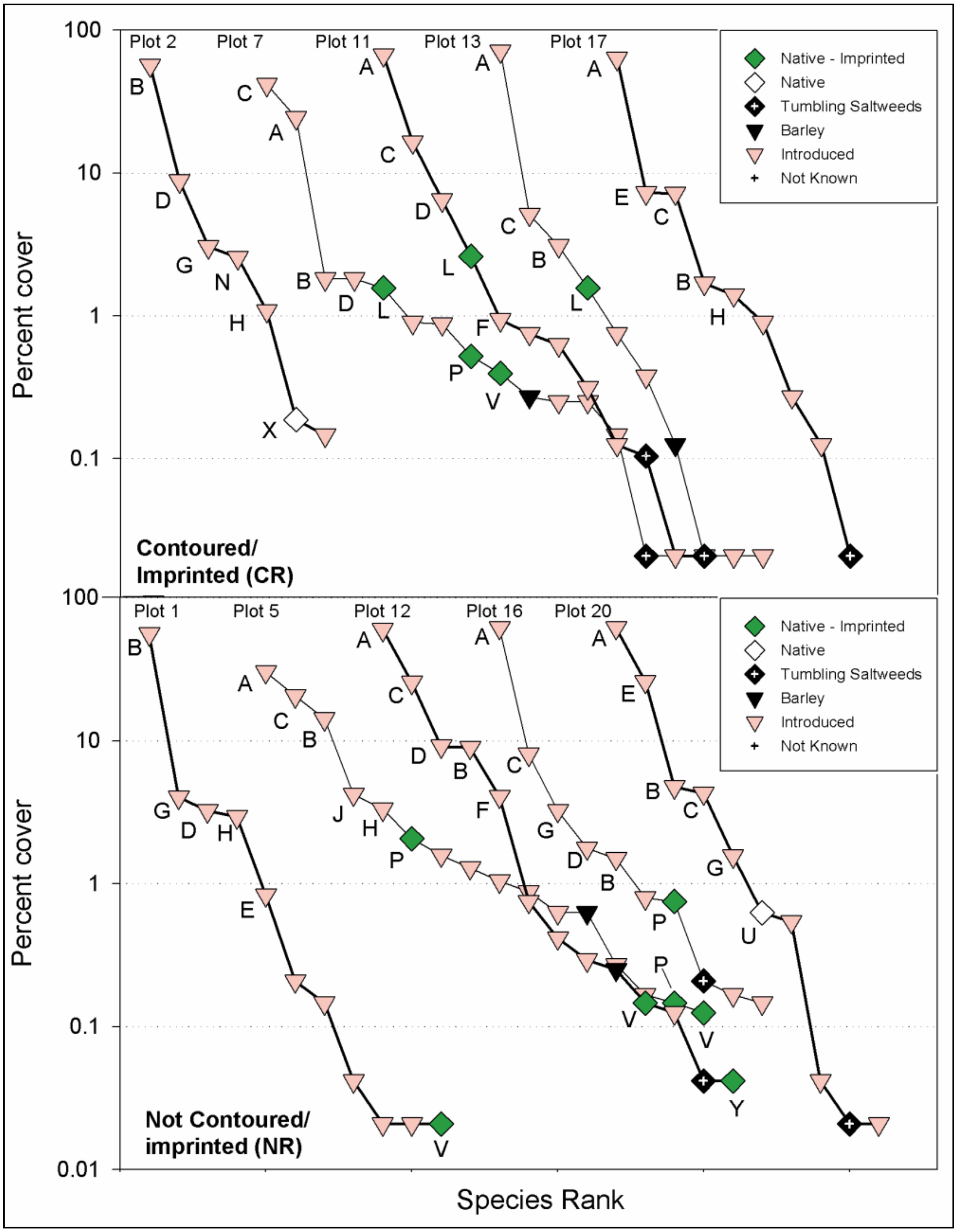


Figure 4-6. Species rank-abundance by treatment, Tranquillity HRS Plots 2003. Species letter codes correspond to those presented in Table 4-7. The five most abundant species in each plot and all native species are identified by letter code.

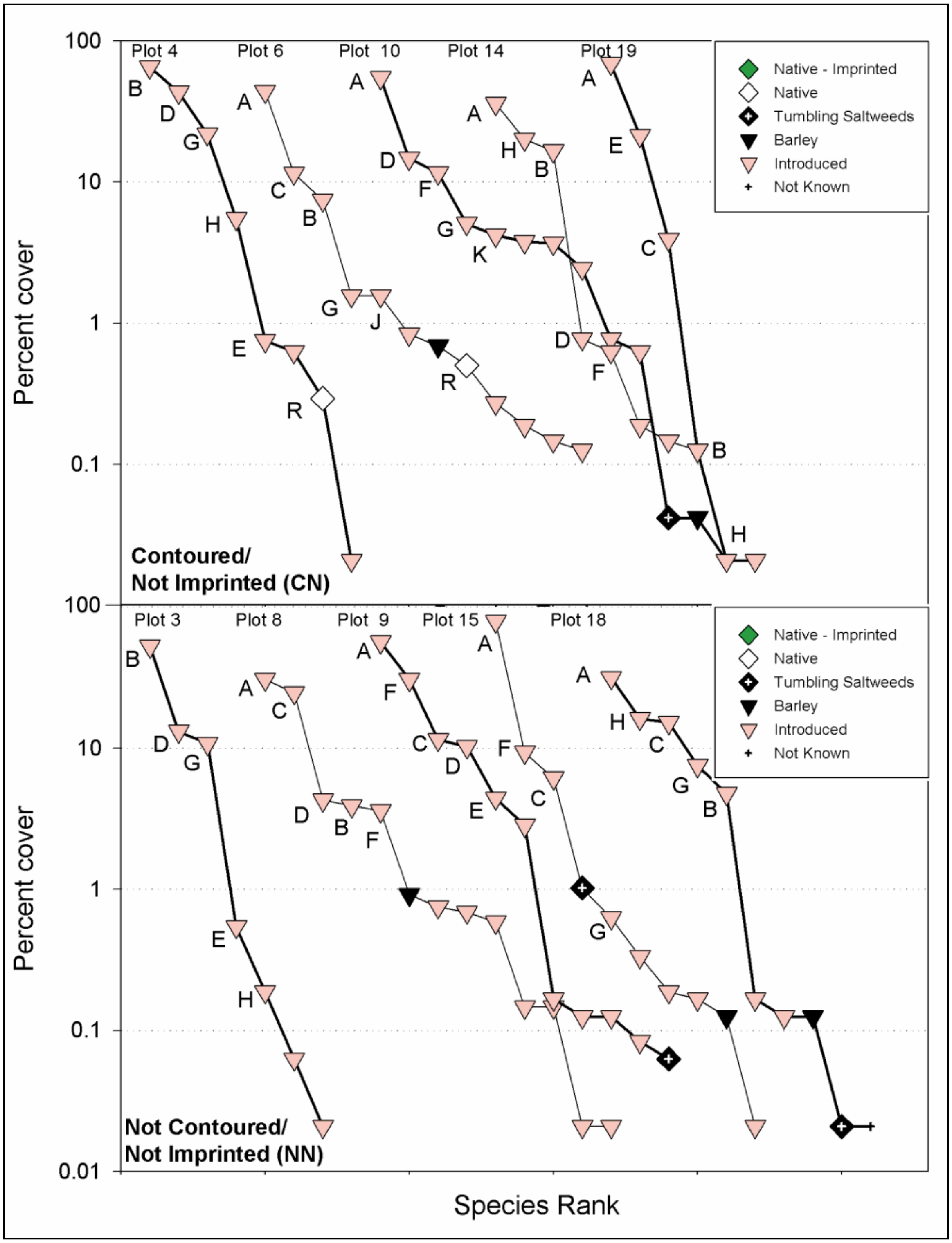


Figure 4-7. Species rank-abundance by treatment, Tranquillity HRS Plots 2003. Species letter codes correspond to those presented in Table 4-7. The five most abundant species in each plot and all native species are identified by letter code.

Regardless of treatment, the most abundant species on all plots were introduced. *Sisymbrium irio* (A) was the most abundant species on 15 plots. *Bromus madritensis* (B) was the most abundant species on 4 plots, and *Capsella bursa-pastoris* (C), the most abundant on a single plot. In no instances were imprinted native species highly ranked.

No strong differences were apparent in the slopes of the curves generated for the restored plots (Figure 4-6) versus those of the non-restored plots (Figure 4-7). This pattern differs from that observed in the preceding year (see Uptain et al. 2004), when the curves for the restored plots were noticeably less steep than those of the non-restored plots. This difference suggests that vegetation on the restored plots was becoming more homogenous, more dominated by a few species, over time.

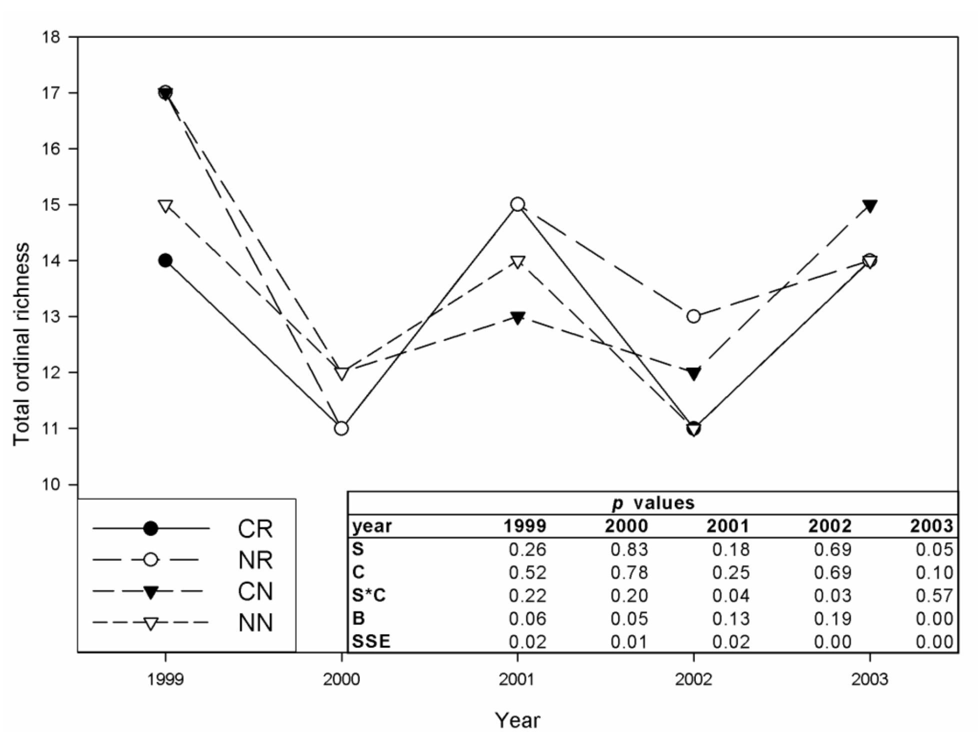
Atriplex polycarpa (L) is seen to have been more abundant on the imprinted and contoured plots (Figure 4-6) than on the imprinted but not contoured plots. This pattern was not surprising, as it was obvious during monitoring that *A. polycarpa*—as well as the other seeded perennial species—were most often located on the berms and associated trenches. In contrast, the most abundant imprinted annual species, *Vulpia microstachys* (P), was somewhat better represented on the non-contoured plots. Although the aforementioned patterns are noteworthy, the strongest pattern evidenced in the rank-abundance curves is the relatively low overall percent contribution of the native species.

The diminished presence of the cultivated barley (*Hordeum vulgare*) and of the tumbling saltweeds (*Atriplex rosea* and *A. argentea*) is of interest. In the first years following imprinting, there was concern that the barley that had persisted on the plots would out-compete the seeded species. While this may have occurred to some extent, the low abundance of barley relative to that of the dominant weed species suggests that this exclusion was not a major limiting factor in the establishment of native species. The low abundance of tumbling saltweeds is noteworthy because these species had dominated much of the site during the first summer after imprinting, and had facilitated the establishment of *Sisymbrium irio* (Uptain et al. 2004). Although *Atriplex rosea* and *A. argentea* were still abundant in re-seeded areas of the buffers in 2003, they had become scarce on the plots by this time. It seems likely that the diminished abundance of the tumbling saltweeds can be attributed to the low levels of soil disturbance on the plots. To elaborate, these species were readily able to colonize the plots in the summer following imprinting, as these areas had been recently disked.

4.3.1.2. Invertebrates

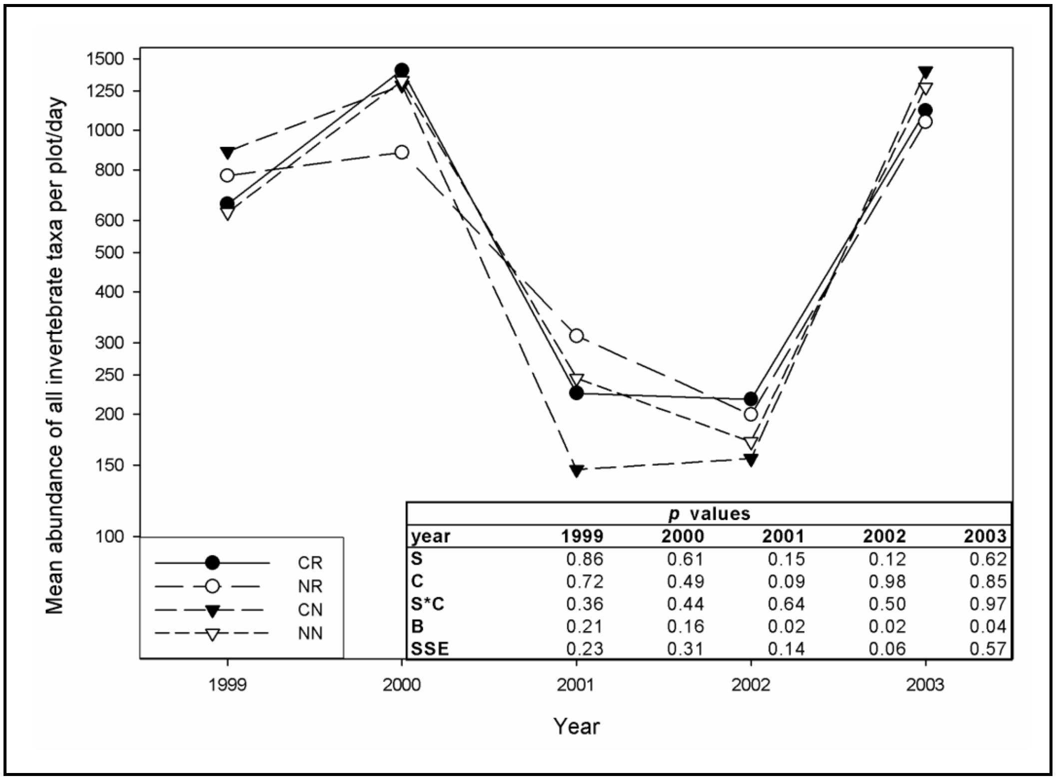
From 1999 to 2003 the richness (number of orders) of invertebrates on each treatment ranged from 11 to 17 (Figure 4-8). When data from all years are combined, the mean richness of invertebrates on each treatment varied only slightly (from 7.9 on contoured and unseeded plots to 8.5 on not contoured and seeded plots). Similarly, when data from all treatments are combined, the mean richness of invertebrates in each year varied only slightly (from 7.5 in 2002 to 8.6 in 2003). An analysis of the treatment factors (seeding and contouring) shows that there were differences between seeded and contoured plots versus not-seeded and not-contoured plots in both 2001 and 2002 (Figure 4-8). However, the mean richness of invertebrates is nearly identical (9.3 vs. 9.1 in 2001 and 7.1 vs. 7.1 in 2002) which indicates that there are no real differences.

There were large differences in invertebrate abundances between years ($p < 0.01$) with the fewest invertebrates present in 2002 (mean = 184.6 invertebrates per plot) and the most invertebrates present in 2000 and 2001 (mean = 1,207.7 invertebrates per plot; Figure 4-9). There were no clear effects of seeding (S) or contouring (C) in any year. There were clear differences in the abundance of invertebrates between the study blocks in 2001, 2002, and 2003.



p values					
year	1999	2000	2001	2002	2003
S	0.26	0.83	0.18	0.69	0.05
C	0.52	0.78	0.25	0.69	0.10
S*C	0.22	0.20	0.04	0.03	0.57
B	0.06	0.05	0.13	0.19	0.00
SSE	0.02	0.01	0.02	0.00	0.00

Figure 4-8. Ordinal richness of invertebrates for all treatments in 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

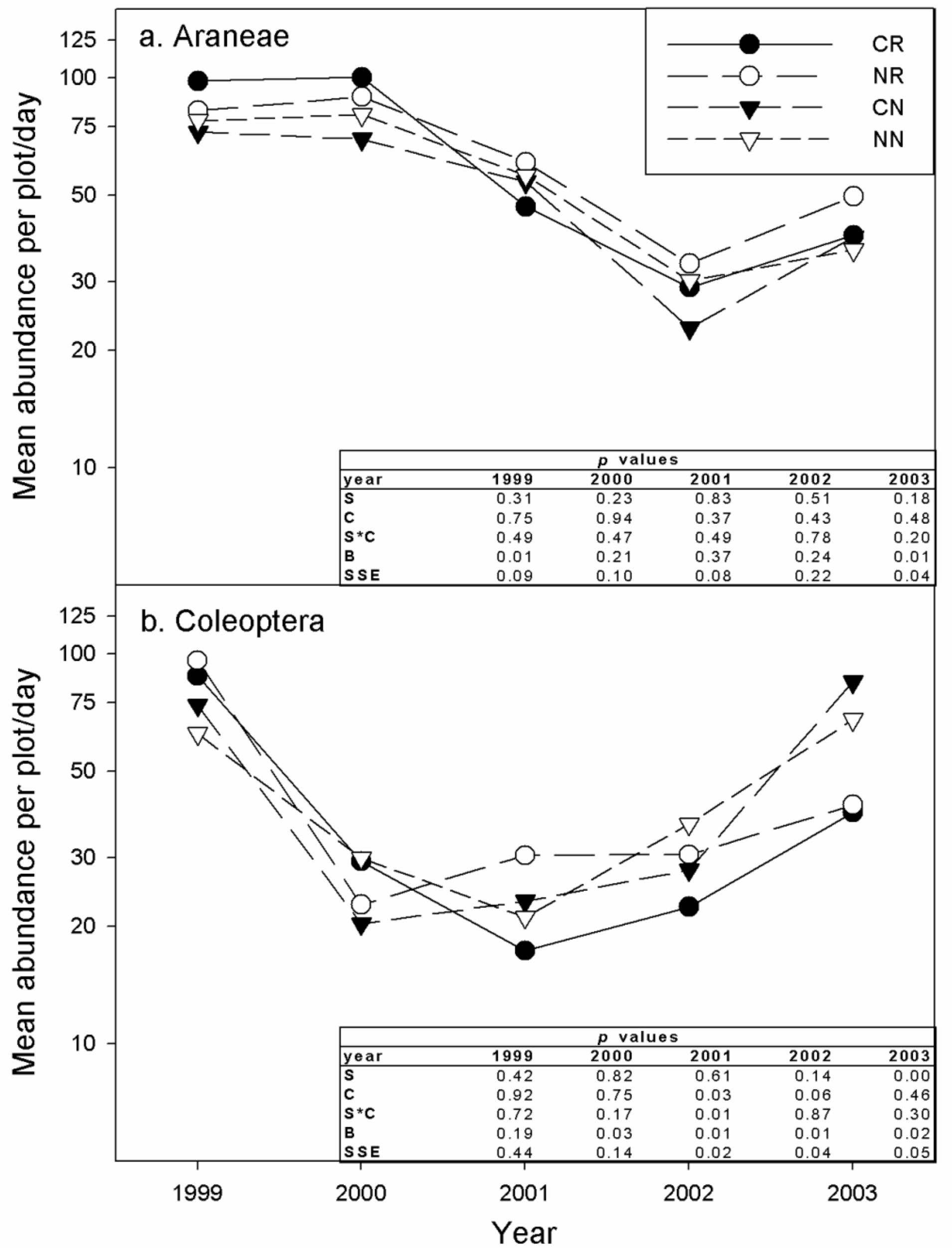


p values					
year	1999	2000	2001	2002	2003
S	0.86	0.61	0.15	0.12	0.62
C	0.72	0.49	0.09	0.98	0.85
S*C	0.36	0.44	0.64	0.50	0.97
B	0.21	0.16	0.02	0.02	0.04
SSE	0.23	0.31	0.14	0.06	0.57

Figure 4-9. Mean invertebrate abundance for all treatments in 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

Neither beetles (Coleopteran) nor spiders (Araneae) showed a consistent response to contouring or seeding (Figure 4-10). However, in 2001 the abundance of beetles was greater on non-contoured plots (mean = 25.3) than on contoured plots (mean = 20.0) and in 2003 beetles were greater on non-seeded plots (mean = 75.7) than on seeded plots (mean = 40.0, Figure 4-10). In 2001 the plots that were seeded and contoured had a lower abundance of beetles (mean = 17.38) than plots that had no treatment applied (mean = 20.89; Figure 4-10), which is attributed to the influence of contouring.

Predators, pollinators, and parasites are beneficial to Central Valley agriculture and several herbivorous invertebrate families contain agricultural pests (N. Smith pers. comm. 2004). There were 12 orders containing at least 57 agriculturally-beneficial families identified on the HRS plots and 8 orders containing 17 families of agricultural pest species (Table 4-8 and Table 4-9Table 4-9).



year	1999	2000	2001	2002	2003
S	0.31	0.23	0.83	0.51	0.18
C	0.75	0.94	0.37	0.43	0.48
S*C	0.49	0.47	0.49	0.78	0.20
B	0.01	0.21	0.37	0.24	0.01
SSE	0.09	0.10	0.08	0.22	0.04

year	1999	2000	2001	2002	2003
S	0.42	0.82	0.61	0.14	0.00
C	0.92	0.75	0.03	0.06	0.46
S*C	0.72	0.17	0.01	0.87	0.30
B	0.19	0.03	0.01	0.01	0.02
SSE	0.44	0.14	0.02	0.04	0.05

Figure 4-10. Mean abundance of Coleoptera and Araneae for all treatments in 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

Table 4-8. Invertebrate families collected on the Tranquillity study plots that contain agriculturally beneficial species, 1999 to 2003.

Order	Family	Functional group(s)
Acarina	Anystidae	Predator
Araneae	Araneidae	Predator
	Clubionidae	Predator
	Gnaphosidae	Predator
	Lycosidae	Predator
	Oxyopidae	Predator
	Pholcidae	Predator
	Salticidae	Predator
	Theridiosomatidae	Predator
	Thomisidae	Predator
Coleoptera	Carabidae	Predator
	Cleridae	Predator
	Coccinellidae	Predator
	Histeridae	Predator
	Melyridae	Predator
	Staphylinidae	Predator
Diptera	Chironomidae	Pollinator
	Dolichopodidae	Predator
	Muscidae	Pollinator
	Sciomyzidae	Parasite/sitiod
	Stratiomyidae	Predator
	Syrphidae	Predator, Pollinator
	Tachinidae	Pollinator, Parasite/sitiod
Hemiptera	Anthocoridae	Predator
	Lygaeidae	Predator
	Nabidae	Predator
	Reduviidae	Predator
Hymenoptera	Andrenidae	Pollinator
	Apidae	Pollinator
	Bethylidae	Pollinator, Parasite/sitiod
	Braconidae	Pollinator, Parasite/sitiod
	Ceraphronidae	Pollinator, Parasite/sitiod
	Chalcididae	Pollinator, Parasite/sitiod
	Chalcidoidea	Pollinator, Parasite/sitiod
	Chrysididae	Pollinator, Parasite/sitiod
	Cynipidae	Pollinator, Herbivore
	Diapriidae	Pollinator
	Encyrtidae	Pollinator, Parasite/sitiod
	Eulophidae	Pollinator, Parasite/sitiod
	Formicidae	Predator, Pollinator
	Halictidae	Pollinator
	Ichneumonidae	Pollinator, Parasite/sitiod
	Megaspilidae	Pollinator
	Mutillidae	Pollinator, Parasite/sitiod
	Platygastridae	Pollinator, Parasite/sitiod
	Pompilidae	Predator, Pollinator
	Pteromalidae*	Parasite/sitiod
	Scelionidae	Pollinator, Parasite/sitiod
	Torymidae	Pollinator, Parasite/sitiod
Mantodea	Mantidae	Predator
Neuroptera	Chrysopidae	Predator
	Hemerobiidae	Predator
Odonata	Coenagrionidae	Predator
	Unknown Odonata	Predator
Opiliones	Unknown Opiliones	Predator
Scorpiones	Unknown Scorp.	Predator
Scolopendromorpha	Unknown Scolo.	Predator

Table 4-9. Invertebrate families collected on the Tranquillity study plots that contain agricultural pest species, 1999 to 2003.

Order	Family	Genus/Species	Common name	Functional group
Acarina	(Astigmata)	*Rhizoglyphus sp.*	Rhizoglyphid mites	Scavenger
Coleoptera	Chrysomelidae	*Chaetocnema repens*	Dichondra Flea Beetle	Herbivore
	Chrysomelidae	*Epitrix hirtipennis*	Tobacco Flea Beetle	Herbivore
	Curculionidae	*Hypera postica*	Alfalfa weevil	Herbivore
	Elateridae	*Aeolus sp.*	Click Beetle	Herbivore
	Elateridae	*Anchastus sp.*	Click Beetle	Herbivore
Diptera	Opomyzidae		Opomyzidae Fly	Herbivore
Hemiptera	Lygaeidae	*Nysius raphanus*	False Chinch Bug	Herbivore
	Miridae	*Lygus hesperus*	Lygus bug	Herbivore
	Pentatomidae	*Chlorochroa sp.*	Green Stink Bug	Herbivore
		Chlorochroa uhleri	Uhler's Stink Bug	Herbivore
		Chlorochroa sayi	Say Stink Bug	Herbivore
		Thyanta punctiventris	Stink Bug	Herbivore
Homoptera	Aphididae	*Macrosiphum euphorbiae*	Potato Aphid	Herbivore
	Cicadellidae	*Circulifer tenellus*	Beet Leafhopper	Herbivore
Lepidoptera	Noctuidae	*Peridroma saucia*	Variegated Cutworm	Herbivore
	Plutellidae	*Plutella maculipennis*	Diamondback Moth	Herbivore
Orthoptera	Acrididae		grasshopper	Herbivore
Thysanoptera	Thripidae	*Frankliniella occidentalis*	Western Flower Thrips	Herbivore
	Thripidae	*Caliothrips fasciatus*	bean Thrips	Herbivore

4.3.1.3. Amphibians and Reptiles

Diversity of amphibians and reptiles increased from a low of one species observed in 1999, to three species observed since 2001 (Table 4-10). Western toads (*Bufo boreas*) were the only amphibian observed and were seen during a variety of surveys and seasons. Two species of reptiles, the western whiptail (*Cnemidophorus tigris)* and the gopher snake (*Pituophis catenifer*), were seen in 1999 and 2000, but were not observed in the following years. They are likely still present in low numbers. California king snakes (*Lampropeltis getulus californiae*) and western fence lizards (*Sceloporus occidentalis*) were observed 3 of the 5 years.

Table 4-10. Diversity of amphibians and reptiles observed at Tranquillity 1999-2003.

Year	Species observed	Richness
1999	western whiptail	1
2000	western toad, gopher snake	2
2001	western toad, western fence lizard, California king snake	3
2002	western toad, western fence lizard, California king snake	3
2003	western toad, western fence lizard, California king snake	3

4.3.1.4. Birds

Bird diversity and abundance surveys Forty-four species of birds were observed using the study plots over the 5-year study period. In addition to these, numerous other species had been documented using neighboring areas including the buffer, roadsides, adjacent lands, and airways. Of the 44 species observed using the study plots, ten are of special status (Table 4-11).

Table 4-11. Special status bird species observed on the Tranquillity study plots, 1999 to 2003. CSC = California special concern species, FSC = federal special concern species, FP = fully protected in California.

Species	Status
western burrowing owl *(Athene cunicularia hypugaea)*	CSC, FSC
California horned lark *(Eremophila alpestris actica)*	CSC
loggerhead shrike *(Lanius ludovicianus)*	CSC, FSC
long-billed curlew *(Numenius americanus)*	CSC
mountain plover *(Charadrius montanus)*	CSC
northern harrier *(Circus cyaneus)*	CSC
prairie falcon *(Falco mexicanus)*	CSC
short-eared owl *(Asio flammeus)*	CSC
white-tailed kite *(Elanus leucurus)*	FP
Vaux's swift *(Chaetura vauxi)*	CSC

The richness (number of bird species present) per year on all plots combined ranged from 13 to 19 and richness per season ranged from 7 to 19. The lowest richness for a restoration treatment was in the summer of 1999 when there was a mean of 0.40 bird species per plot on the control plots (Figure 4-11). Surprisingly, the highest richness was also on control plots in the winter of 2001, when there was a mean of 6.40 bird species per plot. The greatest variation in mean richness among treatments was during the summer surveys, but summer also accounted for the lowest richness in all years. Neither seeding nor contouring, nor their interaction, had a detectable effect on avian richness, except in the summer of 1999 when seeding resulted in a 127 percent greater mean

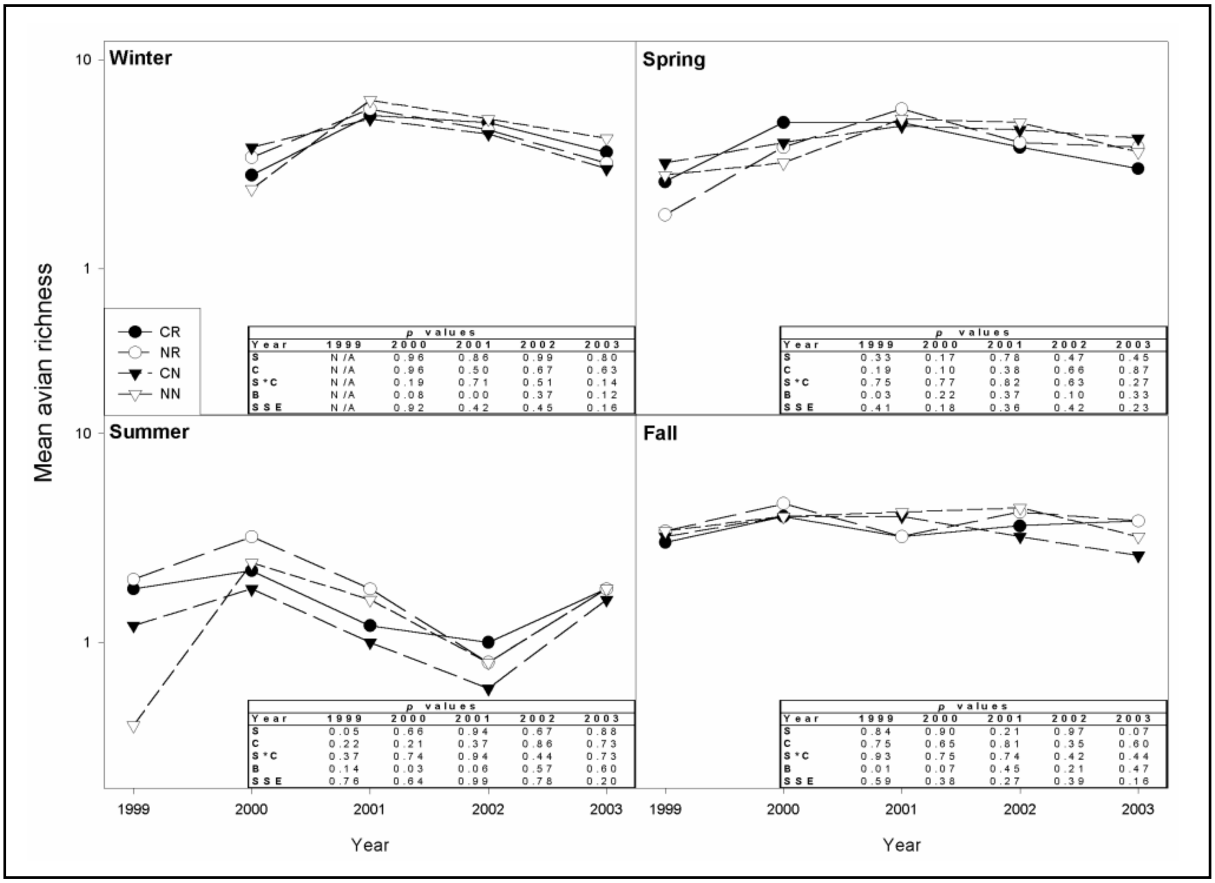


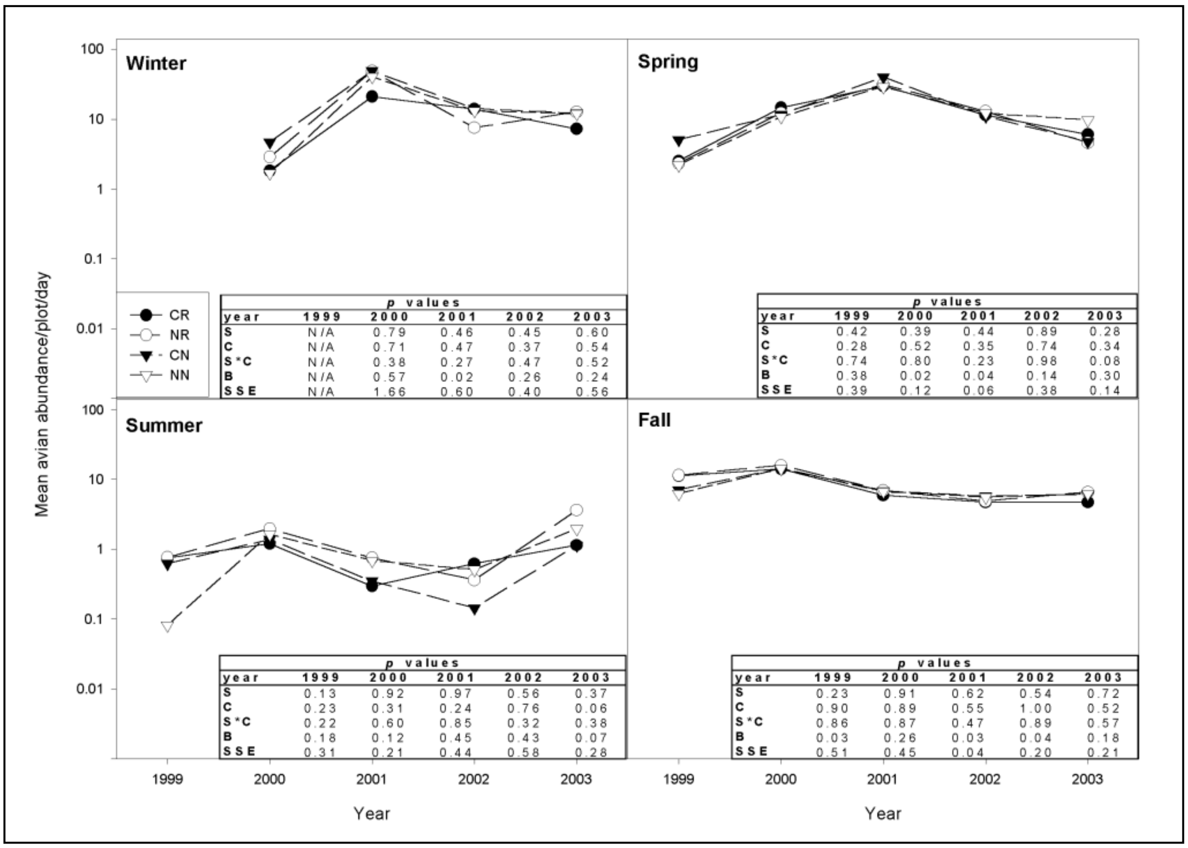
Figure 4-11. Mean richness of birds by treatment in winter, spring, summer, and fall 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

richness than other treatment factors. There were discernable differences in richness between study blocks in all seasons but not in all years. In those instances, blocks 1, 2, and 4 had richness values from 106 to 284 percent greater than on other blocks (Table 4-12).

Table 4-12. Blocks with the highest mean richness of birds, season and year of occurrence, and the magnitude of difference from other blocks (percent greater than the lowest and highest values from other blocks).

Block	Season	Year	Magnitude of difference	p-value
2 and 4	winter	2001	107 to 242%	< 0.01
1	spring	1999	147 to 284%	0.03
2	summer	2000	156 to 280%	0.03
4	fall	1999	106 to 284%	0.01

The seasonal abundances of birds on all plots combined ranged from a low of 35 birds in summer of 2002 to a high of 3,283 birds in winter 2001. The greatest variation in the mean abundance of birds between the various restoration treatments was during the summer survey periods (Figure 4-12). Neither seeding or contouring, or their interaction affected the abundance of birds. However, there were clear differences in avian abundance among blocks in some seasons and years. In those instances, blocks 2, 4, and 5 had from 102 to 835 percent greater abundance of birds than other blocks (Table 4-13). Obligate grassland birds and facultative grassland birds were more numerous than other birds ($p < 0.01$ and $p < 0.01$) by approximately 394 and 325 percent, respectively (Figure 4-13). Obligate grassland birds were more numerous than facultative grassland birds, except in 2001, but these differences were not statistically supported ($p = 0.56$). Neither seeding nor contouring, or the interaction of these factors, influenced the abundance of obligate grassland birds or facultative grassland birds (Figure 4-14). The only exception to this was in 2003 when obligate grassland birds were less common the contoured plots than on the seeded, seeded and contoured, or control plots.



Winter

p values					
year	1999	2000	2001	2002	2003
S	N/A	0.79	0.46	0.45	0.60
C	N/A	0.71	0.47	0.37	0.54
S*C	N/A	0.38	0.27	0.47	0.52
B	N/A	0.57	0.02	0.26	0.24
SSE	N/A	1.66	0.60	0.40	0.56

Spring

p values					
year	1999	2000	2001	2002	2003
S	0.42	0.39	0.44	0.89	0.28
C	0.28	0.52	0.35	0.74	0.34
S*C	0.74	0.80	0.23	0.98	0.08
B	0.38	0.02	0.04	0.14	0.30
SSE	0.39	0.12	0.06	0.38	0.14

Summer

p values					
year	1999	2000	2001	2002	2003
S	0.13	0.92	0.97	0.56	0.37
C	0.23	0.31	0.24	0.76	0.06
S*C	0.22	0.60	0.85	0.32	0.38
B	0.18	0.12	0.45	0.43	0.07
SSE	0.31	0.21	0.44	0.58	0.28

Fall

p values					
year	1999	2000	2001	2002	2003
S	0.23	0.91	0.62	0.54	0.72
C	0.90	0.89	0.55	1.00	0.52
S*C	0.86	0.87	0.47	0.89	0.57
B	0.03	0.26	0.03	0.04	0.18
SSE	0.51	0.45	0.04	0.20	0.21

Figure 4-12. Mean abundance of birds by treatment in winter, spring, summer, and fall 1999 to 2003. Treatment codes are CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

Table 4-13. Blocks with the highest mean abundance of birds, season and year of occurrence, and the magnitude of difference from other blocks (percent greater than the lowest and highest values from other blocks).

Block	Season	Year	Magnitude of difference	*p*-value
2	Winter	2001	116 to 440%	0.02
5	Spring	2000	104 to 214%	0.02
5	Spring	2001	102 to 136%	0.04
2	Fall	1999	135 to 835%	0.03
4	Fall	2001	112 to 167%	0.03
4	Fall	2002	105 to 277%	0.04

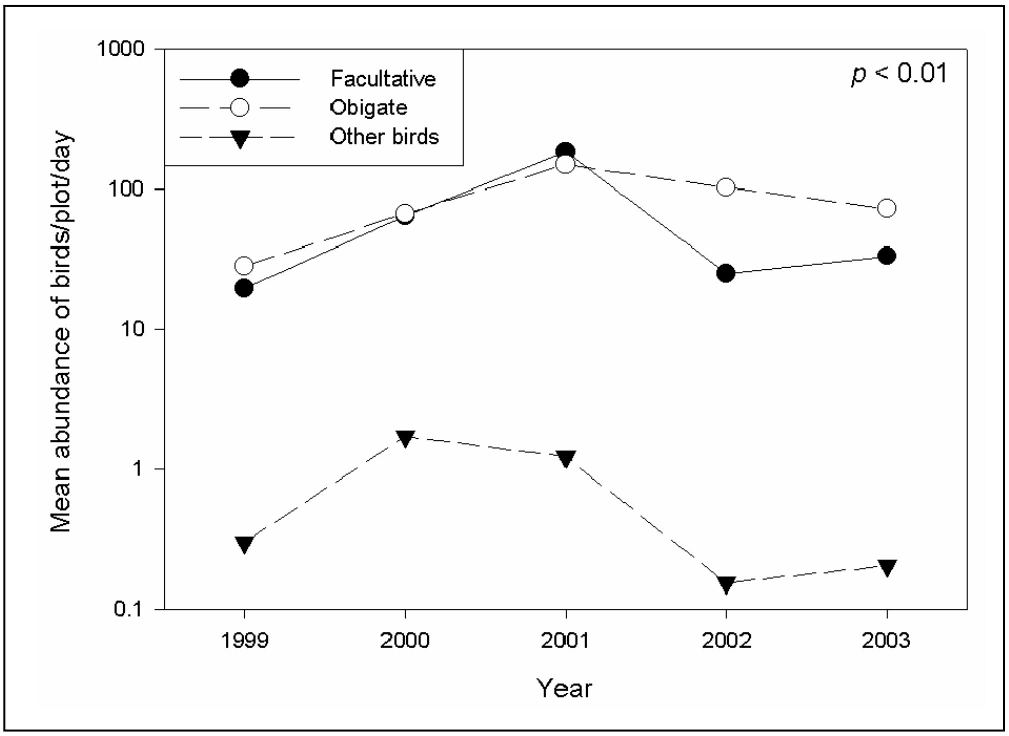


Figure 4-13. Mean abundance (mean number of birds observed per plot per day, all seasons combined) of obligate grassland birds, facultative grassland birds, and other birds, 1999 to 2003.

There were clear differences in the abundance of obligate and facultative grassland birds and other birds between study blocks. When differences occurred, blocks 2 and 4 had a greater abundance of obligate grassland species, Block 2 had a greater abundance of facultative species and Block 1 had a greater abundance of other birds (Table 4-14).

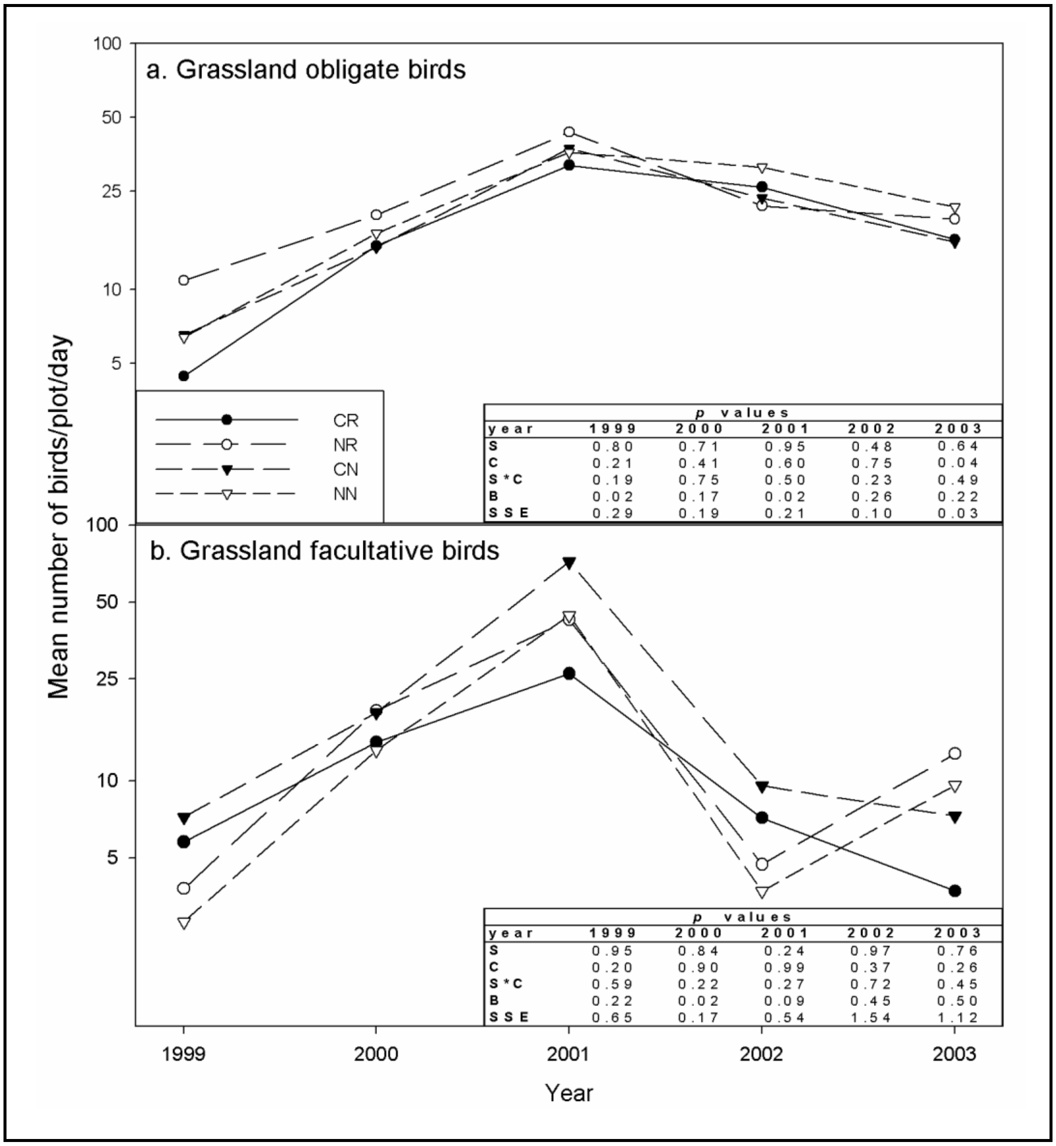


Figure 4-14. Mean abundance of grassland obligates and facultative birds by treatment, 1999 to 2003.

Table 4-14. Blocks with the highest mean abundance of grassland obligate birds, grassland facultative birds, and other birds, season and year of occurrence, and the magnitude of difference from other blocks (percent greater than the lowest and highest values from other blocks).

Grassland niche	Block	Year	Magnitude of difference	*p*-value
Obligate	2	1999	160 to 623%	0.02
	4	2001	110 to 204%	0.02
Facultative	2	2000	113 to 245%	0.02
Other	1	2000	91 to 292%	0.01

Bird nesting on the Habitat Restoration Study plots Seventeen nests of three species were located on the study plots in 2002 (Table 4-15). Six nests of two additional species were found outside of the study plots, five of which were monitored. In 2003, 21 nests of three species were located on the study plots. A single western meadowlark (*Sturnella neglecta*) nest was located in a buffer and it was not monitored. A northern harrier (*Circus cyaneus*) nest that was found on Plot 13 also was not monitored because of the sensitive status of this species and the potential for monitoring to interrupt nesting success. Mallard (*Anas platyrhynchos*) nests declined from 14 in 2002 to 4 in 2003 while red-winged blackbirds (*Agelaius phoeniceus*) did not nest on the site in 2002 but were the most common nesting bird with 16 nests present in 2003.

Table 4-15. Nest abundance and species richness, 2002 and 2003. Parentheses indicate nest numbers off study plot areas and asterisks indicate nests not monitored.

Species	Numbers of nests located	
	2002	2003
horned lark (Eremophila alpestris)	(1)*	0
loggerhead shrike (Lanius ludovicianus)	(2)	0
mallard (Anas platyrhynchos)	14	4
northern harrier (Circus cyaneus)	0	1*
red-winged blackbird (Agelaius phoeniceus)	0	16
short-eared owl (Asio flammeus)	2 (1)	0
western meadowlark (Sturnella neglecta)	1 (2)	(1)*
Total nests	17 (6)	21 (1)
Species richness	5	4

Approximately equal numbers of nests were found on plots with contours and on plots without contours in both 2002 and 2003 (Figure 4-15 and Figure 4-16). In 2002 nests were approximately 352 percent more abundant on non-seeded plots (13) than on seeded plots (4), but in 2003 nests were approximately equal in number on non-seeded (11) and seeded plots (10). The greatest concentration of nests found in 2002 (41 percent) was on plot 6; a plot that was contoured, but not seeded. In contrast, the greatest concentration of nests found in 2003 (33 percent) was on plot 20; a plot that was seeded, but not contoured. In 2002 the distribution of nests was concentrated in Block 2 (48 percent) and in 2003 nests were concentrated in Block 5 (59 percent).

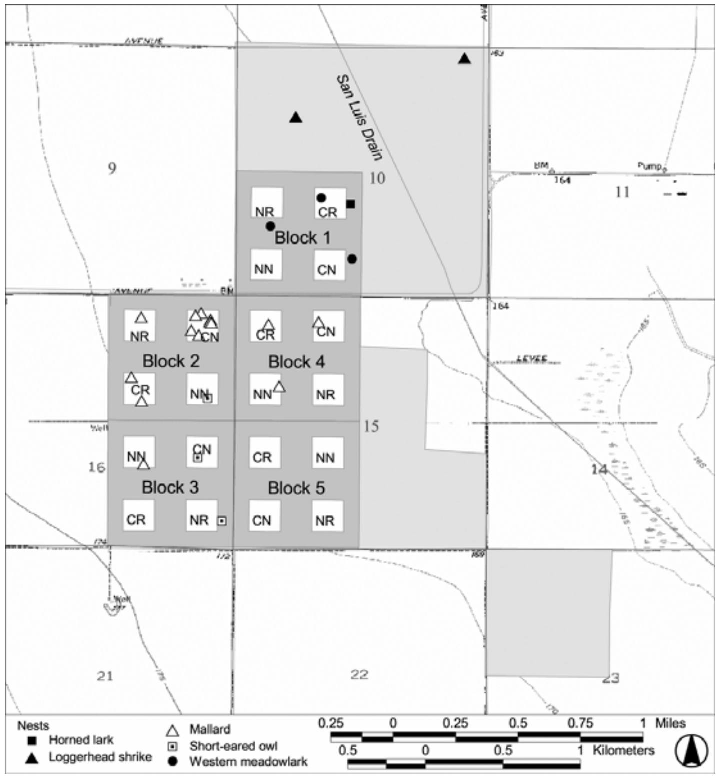


Figure 4-15. Locations of bird nests found in 2002 at the Tranquillity study site.

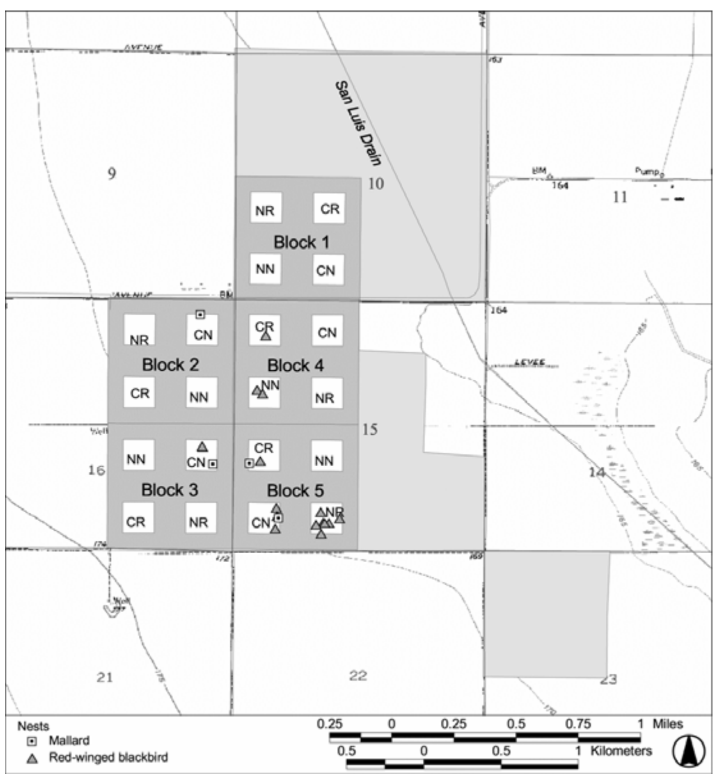


Figure 4-16. Locations of bird nests found in 2003 at the Tranquillity study site.

All nesting bird species initiated clutches in mid-March, except loggerhead shrikes, which initiated clutching in late February (Table 4-16). Mean fledging dates for all species occurred in April. Mean clutch size varied by species from 3.7 to 10.2 eggs. These clutch sizes are within the expected range for each species (Baicich and Harrison 1997). Nesting success rates varied by species from 33 percent in western meadowlarks to 100 percent in loggerhead shrikes (*Lanius ludovicianus*). The clutch size and nest success rate of mallards declined from 2002 to 2003.

Table 4-16. Mean nest initiation dates, mean fledging dates, mean clutch size, and nesting success rates of bird species nesting on the Tranquillity study site, 2002 and 2003.

Year	Species	Initiation date	Fledge date	Clutch size	Success rate	Sample size (n)
2002	mallard (Anas platyrhynchos)	16-Mar	17-Apr	10.2	0.57	14
	short-eared owl (Asio flammeus)	18-Mar	25-Apr	7.7	0.67	3
	western meadowlark (Sturnella neglecta)	19-Mar	09-Apr	3.7	0.33	3
	loggerhead shrike (Lanius ludovicianus)	28-Feb	06-Apr	5.5	1.00	2
2003	mallard (Anas platyrhynchos)	15-Mar	21.5-Apr	8.7	0.50	4
	red-winged blackbird (Agelaius phoeniceus)	11.5-Mar	26.5-Apr	3.4	0.62	16

Two of the three short-eared owl nests found in 2002 were successful, producing five and six fledglings, respectively. Both nests were oriented toward the north and they were approximately 50 cm (20 inches) in diameter. Nests consisted of a ground scrape sparsely lined with dead barley stems. The nests of western meadowlarks were domed structures concealed by a canopy of fine grass with a small tunnel at the entrance of each nest. One loggerhead shrike nest was located in a quailbush (*Atriplex lentiformis*)-hedgerow in the northern section of the project site, approximately 0.4 km (0.25 mi) north of the study plots. Another was located in an *A. polycarpa* shrub growing in the bottom of the Lateral 7 Inlet Canal. Both nests were approximately 1.5 m (5 ft) above the ground. One nest was a cup of small twigs lined with fine grass and no information was obtained on the second nest due to a fire, which occurred post-fledging. One nest produced six fledglings and the other produced five.

The 14 mallard nests present on the site in 2002 and the 16 red-winged blackbird nest present on the site in 2003 were sufficient to calculate various parameters associated with nesting survival. The Mayfield method (Mayfield 1961, 1975) was only applied to these two data sets.

Nesting parameters of mallards Eight of the 14 mallard nests successfully yielded fledglings. The survival rate of nests (nests surviving per day during incubation) was 0.98 resulting in a 55 percent probability of a nest surviving through the 27.5 day incubation period. There was a 95 percent probability that eggs would survive the incubation period within a surviving nest. However, since the success rate of nests is only 55 percent, the actual rate of egg survival is 52 percent. Some surviving eggs did not hatch and produce surviving young. When this is taken into account, there was a 51 percent probability that an egg would produce a hatchling. Due to the precocial behavior of mallard ducklings, determining the exact survival of nestlings and fledglings is difficult without constant nest monitoring following hatching. We have assumed that those eggs that successfully produced a hatchling also produced a successful fledgling (unless there was compelling evidence to the contrary obtained during nest inspections). Accordingly, the fledgling survival rate of 51 percent may be somewhat elevated.

Mallard nests typically were constructed of dead barley (*Hordeum vulgare*) and silver scale (*Atriplex argentea*) stems, contained down lining, and were constructed flush with the ground level. Approximately 80 percent of the nests were partially or completely concealed by shrubs, primarily dead *A. argentea*. One nest was found underneath a live *Atriplex polycarpa*. The vegetative composition surrounding the nest sites was approximately 27 percent forbs, 26 percent shrubs, and 9 percent grasses (Table 4-17). There was an average 3.14 plant species associated with mallard nests and there were no differences between the number of plant species associated with successful nests and unsuccessful nests ($p = 0.95$). There was no positive correlation between nest success and the number of plant species present at the nest sites ($p = 0.48$) and the presence of individual plant species did not affect nest success ($p > 0.34$ for all 6 species tested).

Table 4-17. Vegetative composition and ground cover at mallard and red-winged blackbird nests.

Average estimated percentages for ground cover categories	2002 mallard n = 14	2003 red-winged blackbird = 16
Litter	25%	47%
Bare ground	11%	18%
Grass	9%	35%
Shrub	26%	0
Forb	27%	0
Total green	62%	35%

Nesting parameters of red-winged blackbirds Ten of the 16 red-winged blackbird nests yielded at least one fledgling. The survival rate of nests was 0.96 resulting in a 50 percent probability of a nest surviving through the 14-day incubation period. There was a 96 percent probability that eggs would survive the incubation period within a surviving nest. However, since the success rate of nests was only 50 percent, the actual rate of egg survival was 48 percent. Because some surviving eggs did not produce surviving young, there was a 56 percent probability that a surviving egg would produce a hatchling.

Red-winged blackbird nests were constructed at an average height of 28.57 cm (11.2 inches) on a stand of London rocket (*Sisymbrium irio*). Dead grasses and forbs, primarily barley stems and black mustard (*Brassica nigra*), were woven into a deep cup to form each nest. There was no difference in the height of successful and unsuccessful nests ($p = 0.63$) and there was an average of 3.75 plant species associated with the nest sites. There were no differences in the number of plant species present at successful and unsuccessful nest sites ($p = 0.09$), but there was a positive correlation between nest success and the number of plant species present at the nest sites (R = 0.02). The presence of individual plant species did not affect nest success ($p > 0.25$ for all 11 species tested).

4.3.1.5. Small Mammals

Seven species of small mammals were captured (Table 4-18): deer mice (*Peromyscus maniculatus*), Heermann's kangaroo rats (*Dipodomys heermanni*), house mouse (*Mus musculus*), California vole (*Microtus californicus*), western harvest mouse (*Reithrodontomys megalotis*), ornate shrew (*Sorex ornatus*), and Botta's pocket gopher (*Thomomys botta*). The majority of captures (97 percent) were deer mice. Ornate shrews, California voles, deer mice, and Botta's pocket gophers were captured in pitfalls. Shrews were primarily captured from contoured plots in 1999 and from seeded plots in 2000, 2001, and 2002 (Table 4-19). In 2003 shrews were captured in equal numbers on treated plots but were captured in greater numbers on the control plots.

Table 4-18. The number of small mammals captured in live traps and pitfall traps on the Habitat Restoration Study plots, Tranquillity site, 1999 to 2003.

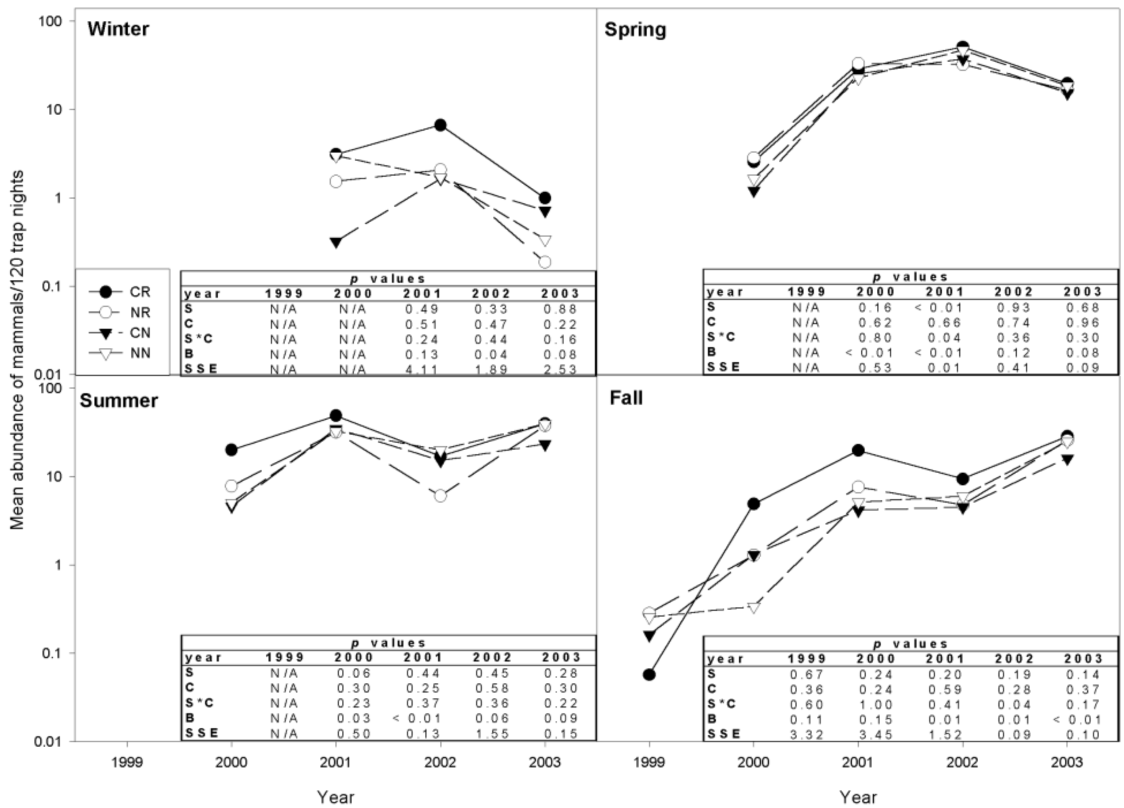
	Species	1999	2000	2001	2002	2003
Live-traps	*Dipodomys heermanni*	0	0	0	12	5
	Microtus californicus	0	0	1	0	0
	Mus musculus	2	14	47	1	0
	Peromyscus maniculatus	24	592	2,310	1,830	1,849
	Reithrodontomys megalotis	0	0	0	1	0
Pitfall traps	*Microtus californicus*	3	0	37	2	1
	Peromyscus maniculatus	0	0	0	40	14
	Sorex ornatus	14	18	25	20	26
	Thomomys botta	0	0	0	2	0
	species richness	4	3	4	7	4

Table 4-19. The number of ornate shrews (*Sorex ornatus*), California voles (*Microtus californicus*), and Botta's pocket gophers captured in the pitfall traps at the Tranquillity study site, 1999 to 2003.

Year	Species	Treatment code[1]				Total
		CR	CN	NR	NN	
1999	*Sorex ornatus*	1	10	2	1	14
	Microtus californicus	1	1	1	0	3
2000	*Sorex ornatus*	7	3	5	3	18
	Microtus californicus	0	0	0	0	0
2001	*Sorex ornatus*	11	0	11	3	25
	Microtus californicus	4	19	10	4	37
2002	*Sorex ornatus*	6	2	8	4	20
	Microtus californicus	1	0	1	0	2
	Thomomys botta	0	1	0	1	2
2003	*Sorex ornatus*	6	6	6	8	26
	Microtus californicus	0	1	0	0	1

[1] Treatment codes: CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded.

There was no clear evidence that restoration treatment ($p = 0.28$) or treatment factor ($p = 0.18$ for the seeded factor and $p = 0.56$ for the contoured factor) consistently affected the abundance of small mammals. However, in some years and seasons, treatment factor did seem to affect the abundance of small mammals (Figure 4-17). In spring 2001, seeding appeared to result in a 108 percent greater abundance of small mammals than non-seeding, and in fall 2002, the combination of seeding and contouring appeared to result in a 125 percent greater abundance of small mammals than not seeding and not contouring. The abundance of small mammals fluctuated yearly ($p < 0.01$), seasonally ($p < 0.01$), and by block ($p < 0.01$). The lowest total abundance was in fall 1999 when there were 27 captures and the greatest abundances were in summer 2001 and spring 2002 when we captured 996 and 995 animals, respectively.



Winter

p values					
year	1999	2000	2001	2002	2003
S	N/A	N/A	0.49	0.33	0.88
C	N/A	N/A	0.51	0.47	0.22
S*C	N/A	N/A	0.24	0.44	0.16
B	N/A	N/A	0.13	0.04	0.08
SSE	N/A	N/A	4.11	1.89	2.53

Spring

p values					
year	1999	2000	2001	2002	2003
S	N/A	0.16	< 0.01	0.93	0.68
C	N/A	0.62	0.66	0.74	0.96
S*C	N/A	0.80	0.04	0.36	0.30
B	N/A	< 0.01	< 0.01	0.12	0.08
SSE	N/A	0.53	0.01	0.41	0.09

Summer

p values					
year	1999	2000	2001	2002	2003
S	N/A	0.06	0.44	0.45	0.28
C	N/A	0.30	0.25	0.58	0.30
S*C	N/A	0.23	0.37	0.36	0.22
B	N/A	0.03	< 0.01	0.06	0.09
SSE	N/A	0.50	0.13	1.55	0.15

Fall

p values					
year	1999	2000	2001	2002	2003
S	0.67	0.24	0.20	0.19	0.14
C	0.36	0.24	0.59	0.28	0.37
S*C	0.60	1.00	0.41	0.04	0.17
B	0.11	0.15	0.01	0.01	< 0.01
SSE	3.32	3.45	1.52	0.09	0.10

Figure 4-17. Mean abundance of small mammals per 120 trap nights in winter, spring, summer, and fall at the Tranquillity study site, 1999 to 2003. Treatment codes: CR = contoured and seeded, NR = not contoured but seeded, CN = contoured but not seeded, and NN = not contoured and not seeded. Treatment factor codes are S = seeded, C = contoured, S*C = seeded and contoured interactions, B = block, and SSE = sum of squares error.

4.3.2. Site-Wide Surveys

4.3.2.1. Spotlighting Surveys

The only amphibians and reptiles that were observed during the spotlight surveys were western toads (*Bufo boreas*) and California king snakes (*Lampropeltis getulus californiae*). These species were observed infrequently, with the greatest rate of observation occurring in 2000 when 0.13 western toads per km (0.6 mi) were observed (Figure 4-18). During the entire survey period, only two California king snakes were observed, one in summer of 2000 and one in fall of 2001 (Table 4-20). Birds and mammals were more common, but the rate of observations of these species never exceeded 0.6 observations per km (0.6 mi).

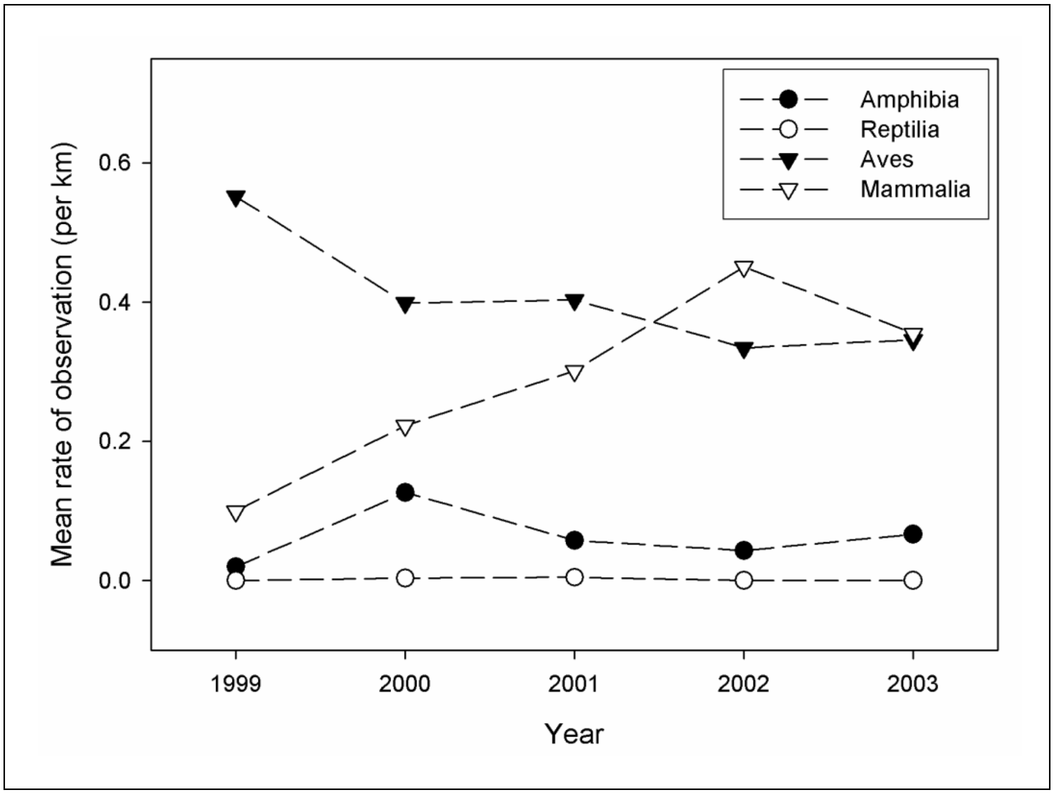


Figure 4-18. Annual wildlife abundance observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

The abundance of western toads did not vary between years, but did vary between seasons ($p < 0.01$, Figure 4-18 and Figure 4-19). They were more common in the summer than in any other season ($p < 0.01$ in all cases) and they were more common in the spring than in the winter or fall ($p < 0.01$ in both cases). The greatest abundance of western toads occurred in summer of 2000 (0.4 per km or 0.6 mile), but they declined by approximately 97 percent by the fall of 2000 ($p < 0.01$).

Table 4-20. Rates of observation (mean number per kilometer) of wildlife species observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003. Asterisks denote zero observations.

Taxa	Code	1999		2000				2001			2002				2003			Mean rate
		FA	WI	SP	SU	FA	WI	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	
Amphibians and Reptiles	BUBO	0.04	*	0.09	0.40	0.01	*	0.09	0.08	*	0.07	0.03	0.05	0.01	0.03	0.15	0.03	0.07
	LAGE	*	*	*	0.01	*	*	*	0.01	*	*	*	*	*	*	*	*	< 0.01
	Sub-totals	0.04	*	0.09	0.41	0.01	*	0.09	0.09	*	0.07	0.03	0.05	0.01	0.03	0.15	0.03	
	Yearly mean	0.02		0.13				0.06			0.04				0.07			0.06
Birds	BCNH	*	*	*	*	*	*	0.30	*	*	*	0.04	*	0.01	*	*	0.01	0.02
	KILL	*	*	0.04	0.01	0.03	0.19	*	*	0.03	0.08	*	*	*	*	*	*	0.02
	NOHA	*	*	*	*	*	*	*	*	*	*	*	*	0.01	*	*	*	< .01
	RTHA	*	0.27	*	*	0.12	0.19	0.01	0.13	0.15	0.01	*	*	0.24	0.04	0.03	0.08	0.08
	AMKE	*	*	*	*	*	*	*	*	*	0.01	*	*	*	*	*	*	< .01
	BAOW	0.56	0.19	*	0.39	0.21	0.11	0.05	0.31	0.15	0.04	0.40	0.23	0.11	0.01	0.23	0.28	0.20
	SEOW	0.01	*	0.05	0.01	0.01	0.01	0.01	0.01	*	*	*	*	0.01	*	*	*	0.01
	BUOW	0.04	0.04	0.16	0.07	*	*	*	*	*	*	0.12	0.03	0.03	0.17	0.09	0.09	0.05
	LENI	*	*	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	<0.01
	WEME	*	*	*	*	*	*	*	0.04	*	*	*	*	*	*	*	*	<0.01
	SAVS	*	*	*	*	*	*	*	*	*	0.03	*	*	*	*	*	*	<0.01
	Sub-totals	0.61	0.50	0.25	0.48	0.37	0.50	0.37	0.50	0.33	0.17	0.56	0.26	0.41	0.22	0.35	0.46	
	Yearly mean	0.56		0.40				0.40			0.35				0.34			0.41
	Unid avian	0.08	0.07	0.15	0.05	0.09	0.04	0.07	0.09	*	0.02	*	*	*	*	*	*	0.04
	Unid duck	*	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	*	<0.01
	Unid egret	*	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	*	< 0.01
	Unid raptor	*	*	*	*	*	*	*	*	*	*	*	*	0.01	*	*	*	< 0.01
	Unid owl	*	*	*	*	*	*	0.01	*	*	0.01	*	*	*	*	*	*	<0.01
Mammals	SYAU	0.04	*	0.17	0.11	0.03	0.04	0.05	0.16	0.11	0.17	0.52	0.35	0.17	0.15	0.05	0.12	0.14
	LECA	0.05	0.09	0.11	0.15	0.05	0.01	0.08	0.12	*	0.01	0.13	0.09	0.07	0.08	0.05	0.23	0.08
	SPBE	*	*	*	*	*	0.01	*	*	*	*	*	*	*	*	*	*	<0.01
	THBO	*	*	*	*	*	*	*	*	*	0.01	*	*	*	*	*	*	<0.01
	DIHE	*	*	0.01	0.11	*	*	*	0.08	*	0.03	0.04	0.04	*	0.12	*	0.20	0.04
	PEMA	*	*	*	*	0.01	*	0.13	0.09	*	0.01	0.07	0.01	*	*	*	0.04	0.02
	MICA	0.01	*	*	*	*	*	0.03	0.03	*	*	0.01	*	*	*	*	*	<0.01
	CAFA	*	*	*	*	*	0.01	*	*	*	*	*	0.04	0.01	*	*	*	<0.01
	CALA	*	*	0.03	*	*	0.04	0.03	*	*	*	*	*	0.01	*	*	*	0.01
	FESY	*	*	*	*	*	*	*	*	*	0.01	*	*	*	*	*	0.03	<0.01
	Sub-totals	0.10	0.09	0.32	0.37	0.09	0.11	0.32	0.48	0.11	0.24	0.77	0.53	0.26	0.35	0.10	0.62	
	Yearly mean	0.10		0.22				0.30			0.45				0.36			0.29
	Unid bat	0.01	*	*	*	*	*	*	0.01	*	0.09	*	*	*	*	*	*	0.01
	Unid leporid	0.01	0.03	*	*	*	0.01	*	*	*	*	*	*	0.01	*	*	*	<0.01
	Unid rodent	*	0.01	0.01	0.01	*	*	0.03	0.01	*	0.01	*	0.01	*	*	*	0.01	0.01
	Unid canid	*	0.01	*	*	*	*	0.01	*	*	0.01	*	*	*	*	*	0.01	<0.01
Totals		0.75	0.59	0.66	1.26	0.47	0.61	0.78	1.07	0.44	0.48	1.36	0.84	0.68	0.60	0.60	1.11	0.77
Species richness		7	4	7	8	8	9	10	11	4	11	8	7	11	6	6	9	7.88

Species codes: BUBO = western toad, LAGE = California king snake, BCNH = black-crowned night heron, KILL = killdeer, NOHA = northern harrier, RTHA = red-tailed hawk, AMKE = American kestrel, BAOW = barn owl, SEOW = short-eared owl, BUOW = burrowing owl, LENI = lesser nighthawk, WEME = western meadowlark, SAVS = savannah sparrow, SYAU = desert cottontail, LECA = black-tailed hare, SPBE = California ground squirrel, THBO = valley pocket gopher, DIHE = Heermann's kangaroo rat, PEMA = deer mouse, MICA = California vole, CAFA = domestic dog, CALA = coyote, FESY = domestic cat

The abundance of birds was approximately 40 percent higher in 1999 than in 2002 ($p = 0.01$) and 2003 ($p = 0.04$, Figure 4-18). The greatest decline in abundance (63 percent) occurred between fall 1999 and spring 2002 ($p < 0.01$, Figure 4-19). The abundance of birds also varied between seasons ($p < 0.01$); spring abundances were up to 72 percent lower than all other seasons ($p < 0.01$ in all cases). Barn owls (*Tyto alba*) or western burrowing owls (*Athene cunicularia hypugea*), a California species of special concern, were the most common birds observed in most years and in most seasons (Table 4-20). Although there was a decline in barn owls of approximately 36 percent between 1999 and 2000, this decline is not statistically meaningful. Barn owls remained more abundant than burrowing owls during all survey years (Figure 4-20). Short-eared owls (*Asio flammeus*), also a California species of special concern, were observed in fall 1999, winter 2002, and during each survey period from spring 2000 to fall 2001 (Table 4-20).

The abundance of mammals increased nearly five-fold from 1999 to 2002 ($p < 0.01$, Figure 4-18). There was an 87 percent decline in mammals from summer 2002 to summer 2003 ($p < 0.01$, Figure 4-19). The high numbers of mammals observed in 2002 was primarily due to an irruption of desert cottontails (*Sylvilagus auduboni*) during the summer and fall (Figure 4-21, Table 4-20).

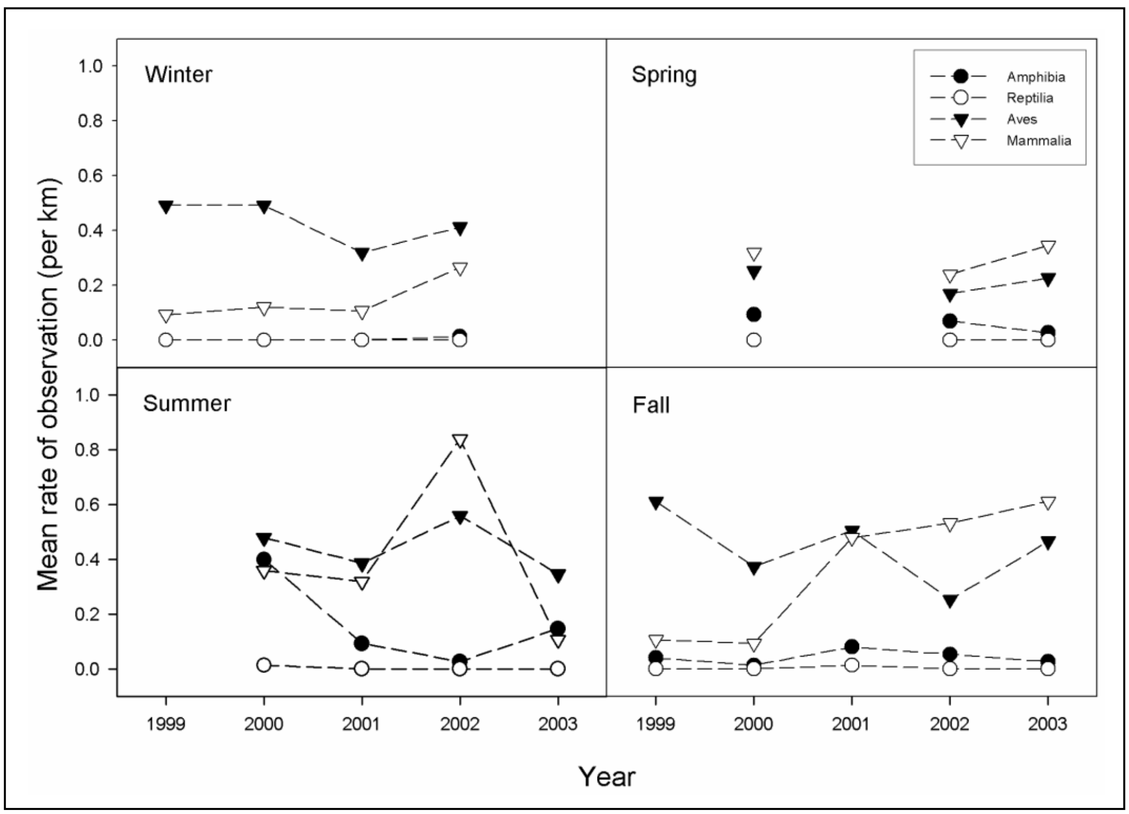


Figure 4-19. Seasonal abundance of wildlife observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

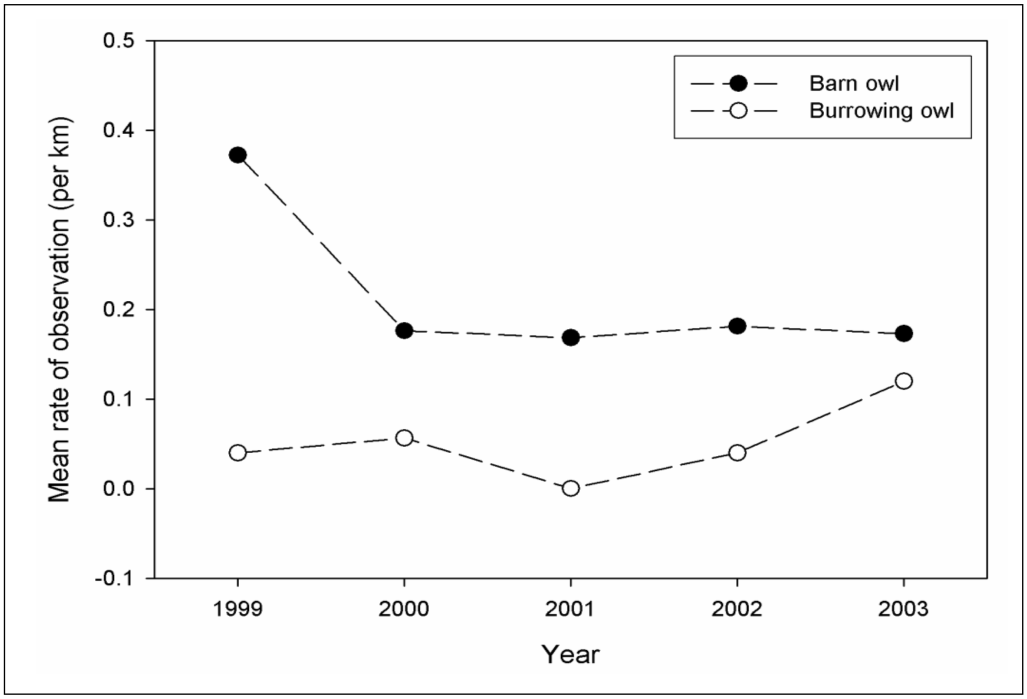


Figure 4-20. Abundance of barn owls (Tyto alba) and western burrowing owls (Athene cunicularia hypugea) observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

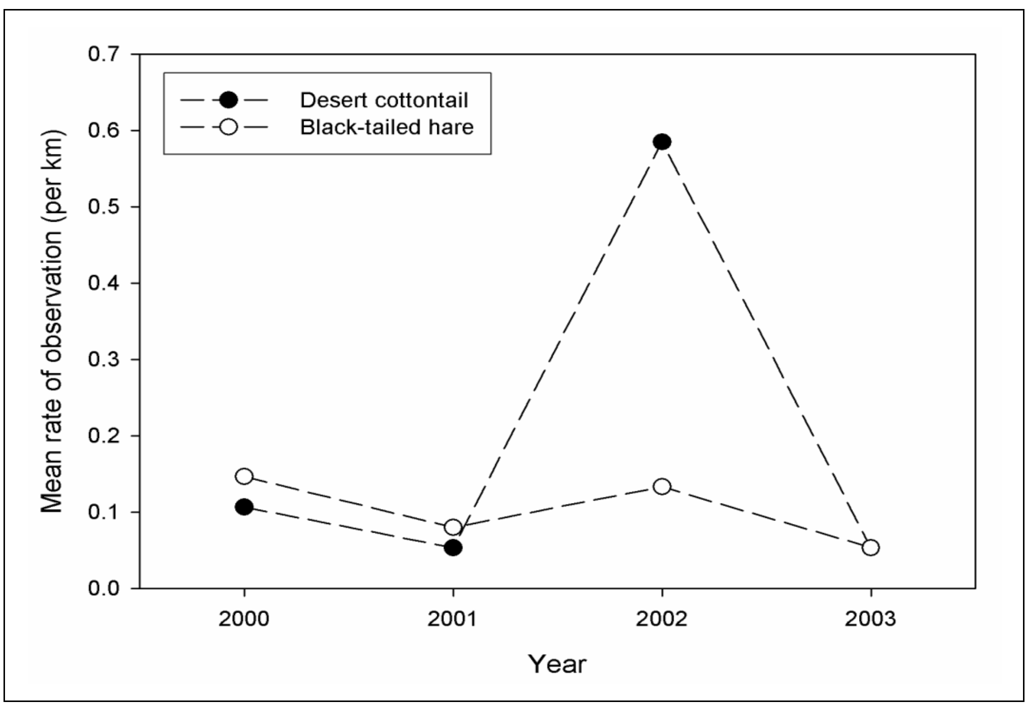


Figure 4-21. Abundance of desert cottontails (Sylvilagus auduboni) and black-tailed hares (Lepus californicus) observed during summer spotlight surveys conducted near Tranquillity, California, 1999 to 2003.

The mean abundance of mammals varied between seasons ($p = 0.01$). The mean abundance of mammals in winter was 80 percent lower than in summer, 78 percent lower than in fall, and 73 percent lower than in spring ($p < 0.01$, $p = 0.01$, and $p = 0.04$, respectively). The abundance of mammals increased more than six-fold from fall of 2000 to fall of 2003 (Figure 4-19, $p < 0.01$) due primarily to increases in desert cottontails, black-tailed hares (*Lepus californicus*), and Heermann's kangaroo rats (*Dipodomys heermanni*, Table 4-20). Domestic dogs and coyotes (*Canis latrans*) were the only species of canids observed and were infrequently encountered (Table 4-20). Both species were observed in the winter, only coyotes were seen in the spring and summer, and only domestic dogs were observed in the fall (Figure 4-22).

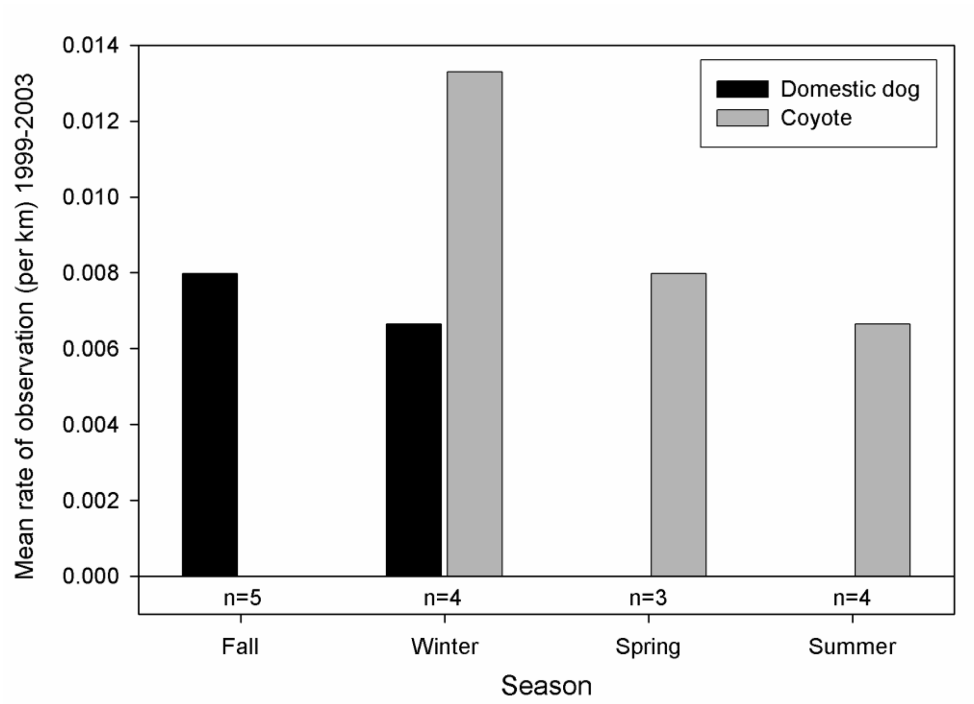


Figure 4-22. Seasonal abundance of coyotes (*Canis latrans*) and domestic dogs (*Canis familiaris*) observed during spotlight surveys conducted near Tranquillity, California, 1999 to 2003. n = number of spotlight surveys conducted for each season over the five-year study period.

4.3.2.2. Track Station Surveys

Nine orders of invertebrates, including seven families within six orders, visited track plates. The most frequent visitors were beetles (25 percent) and isopods (7 percent, Table 4-21). The number of track stations visited by invertebrates varied from 0 to 35 per three-day survey period. The highest rate of visitation was in 2000 (0.41), which was approximately 1.5 to 4.5 times the rate of visitation during other years (Table 4-21). The abundance (mean number of track stations visited) of invertebrates did not vary statistically between years or seasons (Table 4-21, Table 4-22, Figure 4-23, Figure 4-24).

Table 4-21. Annual numbers and mean rates of visitation of wildlife at track stations established at the Tranquillity site, 1999 to 2003. Asterisks denote zero observations.

Taxon	Code	1999	2000	2001	2002	2003	Total	Mean rate
Invertebrate	LYCOSIDAE	*		1	*	*	1	<0.01
	ISOPODA	*	10	5	*	*	15	0.02
	LITHOBIIDAE	*	1	1	*	*	2	<0.01
	ACRIDIDAE	1	*	*	*	*	1	<0.01
	GRYLLIDAE	*	2	*	1	1	4	<0.01
	PHLAEOTHRIPIDAE	*	4	*	*	*	4	<0.01
	CHRYSOPIDAE	1		*	*	*	1	<0.01
	COLEOPTERA	2	31	10	*	11	54	0.06
	DIPTERA	*	*	*	*	14	14	0.02
	APIDAE	1	1	*	*	*	2	<0.01
	UNKNOWN	4	33	7	52	22	118	0.14
Invertebrate total		9	83	24	53	48	217	0.25
Invertebrate mean rate		0.09	0.41	0.12	0.26	0.31	0.25	
Amphibia	BUBO	*	15	5	7	5	32	
Amphibia total		0	15	5	7	5	32	0.04
Amphibia mean rate		0.00	0.07	0.02	0.03	0.03	0.04	
Reptilia	OPHIDIA	*	*	1	*	*	1	<0.01
	SAURIA	*	*	2	*	*	2	<0.01
Reptilia total		0	0	3	0	0	3	<0.01
Reptilia mean rate		0.00	0.00	0.01	0.00	0.00		<0.01
Aves	BUOW	*	1	*	*	*	1	<0.01
	CORA	*	2	2	*	*	4	<0.01
	AMCR	*	1	2	1	3	7	0.01
	RWBL	*	7	7	*	*	14	0.02
	UNKNOWN	*	12	7	14	30	63	0.07
Aves total		0	23	18	15	33	89	0.10
Aves mean rate		0.00	0.11	0.09	0.07	0.22	0.10	
Mammalia	SYAU	2	*	*	1	21	24	0.03
	LECA	1	*	*	*	1	2	<0.01
	LEPORIDAE	3	2	8	14	3	30	0.03
	SPBE	*	5	4	14	22	45	0.05
	DIHE	1	3	*	5	19	28	0.03
	PEMA	*	*	*	6	*	6	0.01
	MICA	1	2	2	*	*	5	0.01
	RODENTIA	10	57	143	88	83	381	0.44
	CAFA	2	1	7	5	9	24	0.03
	CALA	1	*	*	*	*	1	<0.01
	CANIDAE	*	*	*	1	*	1	<0.01
	MEME	*	*	2	*	*	2	<0.01
	MUFR	*	*	*	*	1	1	<0.01
	MUSTELIDAE	*	*	*	4	*	4	<0.01
	FESY	*	1	*	1	*	2	<0.01
	UNKNOWN	*	*	3	*	1	4	<0.01
Mammalia total		21	71	169	139	160	560	0.65
Mammalia mean rate		0.21	0.35	0.83	0.68	1.05	0.65	
Unknown		*	*	6	5	3	14	
Unknown total		*	*	6	5	3	14	0.02
Unknown mean rate		0.00	0.00	0.03	0.02	0.02	0.02	
Year Total		**30**	**192**	**225**	**219**	**249**	**915**	**1.06**
Year Mean Rate		**0.29**	**0.94**	**1.10**	**1.07**	**1.63**	**1.06**	

Key to codes: LYCOSIDAE = wolf spider, ISOPODA = isopod, LITHOBIIDAE = centipede, ACRIDIDAE = grasshopper, GRYLLIDAE = cricket, PHLAEOTHRIPIDAE = thrips, CHRYSOPIDAE = lacewing, COLEOPTERA = beetles, DIPTERA = flies, APIDAE = bees, BUBO = western toad, OPHIDIA = unidentified snake, SAURIA = unidentified lizard, BUOW = burrowing owl, CORA = common raven, AMCR = American crow, RWBL = red-winged blackbird, SYAU = desert cottontail, LECA = black-tailed hare, LEPORIDAE = unidentified leporid, SPBE = California ground squirrel, DIHE = Heermann's kangaroo rat, PEMA = deer mouse, MICA = California vole, RODENTIA = unidentified rodent, CAFA = domestic dog, CALA = coyote, CANIDAE = unidentified canid, MEME = striped skunk, MUFR = long-tailed weasel, MUSTELIDAE = unidentified mustelid, FESY = domestic cat.

Table 4-22. Seasonal mean rates of visitation of wildlife at track stations established at the Tranquillity site, 1999 to 2003. Asterisks denote zero observations.

Taxon/Code	1999		2000				2001				2002				2003			Mean
	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	WI	SP	SU	FA	
Invert rate	0.18	*	0.08	0.98	0.29	0.27	0.16	0.08	0.22	0.02	0.37	0.67	*	*	0.47	0.20	0.27	0.25
Amphib rate	*	*	*	0.18	0.10	0.02	0.04	0.02	0.04	*	*	0.10	0.04	*	0.04	0.06	*	0.04
Reptilia rate	*	*	*	*	*	*	*	0.02	0.04	*	*	*	*	*	*	*	*	<0.01
Aves																		
BUOW	*	*	*	0.02	*	*	*	*	*	*	*	*	*	*	*	*	*	<0.01
AMCR	*	*	*	0.02	*	*	*	*	0.04	*	0.02	*	*	*	*	0.06	*	0.01
CORA	*	*	*	0.02	0.02	*	0.04	*	*	*	*	*	*	*	*	*	*	<0.01
RWBL	*	*	*	*	*	0.14	0.14	*	*	*	*	*	*	*	*	*	*	0.02
Unid avian	*	*	0.06	0.10	0.02	0.06	0.06	0.04	0.02	0.02	0.04	0.16	0.06	0.02	0.18	0.12	0.29	0.07
Aves rate	*	*	0.06	0.16	0.04	0.20	0.24	0.04	0.06	0.02	0.06	0.16	0.06	0.02	0.18	0.18	0.29	
Mammals																		
SYAU	*	*	*	*	*	*	0.02	*	0.04	*	*	*	*	*	*	*	0.02	<0.01
LECA	*	0.02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.02	<0.01
SPBE	*	0.04	*	*	*	*	*	*	*	*	0.02	*	*	*	0.06	*	0.35	0.03
DIHE	0.02	*	*	0.02	0.04	*	*	*	*	*	*	*	0.10	*	0.12	0.18	0.08	0.03
PEMA	0.08	0.12	0.25	0.37	0.25	0.24	0.75	0.80	0.76	0.49	0.71	0.27	0.59	0.16	0.43	0.69	0.51	0.44
MICA	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.02	<0.01
Rodentia	*	*	*	0.02	0.06	0.02	0.02	*	*	0.06	0.04	0.20	0.02	0.02	0.10	0.08	0.25	0.05
CAFA	0.02	0.02	*	*	*	0.02	*	0.02	0.10	0.02	0.02	*	0.02	0.06	0.02	0.12	0.04	0.03
CALA	0.02	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	<0.01
MEME	0.02	*	*	0.04	*	*	*	0.02	0.02	*	*	*	*	*	*	*	*	0.01
MUFR	*	*	*	*	*	*	*	*	*	*	*	0.02	0.06	*	*	*	*	<0.01
Mustelidae	*	*	*	*	*	*	*	*	*	*	*	0.12	*	*	*	*	*	0.01
FESY	*	*	*	*	*	0.02	*	*	*	*	0.02	*	*	*	*	*	*	<0.01
Unid leporid	*	*	*	*	*	*	*	*	0.04	*	*	*	*	*	*	*	*	0.00
Unid canid	*	*	*	*	*	*	*	*	*	*	*	*	0.02	*	*	*	*	0.00
Unid mammal	0.06	*	*	*	0.02	0.02	*	0.10	0.06	*	*	0.24	0.04	*	*	0.06	*	0.04
Mammal rate	0.22	0.20	0.25	0.45	0.37	0.32	0.79	0.94	1.02	0.57	0.81	0.85	0.85	0.24	0.73	1.13	1.29	
Totals	0.40	0.20	0.39	1.77	0.80	0.81	1.23	1.10	1.38	0.61	1.24	1.78	0.95	0.26	1.42	1.57	1.85	1.04

Rate of visitation = number track stations visited / number of survey nights

Species codes: BUOW = burrowing owl, AMCR = American crow, CORA = common raven, RWBL = red-winged blackbird, SYAU = desert cottontail, LECA = black-tailed hare, SPBE = California ground squirrel, DIHE = Heermann's kangaroo rat, PEMA = deer mouse, MICA = California vole, Rodentia = unidentified rodents, CAFA = domestic dog, CALA = coyote, MEME = striped skunk, MUFR = long-tailed weasel, FESY = domestic cat

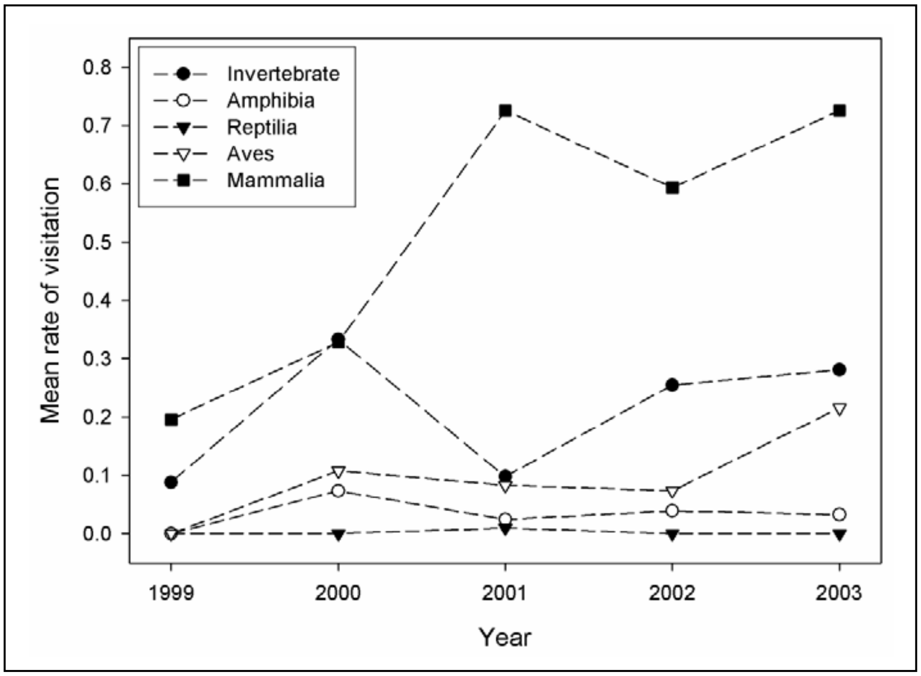


Figure 4-23. The yearly abundance (mean rate of visitation) of wildlife during track station surveys conducted at the Tranquillity site, 1999 to 2003.

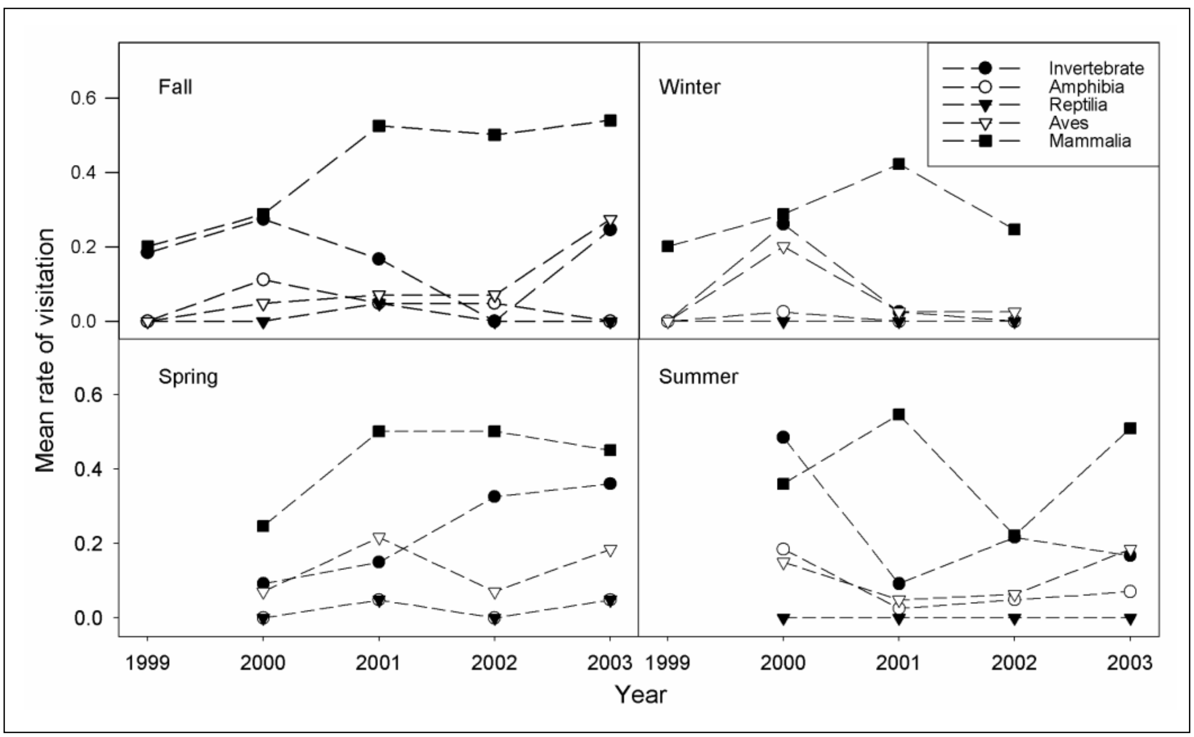


Figure 4-24. The seasonal abundance (mean rate of visitation) of wildlife at track stations established at the Tranquillity site, 1999 to 2003.

Western toads were the only amphibian that visited the track plates. Their abundance varied between years and seasons, but these variances were not statistically meaningful (Figure 4-23 and Figure 4-24). Western toads did not visit the track plates in 1999 but did in all other years (Table 4-21). The highest rate of visitation was 0.18 in summer of 2000 (Table 4-22).

Both lizard and snake tracks were observed. It is likely that these tracks were from western fence lizards and either gopher snakes or California king snakes because these were the only reptiles observed at the site. Reptiles were detected only in the summer and fall of 2001 (Table 4-22); the annual mean rate of visitation was 0.01 (Table 4-21).

At least four species of birds visited the track plates (Table 4-21 and Table 4-22). Approximately 11 percent of all tracks noted were from birds. Tracks of a western burrowing owl (a California species of special concern) were seen on a single track plate in 2000 (Table 4-21). The abundance of birds varied between years ($p < 0.02$, Figure 4-23) but did not vary between seasons (Figure 4-24). No avian tracks were noted in 1999 (Table 4-21). The rate of visitation of birds increased from 0.00 in 1999 to 0.22 in 2003 ($p < 0.01$, Figure 4-23). The greatest increases in the abundance of bird visits were from 1999 to 2000, and from 2002 to 2003. The rate of visitation increased from 0.00 in 1999 to 0.11 in 2000, and from 0.07 in 2002 to 0.22 in 2003.

At least 11 species of mammals visited the track plates over the five-year study period (Table 4-21 and Table 4-22). Mammals were less common in 1999 than 2001, 2002, and 2003 ($p < 0.01$, $p = 0.05$ and $p < 0.01$ respectively; Figure 4-23, Table 4-21). The rate of visitation of mammals increased nearly five-fold from 1999 to 2003. This increase was predominantly due to California ground squirrels (*Spermophilus beechyi*), desert cottontails (*Sylvilagus auduboni*) and Heermann's kangaroo rats (*Dipodomys heermanni*, Figure 4-23, Table 4-21). The yearly rates of visitation of unidentified rodents were and order of magnitude higher than any other taxonomic group and accounted for nearly 42 percent of all observations (Table 4-21).

4.3.2.3. Winter Raptor Surveys

American kestrels (*Falco sparverius*), northern harriers (*Circus cyaneus*), and red-tailed hawks (*Buteo jamaicensis*) were the most frequently observed raptors during the winter raptor surveys (Table 4-23). Although these species were observed during every day of every survey; their abundance was variable. Species richness increased annually (except in 2002) and reached a maximum of seven species in 2001 and 2003. Total raptor abundance ranged from 94 to 144 per survey. The abundance of raptors and additional wintering species increased each year except in 2003, but these increases were not statistically supported ($p = 0.99$). Approximate increases varied between years and differed by 20 percent from 1999 to 2000, 12 percent from 2000 to 2001, 14 percent from 2001 to 2002 and decreased approximately 35 percent from 2002 to 2003.

Table 4-23. Frequency and rate of bird species encountered at the Tranquillity site, 1999 to 2003 during winter raptor surveys.

	Species code[1]	1999			2000			2001			2002			2003		
		Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]	Total	Freq[2]	Rate[3]
Raptors	AMKE	34	100%	1.02	31	100%	0.93	33	100%	0.99	36	100%	1.08	23	100%	0.69
	BAOW	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0%	0.00	1	33%	0.03
	FEHA	0	0%	0.00	0	0%	0.00	3	100%	0.09	0	0%	0.00	5	67%	0.15
	NOHA	24	100%	0.72	32	100%	0.96	37	100%	1.11	13	100%	0.39	12	100%	0.36
	PEFA	0	0%	0.00	0	0%	0.00	1	33%	0.03	2	67%	0.06	0	0%	0.00
	PRFA	1	33%	0.03	2	67%	0.06	0	0%	0.00	0	0%	0.00	3	67%	0.09
	RLHA	3	100%	0.09	1	33%	0.03	1	33%	0.03	0	0%	0.00	0	0%	0.00
	RTHA	21	100%	0.63	22	100%	0.66	24	100%	0.72	30	100%	0.90	28	100%	0.84
	WTKI	6	67%	0.18	14	100%	0.42	7	100%	0.21	1	33%	0.03	1	33%	0.03
Total raptor richness		6			6			7			5			7		
Additional wintering species	LOSH	0	0%	0.00	11	100%	0.33	14	100%	0.42	22	100%	0.66	14	100	0.42
	MOPL	0	0%	0.00	0	0%	0.00	6	33%	0.18	40	33%	1.20	0	0	0.00
	Buteo sp.	4	67%	0.12	0	0%	0.00	1	33%	0.03	0	0%	0.00	0	0	0.00
	unidentified	1	33%	0.03	0	0%	0.00	0	0%	0.00	0	0%	0.00	0	0	0.00
Total abundance		94			113			127			144			87		

[1] Species codes: AMKE = American kestrel, BAOW = barn owl, FEHA = ferruginous hawk, LOSH = loggerhead shrike, MOPL = mountain plover, NOHA = northern harrier, PEFA = peregrine falcon, PRFA = Prairie falcon, RLHA = rough-legged hawk, RTHA = red-tailed hawk, and WTKI = white-tailed kite.

[2] Frequency: Percent of survey with positive observations.[3] Rate: Mean number observed per mile of survey.

4.4. Discussion

4.4.1. Vegetation

Although it may appear that restoration efforts on the study plots were not as successful as initially hoped, a number of restoration goals were met. We successfully established plant cover to stabilize soils, established plant cover to provide wildlife habitat, and established native wildlife. Native shrub species were successfully established on many plots and in various research trials and hedgerows, but the long-term establishment of most native annual plant species has proven to be more problematic. Soil conditions that historically existed on the site were seasonally dynamic, with successive periods of flooding and drying. Decades of intensive agricultural use greatly affected soil characteristics, depleted the native plant seed bank, and promoted the dominance of introduced weeds. These historic conditions greatly increased the challenge in establishing native upland plant communities on the study site.

Although slightly more than two-thirds of the 13 imprinted species have been encountered during vegetation monitoring, establishment of the majority of these species has been quite limited. Additionally, the number of imprinted species encountered during each of the final 2 years of monitoring was less than the number encountered during the initial two post-imprinting surveys.

Some imprinted annual species persisted on the plots, but these species were characterized by low abundances and patchy distributions. Likewise, few additional native annual species were able to become established on the plots. And, although it had been hoped that the vegetation on the plots would be augmented by native seed from the existing seed bank and from adjacent lands, few additional native annual species were able to become established. As with the imprinted annuals, these adventitious natives were patchily distributed and of low abundance.

Generally, the establishment of perennial species was much more successful than that of annual species. Nevertheless, the perennial vegetation declined after attacks by agricultural pests (particularly, false chinch bugs; *Nysius* sp.). Additional decline in the perennial vegetation appeared to be linked to soil motility and extensive soil cracking.

While numerous fertile individuals of *Atriplex polycarpa, Suaeda moquinii* and *Isocoma acradenia* became established on the plots, we saw little evidence of successful second generation from these (potential) progenitors. This lack of successful establishment appears to be primarily attributable to competition from the annual invasive species on the plots. Seedling establishment from the parent native perennials was generally limited to the areas beneath and directly around the parent plants (i.e., areas where there was sufficient open soil). However, these seedlings rarely survived beyond seedling stage—probably due to competition with the parent plants. As noted, precipitation during the course of the Demonstration Project was substantially lower than the 30-year average. This scarcity of rainfall undoubtedly limited these species "expansion."

Non-native species dominated large portions of the HRS plots. By the final year of monitoring, three non-native species, *Sisymbrium irio*, *Bromus madritensis*, and *Capsella bursa-pastoris,* accounted for more than three-fourths of the vegetative cover. The "tumbling saltweeds," *Atriplex rosea* and *A. argentea* were readily established on the disturbed (i.e., tilled) soils of the HRS plots. By the end of the first growing season following imprinting, these species were dominant on many of the plots. Although the abundance of these species was greatly diminished in subsequent years, many of their "skeletons" (i.e., senescent stems and leaves) remained onsite for the following growing season and served to facilitate the establishment of other weeds, as only a few, invasive species were able to become established beneath the skeletons. The mustards, *Sisymbrium irio* and *Brassica nigra*, in particular, benefited in this way.

Bromus madritensis appeared to be particularly effective in limiting the establishment of imprinted species. This pattern is readily seen in the rank-abundance curves (previously shown in Figure 4-6 and Figure 4-7). All plots on Block 1 (represented by the leftmost curves in these figures) were steeper, and were generally poorer in species than plots in the other blocks. As noted, *Bromus madritensis* tended to dominate the northern HRS plots; the buffers of the red brome-dominated plots also tended to have a large component of brome. The northern portion of the HRS area had soils characterized by high electrical conductivity readings and high levels of soluble boron (Figure 2-34; Figure 2-35). However, it should also be noted that Section 10 (i.e., the area with the densest brome component) had a different land-use history than the areas on which the other four blocks were sited. Section 10 had been fallowed for a number of years prior to restoration, and it may be that vegetation on this portion of the site represented a later stage of post-agricultural succession.

Clearly, weed management is essential to ensure the long-term persistence of native species on restored lands. To date, only intensive and repeated weed suppression has successfully reduced weed loads and allowed natives to persist, but this has been costly and labor intensive. Numerous experimental techniques—including herbicide use, establishing cover crops, flaming, mowing, discing, pre-irrigating, solarization, and manual weeding—have been explored for weed-eradication techniques; however, none have yet provided effective long-term results. We are continuing research in an attempt to develop cost-effective and efficient techniques for weed control that would be applicable for large-scale land retirement (see Appendix 1).

The microtopographic contours (berms) persisted throughout the study period, although their height decreased over the course of the study due to compaction and disturbance, and as the shallow furrows along the edges of the berms became partially filled with soil and litter. Still, these contours successfully provided structural and vegetative heterogeneity to what had previously been a homogenous landscape. Topographic contouring clearly facilitated establishment of the perennial vegetation. The majority of the imprinted perennials became established either on the berms, or in the furrows. No clear pattern between establishment of imprinted annual species and contouring was discernable.

No strong statistical support was found for a positive correlation between the diversity and abundance of small mammals and contouring. Nevertheless, we suspect that contours would ultimately enhance the landscape for burrowing animals, and would become an increasingly important component of restored habitats as the wildlife community continues to diversify. The design of the contours could be improved to increase their benefit to wildlife. In restoration efforts that are not strictly controlled by a statistically rigorous study design and other limiting factors, heterogeneity could be greatly increased by fashioning meandering contours of variable height and width.

4.4.2. Invertebrates

The invertebrate community showed little notable response to the treatments, which was expected because of the similarity among the treatments. The overall richness of invertebrates and the abundance of coleopterans showed some limited responses to the treatments, but there were no prevailing trends. The richness and abundance of invertebrates tended to be more influenced by location (study block) than by the application of any particular treatment.

Because of the limited long-term success of our restoration treatments, all of the HRS study plots more closely resemble fallowed lands than restored habitat. Gelt (1993) noted that homogenous plant communities dominated by invasive species often characterize fallowed lands. Reduced grassland plant species richness, characteristic of fallowed lands and monocultures, results in altered invertebrate community structure (Knopps 1999). Because there is a positive correlation between increased habitat diversity and increased invertebrate richness and/or abundance (Dodero 2003, Kremen et al. 2002, Knopps 1999, Speight et al.1999, Erhardt 1985), we would expect that the successful restoration of retired agricultural lands would lead to a more stable and complex invertebrate community.

On the Habitat Restoration Study site, the diversity of agriculturally beneficial invertebrates was greater than the diversity of agricultural pests. Beneficial invertebrates, including predators, parasitoids, and pollinators, provide valuable pest regulation and pollination services to agricultural land (Samu 2003, Kremen et al. 2002, Schowaltzer 2000, Allen-Wardell et al. 1988). In structurally diverse agro-ecosystems, agriculturally beneficial insects tend to be more abundant (Kremen et al. 2002, Thomas et al.1992), and pest populations are typically reduced (Samu 2003, Schowalter 1996). Kremen et al.'s (2002, 2004) work in the Central Valley of California demonstrates the economic and production benefits of incorporating natural habitat into the agricultural landscape. Several studies have demonstrated that monocultures, typical of agricultural expanses, invite sudden, dramatic, and widespread outbreaks of invertebrate pests (Turchin 1988, Root 1973, Irving 1970). Reducing landscape homogeneity through the reestablishment of a diverse native plant community could provide a barrier to the movement of agricultural pests and reduce the severity of outbreak (Schowalter 1996, Piemeisel and Lawson 1937). These benefits could be achieved through the successful restoration of retired lands.

The native plant nursery that has been established on the Tranquillity site houses the greatest diversity of native plant species in the San Joaquin Valley. We have observed heightened invertebrate diversity, particularly with agriculturally beneficial species, in the nursery as compared to the study plots and other surrounding lands. This observation is supported by the competitive exclusion principle (Hardin 1960) and by Speight et al. (1999) who asserted that habitats having greater plant species richness should support greater insect species richness. The HRS study was designed to test for a correlation between the level of native plant diversity and the richness of invertebrates. However, the relatively low success of the restoration treatments precludes a meaningful analysis.

An analysis of invertebrate richness and abundance at the ordinal level, as was conducted in this study, is limiting. We have found that the data are too coarse to provide meaningful information on invertebrate community structure and dynamics. Furthermore, an analysis at the ordinal level is primarily relevant to short-term abiotic factors (Hemerik and Brussaard 2002) rather than long-term biotic factors. There is an opportunity to evaluate the invertebrate community structure, dynamics, and the correlation of invertebrate richness to native plant diversity at the family or species level. These studies could be implemented on lands where research trials or restoration have proven successful. An analysis of specific sensitive indicator orders (Coleoptera, Lepidoptera, and Araneae) has been used to measure restoration success at the ecosystem level (Waltz and Covington 2004, Perner and Malt 2003, Hemerik and Brussaard 2002) and could be incorporated into the design of future monitoring and evaluation efforts.

4.4.3. Amphibians and Reptiles

Amphibian diversity and abundance was low throughout the 5-year survey period. Fisher and Schaffer (1996) note a large-scale decline in native amphibian species in the San Joaquin Valley and suggest lack of suitable habitat as a major factor. The only amphibian species observed at the Tranquillity site, the western toad, is typically associated with lakes, rivers, and streams, but is also found in grassland habitats (Stebbins 1985). Western toads likely emigrated to the study area from canals and ditches that occur on surrounding farmland. These water sources are needed for breeding. Western toad abundance was especially high in the summer of 2001. The potential for the study site to provide a diverse assemblage of amphibians is fairly low in the near term. However, if suitable breeding sites become available, other species of amphibians could become established on the site. Species that could become established include: pacific treefrog (*Pseudacris regilla*), western spadefoot toad (*Spea* (=*Scaphiopus*) *hammondi;* a California species of special concern), and California tiger salamander (*Ambystoma californiense*, federally listed threatened species, USFWS 2004).

California king snake was the only species of reptile observed during spotlighting surveys although a gopher snake and western whiptail have also been observed on the site. A northern pacific rattlesnake (*Crotulus viridus oreganus*) was observed within 8 km (5 mi) of the site. In addition, a local farmer (Robert Jones, pers. comm.) reported seeing coast horned lizards (*Phrynosoma coronatum;* a California species of special concern, CDFG 2003) in the area until approximately 1990. There is one 2002 record of a coast horned lizard from Alkali Sink Ecological Reserve approximately 11 km (7 mi) to the north-northeast of the site (CDFG 2003).

Lack of suitable habitat likely precludes a greater diversity and abundance of reptiles. As native vegetation becomes established and microtopographic features are created due to rain and wind, it is expected that reptiles will colonize the site to a greater degree. Reptile species that may inhabit the site in the future include those listed above that have been seen in proximity to the site and the side-blotched lizard (*Uta stansburiana*), western skink (*Eumeces skiltonianus*), Gilbert skink (*E. gilberti*), southern alligator lizard (*Gerrhonotus multicarinautus*), western yellow-bellied racer (*Coluber constrictor*), San Joaquin Coachwhip (*Masticophis flagellum*), California glossy snake (*Arizona elegans occidentalis*), Valley garter snake (*Thamnophis sirtalis fitchii*), California black-headed snake (*Tantilla planiceps*), and southwestern black-headed snake (*Tantilla hobartsmithi*). Currently, the prey base appears adequate for most colubrid snakes (see Section 4.3.5). In addition, invertebrate abundance and diversity appears to be satisfactory to sustain species that prey upon insects.

4.4.4. Birds

There were no substantial differences in the richness or abundance of birds between treatments or treatment factors, but there were differences between blocks in all seasons. These results are not unexpected because of the similarity of the vegetation on all plots and inherent spatial differences between blocks. The abundance, richness, and composition of birds varied annually and seasonally, but this is expected because of the typical cyclic patterns of birds (circadian rhythms and circannual cycles, Gill 1999). Although the study plots were primarily composed of non-native weedy species, the landscape characteristics closely resembles a grassland and it is not surprising that the greatest abundance of birds were obligate grassland species, followed by facultative grassland species.

Eleven short-eared owlets (*Asio flammeus*) were successfully reared in plots 8 and 10 in 2002. During various surveys conducted in 2003 we observed 14 short-eared owls communally roosting on Block 1, and 10 roosting on Block 5. The only other known short-eared owl nesting locations in the San Joaquin Valley are Mendota Wildlife Area approximately 5 mi (8 km) from the Tranquillity site where one nest was documented in 1987 (CDFG 1987), and Kern NWR, approximately 72 mi (115 km) south of the Tranquillity site (Cooper 2004). There are also numerous western burrowing owls nesting under sections of the displaced concrete lining of the San Luis Drain, which traverses a portion of the Tranquillity site. They have been observed roosting, foraging, and burrowing on the site. The short-eared owl and the western burrowing owl are species of special concern in California (CDFG 1999) and the short-eared owl is a rare species in Fresno and Madera Counties according to Fresno Audubon Society (2001). The widespread use of the Tranquillity site by these species demonstrates the potential of retired agricultural lands to contribute to the recovery of a variety of sensitive species. The reproductive success and population dynamics of the short-eared owl are closely tied to the abundance of its prey (Holt and Leasure 1993), and the high density of deer mice and California voles on the study plots likely contributes to the success of these species at the Tranquillity site.

All of the successful mallard nests were associated with relatively high shrub cover, primarily dead *A. argentea* skeletons. The placement of nests in vegetation has been found to be beneficial (Gloutney and Clark 1997) and it is likely that shrubs contributed to nest success by providing nest cover and concealment. Approximately 57 percent of the nests on Plot 6 were successful, which may have led to high nest-site fidelity. It is not clear why mallards preferentially selected

Plot 6 for nesting when other plots had structural heterogeneity similar to Plot 6. Mallards typically nest within 1.6 km (1 mile) of a water source (Kaufman 1996, Baichich and Harrison 1997) but this was not observed on the Tranquillity site. There are a number of agricultural canals, ditches, and drains on and near the site, but they are dry during the breeding and nesting season and did not provide a source of water.

The most abundant nests in 2003 were of red-winged blackbirds. Male red-winged blackbirds were often observed actively defending nesting territories by mobbing and vocalizing to deter predators. Brown-headed cowbirds (*Molothrus ater*) were observed in the vicinity of blackbird nests, but we did not observe nest parasitism. It is well known that red-winged blackbirds are often parasitized by brown-headed cowbirds (Freeman et al. 1990), but the high degree of territory defense that we observed may have effectively eliminated parasitism. Past studies have shown that group defense against cowbirds may be an important deterrent to nest parasitism (Freeman et al. 1990). Berger (1951), Payne (1973), and Norman and Robertson (1975) found that female cowbirds would use perches to locate and monitor potential nests for subsequent parasitism. Adequate perch sites are extremely limited at the Tranquillity site, which may have contributed to a lack of parasitism. Parasite pressure on red-winged blackbirds may be reduced by an increased availability of other, more preferred hosts (Friedman 1963, Friedman et al. 1977). This is not likely to be the case at the Tranquillity site because there are few alternate hosts nesting on the site. The degree of cowbird parasitism also has been found to be lower in localities where cowbirds are recent arrivals (Friedman 1963, Friedman et al. 1977). It is likely that the lack of parasitism by cowbirds at the Tranquillity site is partially due to the recent conversion of agricultural crops to habitat, the recent nesting efforts by red-winged blackbirds, and the recent arrival of brown-headed cowbirds at the site.

The number of nests and the species of birds that successfully nested on the Tranquillity site changed dramatically from 2002 to 2003. The primary difference was that mallards were the most successful nesting bird in 2002 while red-winged blackbirds were the most successful nesting bird in 2003. We suspect that the principal reason for this shift was a change in vegetative structure and subsequent loss of potential cover. *Atriplex argentea,* which had been associated with all mallard nests, is an annual sub-shrub that was present on the study plots in large numbers in 2002, but was much less common in 2003. London rocket was a dominant component of the landscape in 2003. London rocket was used as nesting supports and nesting material for red-winged blackbird nests. Although both of these plant species have contributed to the nesting success of these two bird species, they are considered weedy, invasive plants and are undesirable. For habitat restoration to be beneficial to nesting birds, these plant species must be replaced by native species that would provide the same or better quality conditions for nesting birds. Furthermore, an increase in the abundance and diversity of native plants would likely provide nesting opportunities for a wider variety of bird species.

4.4.5. Small Mammals

In 1999, when the study plots were planted in barley, deer mice and ornate shrews were the most abundant small mammal species, but they were present in low numbers. Once the barley was replaced by restoration treatments and discing was halted, there was an increase in the abundance and diversity of small mammals. The abundance of deer mice and the diversity of small mammals in general did not differ between treatment or treatment factor. It is not surprising that seeding did not influence small mammal abundance or diversity because of the similarity between seeded and non-seeded plots. However, we are somewhat surprised that contouring did not enhance the small mammal community. Contours are thought to provide a suitable site in which to construct burrow systems and provide topographical relief to act as refugia during periods of high rainfall. The soils on the Tranquillity site exhibit a tremendous potential for shrinking and swelling. Large cracks in the soil are widespread, especially during the dry summer months. We suspect that these soil characteristics provide adequate opportunities for burrow construction and relief from the effects of flooding, and lessen the potential benefits of contouring to small mammals. Currently, the Tranquillity site supports a viable, self-sustaining small mammal community that contributes to the success of predatory birds and mammals. However, this small mammal community is not typical of native habitats in the San Joaquin Valley. Rather, the community is typical of disturbed, ruderal habitats. We would expect that effective restoration would ultimately enhance and naturalize the small mammal community.

4.4.6. Site-Wide Surveys

4.4.6.1. Spotlighting Surveys

Most of the 11 species of birds observed during spotlighting surveys were owls and grassland associated raptors. Barn owls and short-eared owls are associated with open grassland habitats and agricultural fields and small mammals constitute a majority of their diet (Marti 1992, Holt 1993). Because abundance of deer mice was typically very high during the study, we would expect that barn owls preyed significantly upon this species. While barn owls made up a majority of the observations, red-tailed hawks were also well represented throughout the survey period. Black-crowned night herons (*Nycticorax nycticorax*) were observed during four of the 16 survey periods but abundance was especially high in the summer of 2001. Black-crowned night herons are known to feed on fish and frogs (Kaufman 1996) and the relatively high abundance of herons during summer of 2001 may have been related to the high abundance of western toads seen during that same survey period.

There was a dramatic increase in abundance of mammals at the Tranquillity site over the 5-year study period. This increase is likely tied to the continued maturation of the vegetative community and reduced farming disturbance at the site. Leporid abundance fluctuated but was always the dominant mammalian taxa observed throughout the survey although Heermann's kangaroo rats were also highly abundant during the summer of 2000 and fall of 2003. Kangaroo rats are especially adapted to arid conditions (Jameson and Peeters 1988) in the valley grassland and foothill woodland communities of California to southwestern Oregon (Ingles 1965). As fossorial animals, kangaroo rats will provide aestivation and hibernation habitat for a variety of species, including invertebrates and small reptiles. Although coyotes have been observed infrequently during spotlighting surveys, they are known to den on the plots and forage in the area. Because coyotes feed extensively on leporids and small mammals (Jameson and Peeters 1988), we expect that abundance of coyotes will increase in the future. It is interesting that dogs and coyotes appeared to coexist in winter, yet seemed to exclude each other in spring, summer, and fall.

4.4.6.2. Track Station Surveys

Twenty-eight taxa were recorded visiting the trackplates over the 5-year study period. Approximately 75 percent of tracks observed were invertebrates (mostly beetles) or mammals (mostly rodents). Felids and mustelids were recorded in extremely low numbers suggesting that abundance of these taxa are especially low. While coyote and/or dog tracks were recorded during 12 of the 17 surveys, they were recorded infrequently during each survey period, which also suggests that these animals were relatively low in abundance. This is particularly evident given that the target species for track station surveys are typically meso-carnivores including canids, felids and mustelids.

4.4.6.3. Winter Raptor Surveys

There was an increase in the diversity and abundance of raptors on the Tranquillity site over the 5-year study period. The highest diversity was in 2001 and 2003 and the highest abundance was in 2002. The diversity and abundance of raptors present on the Tranquillity site is very similar to the abundance and diversity of raptors at Kern National Wildlife Refuge, (Cooper 2004). California special concern species (CDFG 1999) that were present at the Tranquillity site included ferruginous hawks (*Buteo regalis*), northern harriers, prairie falcons (*Falco mexicanus*), mountain plovers, and loggerhead shrikes. The abundance of northern harrier and the loggerhead shrikes remained relatively constant, but the abundance of the other sensitive species fluctuated. Red-tailed hawks at the Tranquillity site exhibited both light and dark morphologies (in 2003 approximately 25 percent of all red-tailed hawks observed exhibited a dark-morphology). However, the majority of the ground roosting red-tailed hawks were of the dark morphology. Ground roosting is relatively uncommon in this species, especially in light-morphed birds (Preston 1980).

Red-tailed hawks, white-tailed kites, northern harriers, kestrels, loggerhead shrikes, barn owls, western burrowing owls, and short-eared owls have all been observed nesting on and near the Tranquillity site. The presence of a viable, self-sustaining small mammal population likely contributes to the abundance, diversity, and successful breeding of these raptors. Although the Tranquillity site represents relatively high quality raptor habitat, it could be improved by successful restoration. Land retirement and the implementation of effective habitat restoration have the potential to greatly benefit raptors within the San Joaquin Valley.

4.5. Conclusions and Recommendations

4.5.1. Conclusions

The Land Retirement Demonstration Project proved to be a valuable learning experience regarding restoration of retired lands. This pilot project emphasized standard restoration techniques, which we have shown to be generally ineffective and not well suited to retired farmlands on heavy clay soils. By testing these standard methods on a small scale, we avoided the expense and inefficiency that likely would have occurred had these techniques been implemented on a larger scale. Based upon those initial results, we have implemented a wide array of research trials (see Appendix 3) that focus on the limiting factors that we identified. Some of those limiting factors have been overcome, but a number of issues remain to be resolved before restoration can be effectively conducted.

Some of the restoration approaches used on the HRS plots showed promise. Microtopographic contouring appeared to have positive effects in promoting establishment of native vegetation, and potentially providing habitat heterogeneity for small mammals and other biota. Shrub establishment—particularly of *Atriplex polycarpa*—approached densities that would be considered appropriate habitat for some species of concern. Nevertheless, in general, restoration response was less than optimal.

Factors contributing to the limited success of native plant restoration are thought to include inadequate seed delivery methods (imprinting may not be appropriate for use on the HRS soil types and for many of the species), competition from invasive species, inappropriate seed source (most of the seed was purchased commercially and was not obtained from the proximity of the project site), and drought conditions experienced throughout the term of the project.

The Habitat Restoration Study represents a significant expenditure of resources, and has required a concentrated effort by all involved parties. Given the immense challenges associated with the Tranquillity site (e.g., substantial weed loads, difficult soils, deficient rainfall, site history, etc.), it was not surprising that the restoration response was not as pronounced as was originally envisioned. Nevertheless, the HRS can be considered a valuable foundation in developing practical restoration strategies.

We are currently involved in an extensive research program that is advancing the state of knowledge of appropriate restoration technologies and recommendations for large-scale restoration efforts in the San Joaquin Valley (see Appendix 1).

The greatest obstacle to date has been weed control, so current research is primarily focused on that topic, but considerable time and expense is also being spent researching other restoration issues. Among these are: collecting seed from remnant populations of native plants, propagating and increasing the seed supply of locally collected plants, determining germination and propagation requirements of various plant species, and developing appropriate mechanical seed harvesting, planting, and ground preparation procedures. Continuation of this research is essential if land retirement and the restoration of retired lands are expected to proceed.

Because there were few notable differences among the restoration treatments, there were also few observable trends in wildlife diversity and abundance associated with the treatments. However, the information on wildlife diversity and abundance obtained shows that retired agricultural lands are valuable to wildlife. Even in the absence of widespread and successful restoration, retired agricultural lands are important to wildlife. Unquestionably, removing active agriculture and associated recurring disking and irrigating removes threats to wildlife. Over a 5-year period, the following were identified—101 families within 21 orders of invertebrates, 1 species of amphibian, 4 species of reptiles, 48 species of birds, 8 species of small mammals, 1 species of canid (coyote), 2 species of mustelids (skunk and long-tailed weasel), and 2 domesticated species (cat and dog) that utilize the Tranquillity study site. Nine species of birds utilized the study area as breeding habitat and 12 species of sensitive birds were using the study area.

Although there have been some instances of agricultural pest outbreaks and weeds which required control measures, there were no indications that the HRS lands supported greater pest densities than did surrounding retired and fallowed lands. Rather, agriculturally beneficial species were common and widespread on the site, especially in restored areas.

One factor that may have limited the abundance and diversity of native wildlife on the study plots is the lack of nearby lands that support wildlife which could disperse onto the study plots. Only small, remnant parcels of native habitat exist in the vicinity. Within 80 km (50 mi) of the site, fewer than 100 locations containing native plants have been located. The largest and most ecologically diverse areas are the Alkali Sink Ecological Reserve, the Kerman Ecological Reserve, and the Mendota Wildlife Area, all located within 16 km (10 mi) of the project site (see Chapter 1). A few sites in the immediate vicinity of the project site do provide opportunities for some wildlife dispersal. These are primarily limited to the San Luis Drain right-of-way, the Lateral 7 Inlet Canal right-of-way, various dirt roads that cross the site, and land directly north of the site which has been fallowed. The diversity of wildlife on these lands is not great and dispersal of wildlife onto the plots from these areas is expected to be minimal. The barley buffers, which are approximately 101 m (330 ft) wide, may also have contributed to lower abundance and diversity of some taxonomic groups than might otherwise be expected. The width of the buffers, however, was a compromise between the need to allow wildlife to invade the plots, yet at the same time isolate the plots to minimize interactions between restoration treatments.

Although this project did not necessarily emphasize the establishment of threatened and endangered wildlife on the study plots, that is one long-term goal of the land retirement program. We increased the suitability of habitat for a number of rare species of birds and, as restoration techniques are designed and applied, the benefits to wildlife including sensitive species would be expected to increase. With the incorporation of appropriate management actions, the habitat that has been established could become increasingly suitable for various other rare species (e.g., San Joaquin kit fox, blunt-nosed leopard lizard, and San Joaquin kangaroo rats). Many rare upland species seem to be dependent upon an open vegetative structure, independent of native plant diversity or the presence of a fully functional native plant community. Accordingly, habitat for rare species may be more easily established and managed than a diverse, native upland plant community.

The data presented in this report are immensely valuable as a description of baseline conditions that, if compared to data collected from retired lands that are successfully restored to native habitats, would provide insight into the value of restoration to wildlife. There have been no other wildlife studies or monitoring efforts in the central San Joaquin Valley of this duration or scope, making this a unique data set that describes the wildlife community existing on lands dominated by non-native species. Within the San Joaquin Valley, similar conditions are common and widespread among scattered, remnant patches of land that are not intensively farmed.

The three primary objectives of the Habitat Restoration Study have been accomplished. Below is a summary of findings related to each objective.

1. Determine the efficacy of revegetation with native plants as a means to facilitate upland habitat restoration.

Standard native plant revegetation techniques as applied to the study plots (planting commercially purchased seed of an appropriate species mix on prepared ground using a seed imprinter) facilitated upland habitat restoration, but to a degree that was less than optimal. Some species persisted for a short time, some species became established but diminished over time, and others (e.g., *Atriplex polycarpa* and *Suaeda moquinii*) became established on some plots. Competition with weeds appeared to be the primary factor limiting restoration success, although other factors (e.g., low seed viability, seed delivery methods, and insect damage) were problematic. Revegetation research, which became an increasingly important component of the project, led to the development of promising and innovative techniques to combat these issues. A combination of selective herbicide use, application of activated charcoal (to protect native seed from herbicide exposure), and planting seed using a modified seed drill seems particularly promising. These techniques will be applied and tested under field conditions in 2005 and 2006.

2. Determine the efficacy of microtopographic contouring as a means to facilitate upland habitat restoration.

Microtopographic contouring as applied to the study plots (i.e., straight, uniform size, uniform orientation), showed some value in facilitating the establishment of native plant species (particularly shrubs) but appeared to be of limited value to wildlife, at least in the short term. We suspect that with time, their importance to wildlife would increase (as burrowing species such as kangaroo rats become residents). A more complex system of microtopographic contouring would add additional heterogeneity and likely result in increased benefits to plants and wildlife.

3. Examine the responses of plants and wildlife to land retirement and restoration.

A multitude of plants and wildlife responded well to land retirement. The cessation of active agriculture and associated irrigation and disking allowed for the incursion and establishment of many native and non-native species on retired lands. The implementation of improved revegetation techniques and appropriate land management actions would be expected to enhance benefits for desirable species.

4.5.2 Recommendations

A number of tasks remain to fulfill the intent of this project and to ensure that land retirement and the restoration of retired lands can proceed. Continuation of current restoration research, the implementation of new restoration research topics, and other high priority tasks are needed. Specific tasks that should be accomplished include:

- Publish findings of completed and on-going research in the open scientific literature, which is subjected to world-wide scientific scrutiny. It is important to have this information widely available, especially to those attempting restoration in the San Joaquin Valley. Unfortunately, information contained in unpublished, gray literature is often overlooked or unavailable to scientists and managers. Government agencies should always provide their personnel and consultants with strong incentives and the time and resources to publish their work.

- Develop a long-term management and monitoring plan for the Tranquillity site. This management plan should include long-term wildlife monitoring on the HRS plots (or a subset) every 3 to 5 years to document changes in biota over time, monitoring of selenium levels to ensure safe conditions for wildlife, and developing and implementing a restoration strategy for Tranquillity site lands.

- Continue maintenance and expansion of the native plant nursery and seed collecting activities. The native plant nursery has proven to be an essential component of restoration. It facilitates research on seed delivery methods, propagation techniques, and harvesting techniques, and it also functions to increase the stock of locally collected native plant seed. The nursery has proved itself invaluable in outreach activities by providing a visually appealing representation of native landscapes. The continuation of seed collecting activities is necessary to increase the number of species of native plants and to improve the genetic diversity of local genotypes of plants that would be available for restoration.

- Continue research on development of restoration technologies, including seed delivery techniques, weed control methods, harvesting techniques, and seed cleaning techniques. Currently, there is an insufficient seed source and a severe lack of restoration technologies that are appropriate for the implementation of large-scale restoration in the San Joaquin Valley. Continuation of these activities is vital to a successful large-scale land retirement project and other large-scale restoration efforts in the region.

- Document and protect localities of known populations of native plants and animals in the project vicinity to ensure the survival and persistence of existing populations. Native populations of plants and wildlife in the San Joaquin Valley are exceedingly small in size and rare in occurrence. These fragmented populations are vital stockpiles of resources that would be needed for restoration.

- Develop criteria and methods for the propagation and translocation of threatened and endangered species to restored lands. Because there is a paucity of existing native lands (and those that do exist are isolated by large expanses of agricultural lands that act as barriers to the movement of wildlife) occurring in the western San Joaquin Valley, it is not likely that many threatened and endangered wildlife species would emigrate to retired lands. Accordingly, to ensure maximum benefits to threatened and endangered wildlife, techniques must be developed for the safe and successful translocation of these species.

- Provide public awareness of the positive effects and benefits of land retirement. An ongoing outreach program is essential to generate public interest and acceptance of land retirement and native lands restoration. Appropriate outreach can also be instrumental in developing and securing additional funding.

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