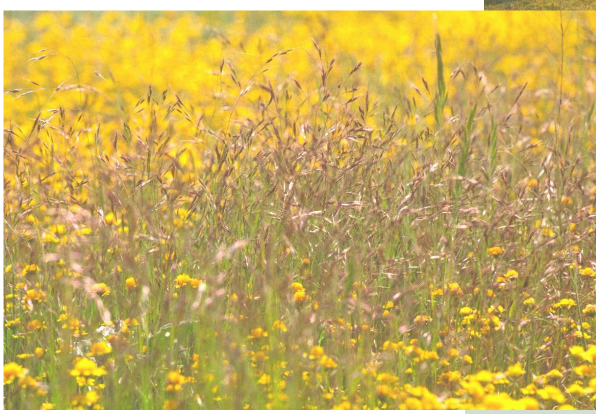
EXOTIC AND NATIVE PLANT MONITORING AT JEPSON PRAIRIE PRESERVE, 2002



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Front cover photos: Top: monitoring transect 19, April 2001. Left: *Deschampsia danthonioides* and *Lasthenia* spp. Bottom: monitoring transect 16, April 2002.

EXECUTIVE SUMMARY

This report describes the development of a monitoring system to assess populations of selected exotic and native plants at the Jepson Prairie Preserve in Solano County, California. The monitoring system is based on the use of permanent belt transects (20 m wide) that traverse all of the pastures at the preserve. Transects are divided into segments 50 m in length for purposes of data collection and analysis. Percent cover of each monitored species within each transect segment is estimated visually and assigned to one of four cover ranks. In addition to transect-based monitoring, populations of uncommon weeds located outside of transects are mapped with the aid of a GPS receiver. Initial monitoring along the transects was conducted during a one-week period in mid-April 2001 and transects were resurveyed in April 2002. The results of these surveys are reported in this report and a previous report (Swiecki and Bernhardt 2001).

We used paired comparisons of data collected along the same transect by different sets of evaluators to assess the amount of variation in cover ranks that could be attributed to differences between evaluators and to GPS receiver position error. Measurement error associated with these factors was acceptably low. Quality control on data collected in successive years can be maintained by ensuring that evaluators are adequately trained, plant phenology is optimal for observations, and differentially-corrected GPS readings are used.

For most monitored species, cover ratings in 2001 and 2002 did not differ significantly. However, some species, including the native grass *Pleuropogon californicus* and the exotics *Carduus pycnocephalus* (Italian thistle) and *Lactuca serriola* (prickly lettuce) showed general increases in cover that may be related to differences in rainfall patterns in the two years. Monitoring data also documented that controlled burns in 2000 and 2001 provided virtually complete suppression of the exotic grass *Taeniatherum caput-medusae* (medusahead) for at least 2 years in some pastures. However, burns conducted in some pastures in the same years were ineffective at controlling *T. caput-medusae*. Analysis of paired pre- and post-fire data also indicates that the cover of *Triphysaria eriantha, Viola pedunculata,* and *Erodium* spp. was significantly elevated in burned transect segments relative to matched nonburned segments.

Among the target weeds surveyed, *Lepidium latifolium* (perennial pepperweed) and *C. pycnocephalus* appear to have spread significantly since 1995. *Centaurea calcitrapa* (purple star-thistle) may also show some expansion in its distribution since 1995. However, 1995 baseline data are inadequate to determine whether most target weed species show long-term gains in cover. A number of target weed species that have limited distribution at the preserve were rarely detected in transects, but mapped points and polygons document that they occur at various locations throughout the preserve.

The combination of annual transect-based monitoring and point/polygon mapping of uncommon target weeds provides a practical means for assessing the spread of invasive species at the preserve. It can also provide information on the efficacy of management activities such as burning and the impact of management actions on various native species. Adaptive management of Jepson Prairie grassland vegetation will be facilitated by consistently implementing the monitoring protocols described in this report.

INTRODUCTION

Jepson Prairie Preserve is managed by the Solano Land Trust (SLT) to maintain a Central Valley vernal pool and native grassland ecosystem. The Preserve currently supports a wide diversity of native plants as well as a number of exotic plants. Some of these exotic plants have the potential to displace native plants and seriously degrade the integrity of the ecosystem. The purpose of this project is to develop a system to monitor exotic and native plants so that changes in vegetation can be detected and hopefully corrected before they lead to serious degradation of the ecosystem.

Several factors needed to be taken into consideration in the design of the monitoring system. First, soil conditions at Jepson Prairie are diverse, both in terms of soil chemistry and microtopographical relief. These soil factors strongly influence plant distribution. Hence, in order to make valid comparisons between different years, variation due to differences in soil type or microtopography should be eliminated. This is most readily accomplished by ensuring that the same specific areas are resurveyed in successive years. Otherwise, changes observed may be due to positional change of the observer rather than to actual change in species composition.

Second, the monitoring method needs to be as independent of observer bias as possible. Monitoring will be conducted over a period of many years, so it is likely that different personnel will be collecting data in different years. Subjective cover ratings, such as those used in the 1995 survey (The Nature Conservancy 1996) may be interpreted differently by different evaluators. If different observers provide different ratings for the same amount of cover, the variation in ratings attributable to evaluators will obscure actual cover changes. To the degree possible, vegetation assessments need to be objective and quantifiable to reduce this source of error. However, given the constraints of time and resources available for monitoring, assessment methods must also be relatively simple and fast, while still maintaining a high level of reproducibility.

Changes in weather conditions, such as the timing and amount of winter rainfall, can favor some species and disfavor others. Hence, some of the year to year variation in vegetation composition will be associated with weather conditions alone. By minimizing error associated with other controllable factors, such as location and observer bias, our ability to model the variation associated with weather will be improved.

One of the major questions for preserve managers is whether management practices such as burning and grazing are having the desired vegetation management effects and whether changes in the timing, frequency, and/or intensity of these practices can be used to provide more effective control of target weeds. The data from the annual native and exotic plant monitoring can be used to some degree to assess the impacts of various management factors. The use of monitoring data to assess treatment effects is somewhat limited because the factors under study (burning, grazing, and soils) are confounded to varying degrees over space and time. Nonetheless, the monitoring data can be used to address certain management questions and may also provide information that can be used to form hypotheses that can be tested through controlled experiments. The design and execution of planned studies to investigate the effects of various management regimes are beyond the scope of the monitoring program discussed herein.

Detailed results of the first year of monitoring (2001) have already been presented (Swiecki and Bernhardt, 2001). This report presents results of monitoring in 2002 and does not reiterate results already discussed in the 2001 report except with reference to various comparisons between the two years. Detailed methods used to conduct the monitoring are also presented in this report.

METHODS

Plant species monitored

Targeted exotic plants to include in weed monitoring were chosen based on conversations with SLT staff and review of the results of an earlier weed monitoring program conducted by The Nature Conservancy (1996). The targeted weeds have the potential to displace native species at the preserve. With the exception of *Taeniatherum caput-medusae*, most target weeds (Table 1) currently have relatively limited distributions and/or populations. Controlling the spread and/or density of the targeted exotics may be possible through available management practices. A number of common weedy species, including *Bromus diandrus* (ripgut brome) and *Lolium multiflorum* (annual ryegrass), have not been included on the list because they are widespread, occur in relatively high densities, and are not currently thought to be manageable.

The targeted weed species include perennial forbs, late season annual forbs, and grasses. *Erodium* spp. were included in the monitoring of exotics to represent the early season exotic forb plant guild (Pollak and Kan 1998) even though they are not considered to be targeted weeds.

The list of plants to include in native plant monitoring (Table 2) was chosen after consulting with Kevin Rice (UC Davis) and Carol Witham (Vernalpools.org). Species were selected as common representatives of native plant guilds (native graminoids, native early forbs, and native late forbs) described in Pollak and Kan (1998).

Transect based monitoring

We established a system of parallel belt transects which form the backbone of the monitoring system (Figures 1 and 2). At least one transect passes through each pasture on the preserve. We used the mapped soil types (Bates 1977) to guide placement of transects to ensure that most or all of the soil types present within each pasture were represented within that pasture's transect(s). In four pastures, transects were divided into offset segments or legs to avoid areas that could not be sampled (e.g., pond in Norris pasture, transect 18). Almost all of the transects are oriented along straight east-west lines, but three pastures have north-south oriented transects and one transect (transect 7) has a section oriented along a northwest-southeast bearing near Olcott Lake (Figure 1).

Each transect was divided into segments 50 m long. For each transect segment, an area extending out 10 m on either side of the centerline of the transect was evaluated. Each transect segment was therefore 50 m by 20 m or 1000 m^2 in area (0.1 ha). Because the length of most transects was not an exact multiple of 50 m, the final segment in most transects was either slightly longer or shorter than the 50 m target length. The total area surveyed in the transect system amounts to about 5% of the total area of the pastures at the Jepson Prairie Preserve, excluding Olcott Lake (Table 3). The distribution of transect segments by pasture is shown in Table 4.

Table 1. Monitored exotic plant species arranged by plant family.

Common name	Scientific name	Category
Apiaceae		
Fennel	*Foeniculum vulgare*	late perennial forb
Asteraceae		
Italian thistle	*Carduus pycnocephalus*	late annual forb
Purple star-thistle	*Centaurea calcitrapa*	late annual forb
Yellow star-thistle	*Centaurea solstitialis*	late annual forb
Bull thistle	*Cirsium vulgare*	late annual forb
Wild lettuce	*Lactuca serriola*	late annual forb
Milk thistle	*Silybum marianum*	late annual forb
Cocklebur	*Xanthium strumarium*	late annual forb
Brassicaceae		
Perennial pepperweed	*Lepidium latifolium*	late perennial forb
Geraniaceae		
Filaree[1]	*Erodium* spp.	early annual forb
Poaceae		
Goat grass	*Aegilops cylindrica*	annual grass
Medusahead grass	*Taeniatherum caput-medusae*	annual grass

[1]*Erodium* spp. are not considered to be target weeds.

Table 2. Monitored native plants arranged by plant family.

Common name	Scientific name	Category
Asteraceae		
Yarrow	*Achillea millefolium*	late perennial forb
Goldfields	*Lasthenia* spp. (species with conspicuous ray flowers, including *L. californica* and *L. fremontii*)	early annual forb
Poaceae		
Annual hairgrass	*Deschampsia danthonioides*	annual grass
Semaphore grass	*Pleuropogon californicus*	annual grass
Purple needle grass	*Nassella pulchra*	perennial grass
Scrophulariaceae		
Butter and eggs	*Triphysaria eriantha* ssp. *eriantha*	early annual forb
Violaceae		
Johnny-jump-up	*Viola pedunculata*	early perennial forb

Table 3. Transect dimensions relative to Jepson Prairie Preserve area.

Total transect length	16,115 m (10 miles)
Transect width	20 m
Total area covered by transects	32.23 ha
Total Preserve pasture area	602.8 ha (1,490 acres)
Percent sampled in transects	5.35%

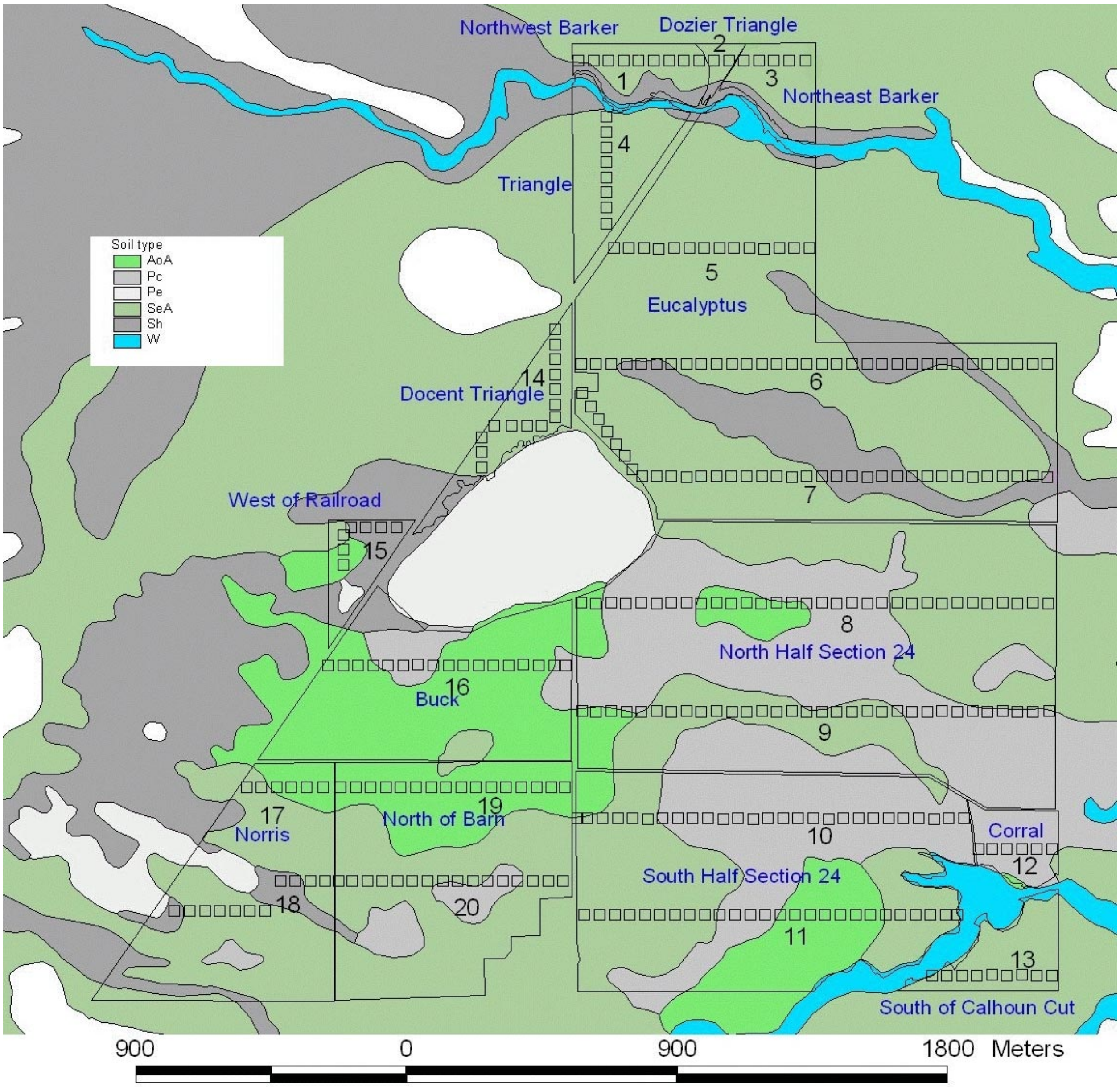

Figure 1. Transect segment locations superimposed on pasture map and soil types. Pasture names are in blue. Numbers assigned to each transect (1 to 20) are shown in black. Black squares which mark transect segments are centered over the midpoint of the segment and are not to scale. Soil types: AoA=Antioch - San Ysidro complex, Pc=Pescadero clay loam, Pe=Pescadero clay, SeA=San Ysidro sandy loam, Sh=Solano loam, W=water.

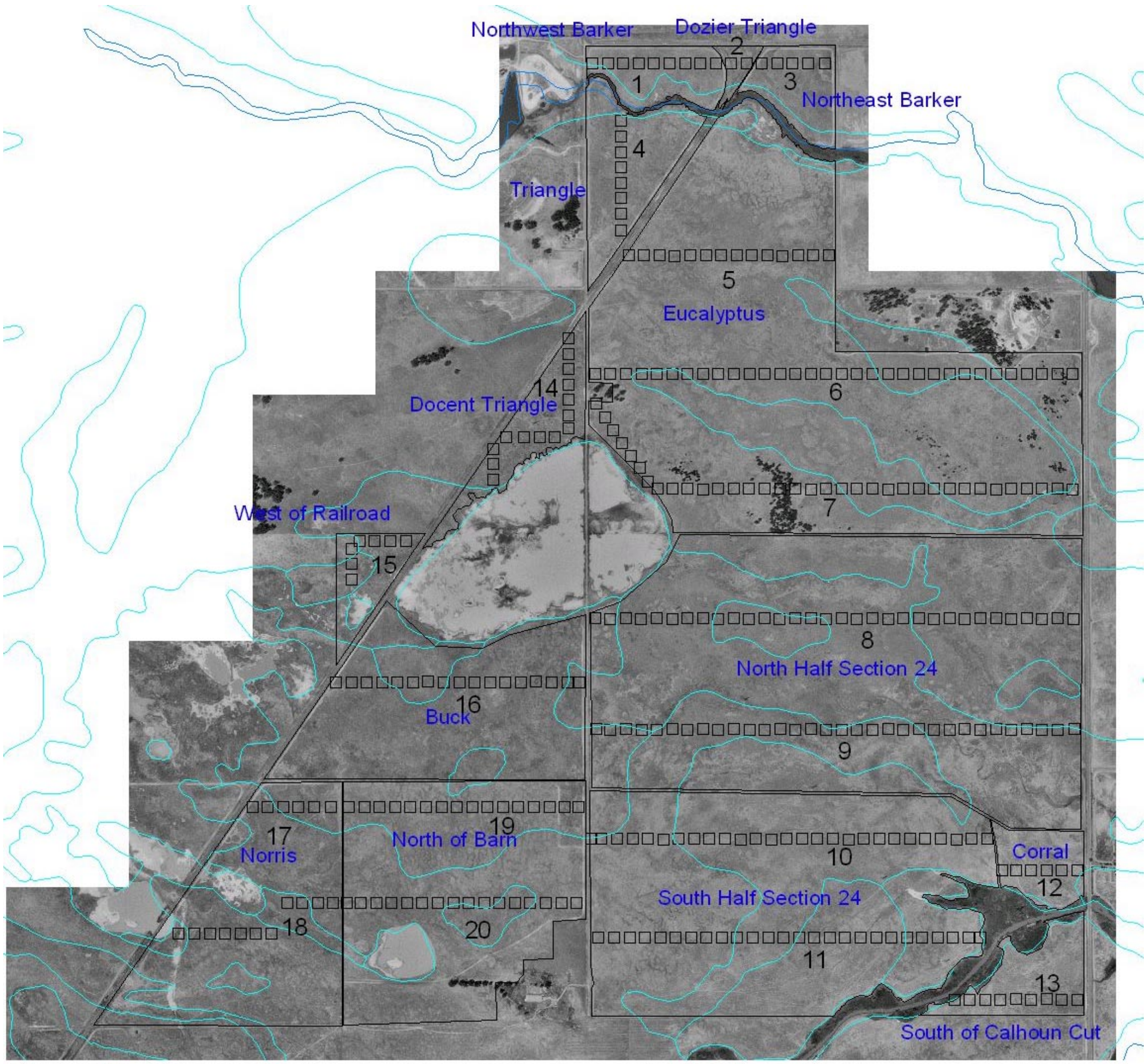

Figure 2. Transect segments, pasture outlines, and soil type outlines superimposed on digital ortho imagery of the preserve (June 1993). Soil type outlines are in light blue. Pasture names are in dark blue. Numbers assigned to each transect (1 to 20) are shown in black. Black squares which mark transect segments are centered over the midpoint of the segment and are not to scale.

For the first year of monitoring (2001) we used a handheld Garmin® 12XL GPS receiver operating without differential correction to establish the starting point of each transect and to navigate along transects in the field. Transect ends were marked temporarily with flagging tape at the time of the original monitoring. We subsequently installed a cylindrical galvanized steel post (1.6 m long, 3.2 cm diameter) to which we attached a perforated galvanized plate (8 by 18 cm) at the start and end of each transect or transect section. The 6 posts that are not located adjacent to fence lines (transects 4, 15 and 18) were also painted with red heat-resistant paint to increase their visibility. The position of each post was subsequently remeasured using a Garmin® GPS 76 receiver operating with WAAS differential correction. The nominal positional accuracy in differential correction mode is 3 meters. Several of the posts, mostly those located away from fences had been knocked out by livestock and were repositioned with the aid of a GPS 76 receiver prior to the 2002 monitoring. Garmin® GPS 76 receivers operating with WAAS differential correction were used by evaluators to navigate along the transects in the 2002 monitoring.

Garmin® GPS 76 receivers operating with WAAS differential correction were used by evaluators to navigate along the transects for monitoring in 2002. The GPS display was set to read in UTM coordinates, so position was displayed as X and Y coordinates in meters along a uniform grid. The transect centerline was established by maintaining the appropriate coordinate constant on the GPS (e.g., northing or Y coordinate for east-west transects). Transect segment length was also determined using GPS readings. A measuring tape was used to help the evaluators determine the 10 m distance from the centerline initially and was used for spot checking visual distance estimates during the evaluation. In 2002, we found that visual calibration of the 10 m distance could be maintained more easily if one member of the survey team dragged 10 m of measuring tape behind them as they walked the transect.

Monitoring was conducted by crews of two to four persons. In general, a minimum of three persons per crew is desirable. In a three person crew, one person monitors position with the GPS and walks along the transect centerline. The other two crew members record cover data for target native and weed species respectively, aided by the GPS operator. In a two person crew, the GPS is monitored by one crew member who also rates either native or exotic species, preferably the group with fewer species represented. To permit the use of prenumbered data sheets and increase efficiency in the field survey, we organized the transects in seven routes (Table 5) which were used in the 2002 survey.

In 2001, weed and native plant cover were rated between 12 and 18 April by the authors of this report. In 2002, monitoring was conducted between 16 and 18 April. We trained SLT staff members and volunteers in the methods used to monitor transects prior to data collection and participated in data collection on all transects in the April 2002 monitoring. This allowed us to maintain some level of quality control for all monitoring crews. SLT staff members Ken Poerner and Julian Meisler were also members of monitoring crews for all transects in April 2002. Volunteers Kate Mawdsley, Jim Steinert, Trisha Tierney, Virginia Boucher, Celia Zavatsky, Don Taynton, and Mal Evett participated in the April 2002 monitoring crews on one or more days. In 2002, each monitoring day required 5 to 6 hours of field time, including time for lunch in the field. Field time on the first day (16 April) included about an hour of orientation and training that included a small practice transect.

Table 4. List of pastures monitored, including approximate pasture areas (based on grazing records), transect segments, and approximate sample percentage. Pasture areas calculated from ArcView® differ from those used in grazing records. To maintain consistency with other documents, we have used areas reported in the grazing records. Areas of the nongrazed Docents, Dozier, and West of Railroad pastures are based on ArcView calculations because their areas are not reported in grazing records.

Pasture	Approximate area (acres)	Approximate area (ha)	Transect number(s)	Number of transect segments	Approximate sample percentage
Buck	100	40	16	17	4
Corral	20	8	12	6	7
Docents	23	9	14	14	15
Dozier	3.5	1.4	2	2	14
Eucalyptus	370	150	5, 6, 7	81	5
Norris	120	49	17, 18	17	4
North Half Section 24	340	138	8, 9	64	5
North of Barn	150	61	19, 20	32	5
Northeast Barker	15	6	3	5	8
Northwest Barker	15	6	1	9	15
South Half Section 24	248	100	10, 11	53	5
South of Calhoun Cut	35	14	13	9	6
Triangle	35	14	4	8	6
West of Railroad	15	6	15	7	12

Table 5. Routes used for transect monitoring in 2002 and the order in which monitoring occurred.

Route	Transect numbers	Day monitored
1	1 - 5	1
2	6, 7	3
3	8, 9	3
4	10, 11	2
5	12, 13	3
6	17 - 20	2
7	14 - 16	1

Estimating and recording plant cover

Data collected during transect monitoring consisted of cover ranks for each of the monitored exotic and native species for each transect segment. Cover for each monitored species was estimated visually using the cover classes shown in Table 6. Cover is estimated in a manner analogous to cover type mapping from aerial photographs. Very small gaps between plants or leaves within a plant that would be measured in very precise field point intercept methods are essentially ignored when estimating cover area.

Because many of the monitored plants are annuals, the actual cover for these species will change over time in a given season. The survey is timed to be near peak cover for most of the monitored native spring annuals. This tends to be slightly earlier than optimal for assessing final cover of exotic summer annuals, but as noted in our previous report (Swiecki and Bernhardt 2001), this is probably the best timing for a single spring survey. Even if the survey is timed for peak cover, some plants (e.g., *Lasthenia* spp. and *P. californicus*) in some areas (such as poor soil areas) may be in varying stages of senescence at the time of rating. To avoid bias associated with early senescence, evaluators should include dead and senescent current-season biomass when assessing plant cover. Cover estimates of senescing native plants should be adjusted to reflect the level of cover at peak bloom.

Table 6. Cover classes used for estimating exotic and native plant cover and associated calibration guidelines.

Cover class rank	Plant cover	Equivalent area within 0.1 ha transect segment	Ratio of hits to sampled points
0	Not observed	Not observed	Not observed
1	>0 to <1% cover	<10 square meters	less than 1 in 100
2	1% to 10% cover	10 to 100 square meters	between 1 in 100 and 1 in 10
3	>10% cover	>100 square meters	more than 1 in 10

In practice, the evaluator needs to answer up to three questions for each scored species in each segment in the sequence noted below.

A. Is the target species present in the segment? (if yes, evaluator scores presence with a dot, i.e., cover rank is at least 1; otherwise cover = 0)
B. If A is true, is cover greater than or equal to 1%? (if yes, observer adds a second dot; i.e., cover rank is at least 2; otherwise cover = 1)
C. If B is true, is cover greater than 10%? (if yes, observer records cover rank as 3; otherwise rank = 2)

At the end of each transect, the evaluator translates all dots into numbers on the data sheet and draws a horizontal line through cells with no cover. This helps ensure that data from the next transect segment is not recorded in the wrong cell.

We developed two types of calibration guidelines to help maintain consistency of ratings between observers and for the same observer over time.

Area-based calibration guideline. To use the area-based calibration guideline, the evaluator mentally sums the cover area for a given species and determines whether the area exceeds either of the cover class cutoffs, 10 m^2 or 100 m^2 for a full 50 m-long transect segment. The summed area is based on 100% cover for the rated species over the mentally-consolidated area of coverage. We produced a visual guide (Figure 3) that superimposes diagrams of the cover class cutoff areas over a schematic of the transect segment. The guide also includes an auxiliary table that provides the cutoff areas for end transect segments that are longer or shorter than the standard 50 m length. This calibration guideline works best for plants that occur in distinct patches of nearly complete cover (e.g., *Lasthenia* spp.). However, it can be used for most species by adjusting the area for plants that that occur in patches with lower than 100% percent cover within the patch.

Intercept-based calibration guideline. When monitored species are widely dispersed over the transect segment and are not in discrete patches, an alternative method for estimating cover may be more useful. This is essentially a visualization of a point-intercept rating or a dot-grid count of an overhead image of the transect segment. The evaluator visualizes 100 small points (e.g., paint drops) dispersed randomly across the transect segment. In repeated trials, a plant with more than 1% cover would be hit by one or more of these points on average. For the 10% cover cutoff, the evaluator can visualize repeated trials using ten random points. This calibration guideline is probably more difficult to use on a routine basis than the area-based guideline, but is useful for certain situations.

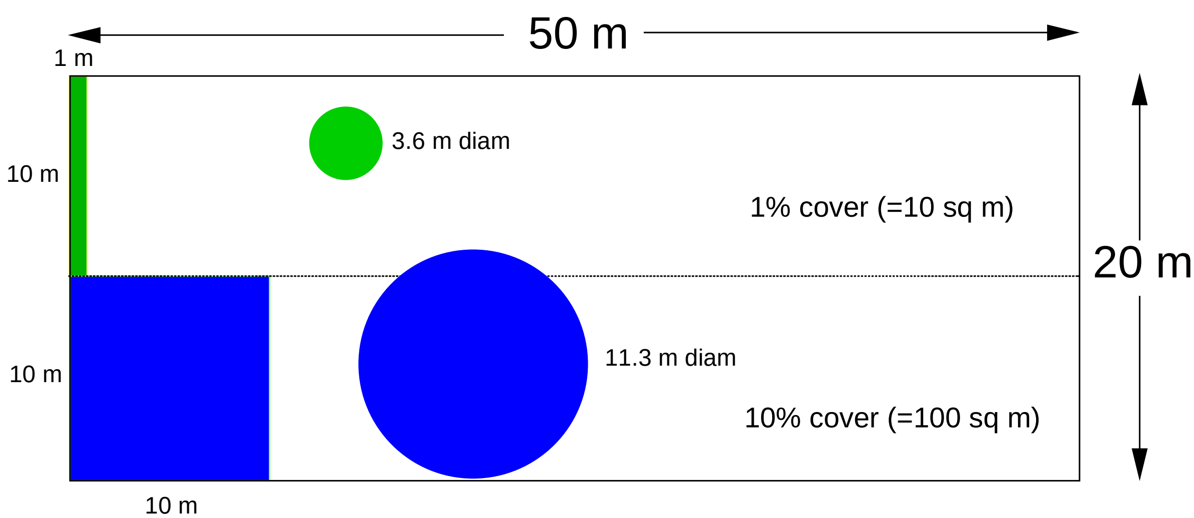

Figure 3. Visual aid used for area-based method of estimating cover classes illustrating overall transect segment dimensions and area equivalents for 1% and 10% cover cutoffs.

Polygon monitoring

We also used GPS receivers to map polygons (large patches) and/or points (small patches) of rarely occurring target weed species that were observed outside of the transects. Individual weeds or small patches (<10 m along one axis) were recorded as single points. Larger patches were mapped by recording the coordinates of two or more points along the outer border of the patch. For each mapped weed point or polygon we recorded the following data:

- weed species present
- the number of weeds in the patch by species. The exact count was recorded for patches of 10 or fewer plants. Approximate count classes (11-50, 51-100, 101-500, >500) were recorded for patches with larger numbers of plants.
- the predominant microtopography at the site of weed occurrence, using the following categories: depressed area (e.g. swale or pool), flat (average elevation), or elevated area (e.g., mound).

Additional site variables

GIS layers of the mapped soil type were downloaded from the USDA National SSURGO database. Grazing records for the interval July 1993 through June 2001 were obtained from the grazer through SLT and were entered into a spreadsheet for summarization and calculation of derived variables. Grazing data were expressed as average AUM (animal unit months) per acre for each pasture and are based on the grazer's reports. We also obtained fire records for the period 1996 through 2001 from Ken Poerner of SLT. Controlled burns were conducted in late May or early June. No burning occurred in 1996, 1997, or 1998.

Data analysis

We used JMP version 4 statistical software (SAS Inc., Cary NC) and R 1.5.1 (R Development Core Team) for data analysis. Unless otherwise indicated, effects or differences are referred to as significant if $P \leq 0.05$. We used nominal logistic regression to test for effects of selected predictors on the binary presence/absence outcome. McNemar's test of correlated proportions with continuity correction was used to compare the proportions of transect segments with or without a given species (presence/ absence outcome) in the two years. We used the Wilcoxon signed-rank test to compare differences between cover ranks on transect segments in the two years. We used repeated measures analysis of variance to compare sums of cover class ranks. For these analyses, sums of cover class ranks within transect segments were transformed to the square root of (rank sum + 0.5) prior to analysis to stabilize the variance (Steele and Torrie 1960).

RESULTS AND DISCUSSION

Plant phenology at the time of monitoring

In general, phenological stages of the monitored native species were similar at the time that transects were read in 2001 and 2002. In both of the April surveys, *Lasthenia* spp. were at peak bloom to slightly past, most *T. eriantha* and *V. pedunculata* were past peak bloom, and *A. millefolium* was just starting to bloom. Most *D. danthonioides* and *P. californicus* plants were fully headed out whereas most *N. pulchra* were vegetative or just beginning to head. As a group, these plants were at nearly optimal stages for cover estimation. In 2001, the tops of *D. danthonioides* and *P. californicus* were eaten off in pastures where sheep had recently grazed, which made these species more difficult to rate in some areas (Swiecki and Bernhardt 2001). In general, few areas had been affected by recent sheep grazing at the time of the April 2001 monitoring, and the impacts of sheep appeared to be less in April 2002 than in April 2001.

Among the monitored exotics, *Erodium* spp. ranged from full bloom to past bloom in both years. In both years, *L. serriola* and most of the thistles were still in rosette stage, although some *C. pycnocephalus* had started to bolt. Flowering in both *L. latifolium* and *T. caput-medusae* was more advanced in the April 2001 survey compared with the April 2002 survey. *L. latifolium* was beginning to bolt in numerous locations at the time of the April 2001 survey, but very few infloresences were elongating at the time of the 2002 survey. *T. caput-medusae* had not headed out in all areas by the time of either the April 2001 or 2002 surveys, but flowering in 2001 was more advanced than in 2002 at the time of the survey.

Factors related to differences in cover ratings

Before we present and interpret differences between Spring 2001 and 2002, it is important to understand the array of factors that may contribute to these differences. These factors can be divided into two categories. The first category includes a set of interacting factors that actually influence species diversity and distribution over time and space. They include:
1. weather conditions, such as rainfall and temperature;
2. soil type and properties (e.g., salt and nutrient levels, compaction);
3. topographical variation, especially slight elevational differences that affect drainage;
4. previous plant cover (and hence the soil seed bank) and proximity to current seed sources;
5. damaging factors (e.g., fire, grazing, diseases, insects) that may affect seed production, seed viability, plant germination and/or survival.

Fire and grazing are the two most important management factors that influence vegetation at the preserve. The major effects of these two management factors are included in the list above under items 5 (damage), 4 (previous plant cover), and to a lesser extent 2 (soil properties). Impacts of fire and grazing on the seed bank and soil conditions can persist over several years, so the history of fire and grazing patterns must be considered when assessing the effects of these factors. Because all of the above factors interact and vary over time and space, it is generally difficult to attribute observed changes in vegetation to any single factor, although some examples exist (e.g., effect of fire on *T. caput-medusae* cover, as discussed later).

The second set of factors that contribute to variation in cover ratings consists of measurement errors that are associated with the monitoring method itself. This variation tends to reduce our ability to detect changes associated with factors in the first category. Although the monitoring methods have been designed to minimize measurement errors, they are constrained by the resources available for the monitoring program, including time and personnel constraints. Hence, the selected methods represent a compromise, and do not necessarily represent methods with the lowest possible levels of measurement error.

The main types of measurement error associated with the monitoring method are as follows:

1. Inaccurate estimates of plant cover by evaluators. Virtually all methods used to assess plant cover are subject to measurement error. For transect monitoring at the Jepson Preserve, we decided to use visual estimates to assess plant cover. Visual estimates are much faster and easier to perform than many other methods for estimating cover, and were therefore well suited to the rapid, large-scale, multispecies monitoring effort that was required. However, visual estimates are subject to several potential sources of error that can result in inconsistency of ratings made by different evaluators or by a given evaluator at different times.

In general, the consistency and accuracy of visual cover estimates improves with the level of training and/or skill of the evaluator. We have made efforts to reduce the likelihood of measurement errors by using few cover classes (4, including zero) and providing evaluators with calibration aids and training. However, some variation in the assessment of plant cover is to be expected, especially when the actual cover is near one of the cover class cutoffs (1% or 10%). In addition, even ratings made by a skilled evaluator may be affected by adverse conditions that may occur during the survey, such as high winds or poor lighting. The accuracy of the cover ratings for species such as *T. caput-medusae* may be affected by such conditions. Recent grazing damage, as noted on *D. danthonioides* and *P. californicus* in 2001 (Swiecki and Bernhardt 2001), could also affect the reliability of cover estimates for some species. Differences in plant phenology can also affect the ability to detect some species and could lead to differing plant cover estimates. Species such as *T. caput-medusae* and *N. pulchra* are more easily identified when flower or seed stalks are present, and may be underrated before flowering occurs.

2. Positional changes in the location of transect segments. Transects have been established in fixed locations to avoid variance associated with the spatial distribution of the monitored species. However, the spatial coordinates provided by GPS units using differential correction can be in error by up to 3 m. Without differential correction, positional errors can be as great as 15 m, though they are more commonly in the range of 5 to 10 m. For most common species, positional errors that shift the transect segment several meters or more will have little or no effect on cover ratings. However, positional shifts may affect ratings of species that are uncommon and that lie near the outer edges of the transect segment. Such species may be shifted in or out of a segment by a positional shift of as little as 1 to 2 m. In some cases, the species' recorded position may shift from one segment to the adjoining segment if the isolated plants occur near the border between two segments.

Assessment of measurement error

To get an idea of the amount of variation that could be expected due measurement errors, we performed a small-scale comparison of ratings made independently by different evaluators on a single set of transect segments. On 12 April 2002, exotics and natives in transect 5 were scored by E. Bernhardt and T. Swiecki, respectively. On 16 April 2002, the transect was rated again, by K. Poerner and J. Steiner evaluating exotics and K. Mawdsley and T. Swiecki evaluating natives. Transect 5 has 14 transect segments.

This limited test potentially includes variation associated with the following factors:

- changes in plant phenology over the 4 day interval between the ratings could have altered the evaluators' ability to detect some species, especially *T. caput-medusae*;
- slight shifts in the position of the transect segments are possible due to different GPS-reported positions in the two rating sessions;
- the 16 April crew had twice as many evaluators (4) as the 12 April crew (2)
- different sets of evaluators are involved in rating exotic species on the two days
- one evaluator (T. Swiecki) was involved in rating native species on both days.

All of these factors may come into play during the monitoring effort, which lasts for several days and utilizes crews of varying composition on different days. Hence, this limited test gives an idea of how much variation may be due solely to these typical sources of error.

Of the species monitored, *Centaurea calcitrapa, Cirsium vulgare, Foenicium vulgare, Lepidium latifolium,* and *Silybum marianum* were not detected by either monitoring crew. For the species that were detected, differences between the two sets of ratings are summarized in Table 7 below.

For all species, some transect segments received different ratings on the two dates. Most of the differences were quite minor, and involved single-class shifts in cover ranks. Only three of the 168 individual segment by species ranks differed by two ranks, and two of these were differences between the ranks 0 (not detected) and 2 (1-10% cover).

For four species, overall detection (presence/absence per segment) differed by more than 1 segment in the 14 segments that were evaluated by the two different crews (Table 7). Three of these species are perennials (*A. millefolium, N. pulchra*, and *V. pedunculata*). Although changes in phenology could have contributed to the recorded differences, positional errors associated with GPS drift could also contribute to differences in cover ranks. The differences in the presence/absence outcome for 2001 and 2002 were not significant for any of the species according to McNemar's test (Table 7).

For species, *C. pycnocephalus* and *T. caput-medusae,* paired t-tests on the two sets of cover ranks were significant, i.e., the mean of the differences in cover rank differed from zero. However, if the more conservative, nonparametric Wilcoxon signed-rank test is used none of the mean rank differences differ significantly from zero. For both of these species, cover ranks of the later evaluation were greater than those of the earlier rating. It seems likely that both phenology and crew size contributed to the higher ranks for the 16 April reading. Very few *T. caput-medusae* were headed out by 12 April, and *C. pycnocephalus* were mostly very small rosettes at this time.

Detection efficiency would have improved both with 4 additional days of growth and the presence of more evaluators (4 vs. 2).

Table 7. Comparison between cover ranks of transect 5 (14 segments) made on 12 April and 16 April 2002 by different monitoring crews.

Species	**Mean rank**[1]	**Frequency distribution of ranks** 12 Apr 16 Apr				**Number of ranks differing by:**			**Presence/ absence differences**[2] (number of segments)
	12 Apr 16 Apr	**0**	**1**	**2**	**3**	**0**	**1**	**2**	
Natives									
Achillea millefolium	0.21 0	12 14	1 0	1 0		12	1	1	2
Deschampsia danthonioides	0.21 0.29	11 10	3 4			13	1		1
Lasthenia spp.	1.00 0.86	5 5	5 7	3 1	1 1	12	2		0
Nassella pulchra	0.50 0.36	7 9	7 5			8	6		2
Pleuropogon californicus	1.07 1.00	5 5	5 5	2 3	2 1	13	1		0
Triphysaria eriantha	0.71 0.64	5 6	8 9	1 0		11	3		1
Viola pedunculata	0.36 0.50	9 7	5 7			12	2		2
Exotics									
Carduus pycnocephalus[3]	0.86 1.14	5 4	6 4	3 6		10	4		1
Centaurea solstitialis	0.07 0.14	13 12	1 2			13	1		1
Erodium spp.	2.57 2.43	0 0	1 3	4 2	9 9	12	2		0
Lactuca serriola	1.64 2.00	0 0	7 4	5 6	2 4	8	5	1	0
Taeniatherum caput-medusae[4]	0.86 1.36	4 0	8 9	2 5		6	7	1	4

[1] Mean rank differences are all nonsignificant at P=0.05 based on Wilcoxon signed rank test
[2] Differences are all nonsignificant at P=0.05 according to McNemar's test.
[3] Matched pairs t-test P level=0.0401
[4] Matched pairs t-test P level=0.0285

A more indirect assessment of measurement error can be made by comparing the 2001 and 2002 cover ranks of the monitored perennial species, i.e., *A. millefolium, N. pulchra, V. pedunculata*, and *L. latifolium*. Except in fields that have been burned recently, we would expect that cover changes due to recruitment or mortality should be very minor for these perennials. Differences between 2001 and 2002 cover ranks for these species, excluding transect segments that have burned within the last three years, are summarized in Table 8. Paired comparisons of cover ranks were significant only for *N. pulchra*, and no significant differences were detected for the binary presence/absence outcome.

The significance of the cover rank difference for *N. pulchra* could be due to factors that tend to increase measurement error for this species. For instance, recent grazing intensity or delayed phenology in 2002 relative to 2003 could have influenced evaluator's ability to see this species in the transects and could have led differences in cover ratings. Because this species sometimes occurs in dense patches, positional error could have a disproportionate effect on cover ranks of this species relative to the other perennials. We would need to observe a trend in cover ranks over several years to be able to conclude with confidence that a real change in *N. pulchra* cover had occurred.

Table 8. Comparison between 2001 and 2002 cover ranks of perennial monitored species in segments that had not been burned since before 1999 (n=221 segments)

Species	Mean of cover ranks 2001	Mean of cover ranks 2002	Difference in cover ranks Wilcoxon test P level	Percent of segment with species 2001	Percent of segment with species 2002	McNemar's test on presence/ absence P level
Achillea millefolium	0.17	0.17	NS	11.8	12.7	NS
Nassella pulchra	0.60	0.48	<0.001	51.6	46.1	NS
Viola pedunculata	0.15	0.14	NS	14.9	13.1	NS
Lepidium latifolium	0.04	0.02	NS	3.62	2.26	NS

Although these comparisons are limited in scope, we can draw several conclusions that pertain to the analysis of differences between cover ranks in different pastures and different years.

A. Using the paired t-test, differences near the P=0.05 significance level can occasionally be expected to occur due to measurement errors alone. Using a more conservative test statistic, such as the Wilcoxon signed-rank test will tend to reduce the risk of Type 1 error (i.e., detection of a difference when no real difference exists).

B. Small differences in the frequency distribution of rank sums are likely to occur due to measurement error. Changing cover ranks to the binary presence/absence outcome does not completely eliminate the detection differences that occur as a result of measurement error, but may reduce differences due to measurement error below statistical significance.

C. The magnitude of errors related to the monitoring method may differ between species. Greater errors are to be expected for species that may be more difficult to detect, especially summer annual exotics that are not flowering at the time of monitoring. Conversely, relatively little measurement error is likely to be associated with ratings of the most obvious species (e.g., *Lasthenia* spp).

Based on these findings, we can make the following recommendations for future monitoring to minimize measurement errors.

1. Evaluators should be well-trained and calibrated prior to the start of data collection. A practice session using several transect segments may be necessary at the start of the monitoring effort to ensure that all rating teams can provide uniform ratings. At least one trained evaluator that has been involved in monitoring from previous years should be in each monitoring crew to help provide quality control.

2. Use real-time differential GPS positions, as provided through WAAS or other radio-based services to minimize position error. Ideally, the position of transect segment boundaries should

not drift by more than 3 to 4 m from year to year. Although monumenting the transect segment ends would in theory eliminate positional drift, more than 320 monuments would need to be installed and maintained to mark the entire transect system. A number of the monuments that we installed at transect ends were knocked out by sheep in less than a year, so maintaining many monuments could be difficult. The cost and potential maintenance problems render the option of monumented transect ends impractical at present.

3. The monitoring survey should be timed to maximize ability to detect target species. The date will vary from year to year and should be based on plant phenology. Ideally, *T. caput-medusae* and *N. pulchra* inflorescences should be visible and most native spring annuals should be at peak bloom. To permit accurate ratings of summer annual exotics, it is probably better to time monitoring as late as possible before spring annuals become senescent. The timing of both the 2001 and 2002 ratings was very close to optimal.

4. To help develop a better estimate of measurement errors, additional duplicate ratings of a given transect by two teams should be conducted in subsequent years. This would also serve as a quality-control check on the monitoring process. To remove spatial errors, segment endpoints could be flagged by the first crew so that the second crew could follow in the same segments more or less exactly. This would allow for a direct comparison of evaluator ratings only.

Overall comparisons between April 2001 and April 2002 monitoring results

Year to year differences in plant cover that occur generally throughout the preserve may potentially be related to weather-related effects. Because soils and recent management actions, such as burning, may interact with weather conditions, it is useful to view several layers of information concurrently when screening monitoring results for possible patterns of interest.

Figures 13 through 26 at the end of this report show how several types of data can be overlaid on spatial plots that show monitoring results over the entire preserve. We used ArcView® GIS software to create these plots, which integrate plant cover data from both years with fire history and soils data. In these figures, segments with no cover of the monitored species are shown as black triangles with a white fill for 2001 data and are not plotted for 2002 data, so segments lacking a species in both years plot as a white triangle only. For segments in which a species occurs, cover class ranks are denoted with the same colors for both 2001 and 2002.. The 2001 marker, a small triangle, is laid over the 2002 marker, a square. As a result, segments displaying as a uniformly-colored square had equal, nonzero cover ranks both years. A triangle surrounded by a darker square represents a segment with a higher cover rank in 2002 than in 2001. A colored triangle surrounded by a lighter-colored square or no square denotes a segment with a lower cover rank in 2002 than in 2001. The GIS and database files used to produce these figures have been delivered to the Solano Land Trust.

Several types of vegetation changes can be seen from these presentations. From Figure 17, it appears that the cover of *P. californicus* was greater in a number of pastures in 2002 than it was in 2001. From Figure 25, we can see that that cover of *T. caput-medusae* was virtually eliminated from some pastures for 2 years following controlled burns. It is also apparent from this figure that burning did not provide complete control of *T. caput-medusae* in the Corral, Northeast Barker, and portions of the Norris pastures.

Various other types of overall data summaries are also useful for highlighting large differences between years. Frequency distributions for the number of monitored native and exotic species per transect segment are shown in Figure 4. The mean number of native species per transect segment in 2002 (3.5) was significantly greater (matched pairs t-test $P<0.0001$) than that observed in 2001 (3.0). As shown in Table 9, four monitored natives were detected in significantly higher percentages of transect segments in 2002 than in 2001. The magnitudes of the differences can also be seen by comparing Figures 5 and 6, and the spatial patterns of the differences can be seen in Figures 14, 17, 18, and 19.

Given that most of these differences are significant for both the binary outcome (presence/absence) and the Wilcoxon test on the difference in cover ranks (Table 9), it seems likely that they reflect actual cover increases rather than measurement error alone. Furthermore, three of the species are annuals, so it is reasonable to expect that these species could show significant fluctuations in cover in two consecutive years. Rainfall patterns prior to the two spring monitoring surveys were quite different (Figure 8), with greater early rainfall totals preceding the 2002 growing season. Increases in species such as *P. californicus* may be largely due to differences in the rainfall amount and timing in these two years.

Table 9. Changes in occurrence and cover rank of monitored native species from 2001 to 2002.

Species	**Relative % change in occurrence from 2001 to 2002**[1] n varies	**Overall % change in occurrence from 2001 to 2002**[2] n=324	**McNemar's test on presence/ absence P level**	**Difference in cover ranks Wilcoxon test P level**
Achillea millefolium	+11	+1.5	NS	NS
Deschampsia danthonioides	+32	+11.1	<0.0001	NS
Lasthenia spp.	+3	+2.5	NS	NS
Nassella pulchra	-5	-3.1	NS	0.001
Pleuropogon californicus	+75	+17.9	<0.0001	<0.001
Triphysaria eriantha	+10	+7.7	0.0039	<0.001
Viola pedunculata	+43	+6.8	0.0030	<0.001

[1] (Number of segments with plant present in 2002 - number of segments with plant present in 2001)/number of segments with plant present in 2001

[2] (Number of segments with plant present in 2002 - number of segments with plant present in 2001)/total number of transect segments

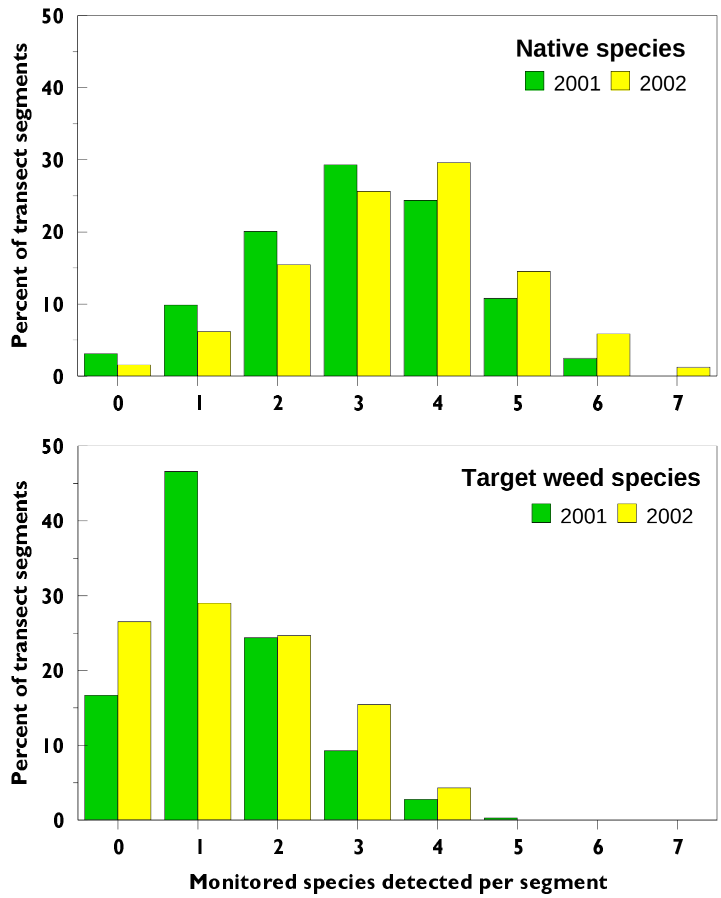

Figure 4. Percent of transect segments having various number of monitored native and target weed species in 2001 and 2002. *Erodium* spp. are not included in the counts of target weeds.

Although the distribution for the number of target weeds detected per segment shifted somewhat from 2001 to 2002 (Figure 4), the mean number of target weeds per segment did not differ in the two years. The distributions of ranks in the two years are shown in Figures 8 and 9. *T. caput-medusae* shows an obvious decrease in cover in 2002 compared to 2001 whereas *C. pycnocephalus* and *L. serriola* had increased cover ranks in 2002. Both the change in percent occurrence and the difference in cover ranks were highly significant for these three species (Table 10). In addition, *Erodium* cover ranks show a significant difference in cover rank only.

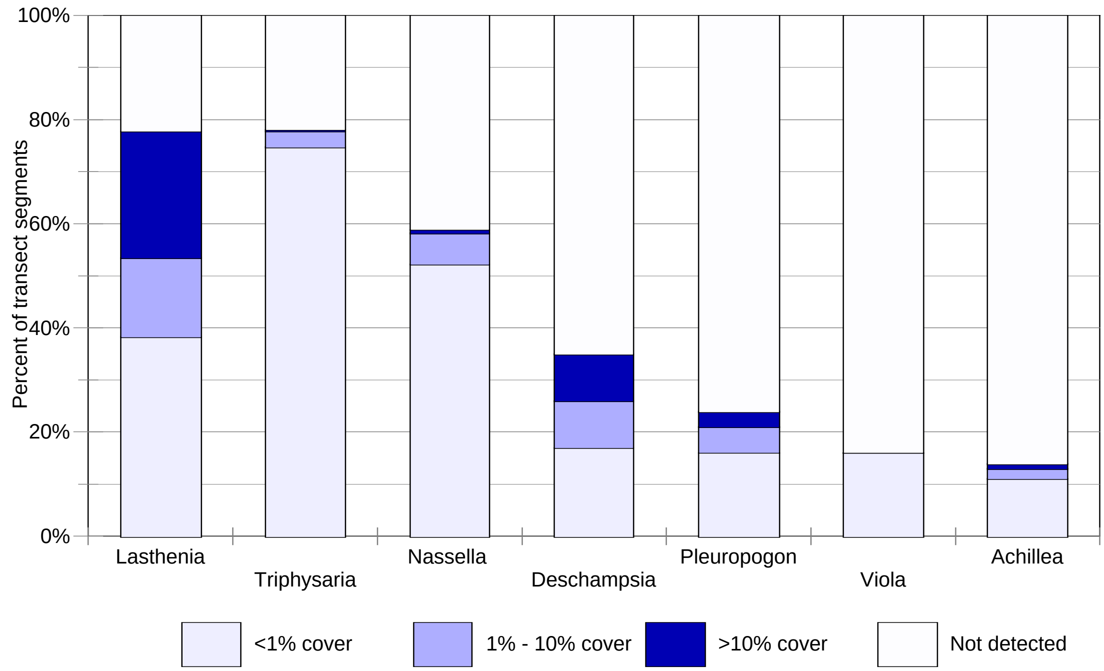

Figure 5. Percent of transect segments scored at each cover rank for monitored native plants, April 2001.

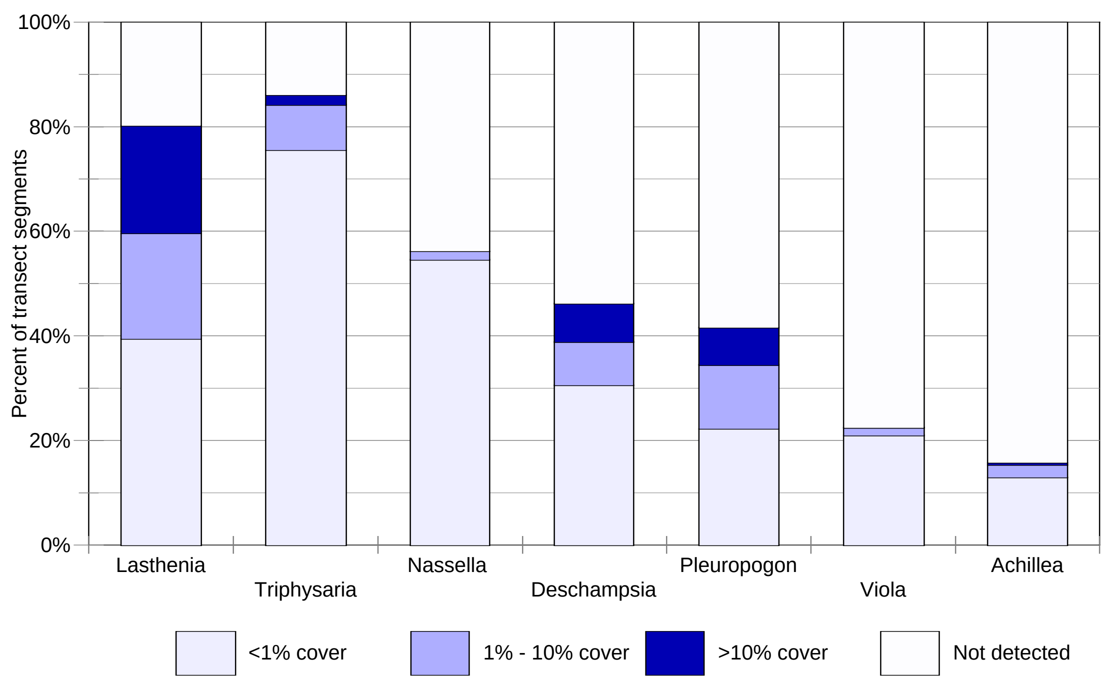

Figure 6. Percent of transect segments scored at each cover rank for monitored native plants, April 2002.

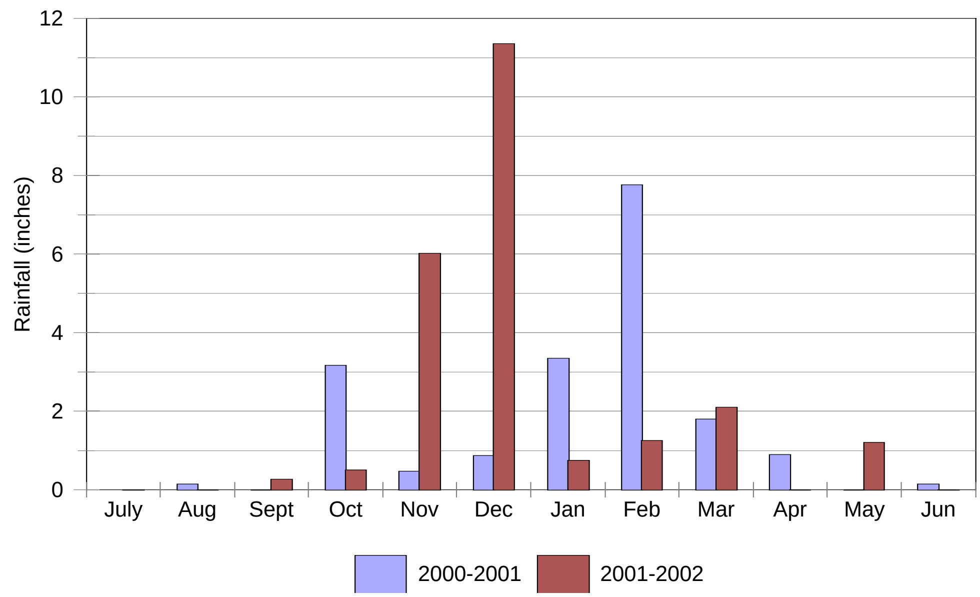

Figure 7. Vacaville rainfall by month for 2000/2001 and 2001/2002 rainfall years.

Table 10. Changes in rated occurrence and cover rank of monitored exotic species from 2001 to 2002.

Species	**Relative % change in occurrence from 2001 to 2002**[1] n varies	**Overall % change in occurrence from 2001 to 2002**[2] n=324	**McNemar's test on presence/ absence P level**	**Difference in cover ranks Wilcoxon test P level**
Carduus pycnocephalus	+72	+13	<0.0001	<0.001
Centaurea solstitialis	-3	-0.3	NS	NS
Erodium spp.	-2	-1.9	NS	<0.001
Lactuca serriola	+42	+12	0.0004	<0.001
Lepidium latifolium	+6	+0.3	NS	NS
Taeniatherum caput-medusae	-26	-19	<0.0001	<0.001

[1] (Number of segments with plant present in 2002 - number of segments with plant present in 2001)/number of segments with plant present in 2001

[2] (Number of segments with plant present in 2002 - number of segments with plant present in 2001)/total number of transect segments

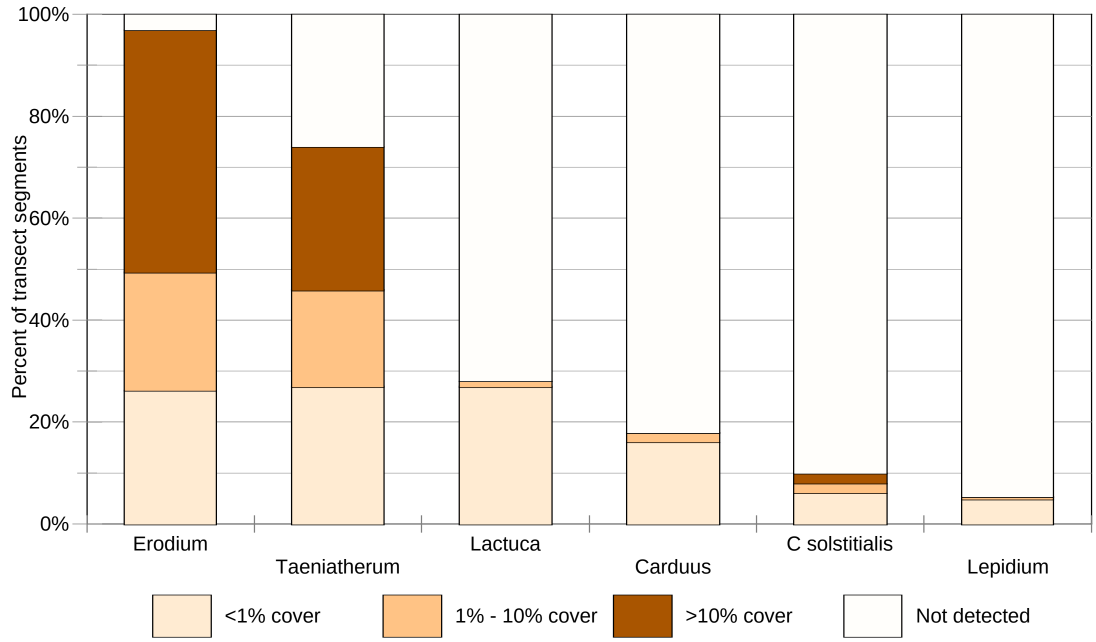

Figure 8. Percent of transect segments scored at each cover rank for monitored exotic plants, April 2001.

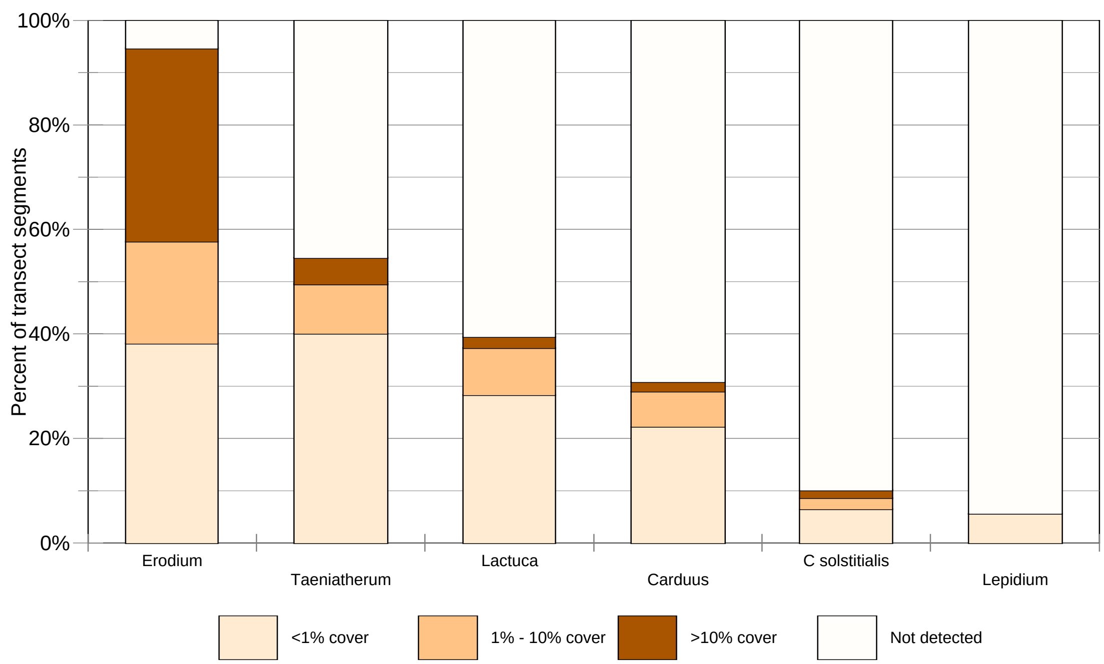

Figure 9. Percent of transect segments scored at each cover rank for monitored exotic plants, April 2002.

Overall target weed and native cover by pasture

With some exceptions, fire and grazing regimes do not vary within a pasture, but differ between pastures (Figure 10). Pastures also differ with respect to the distribution of soil types present (Figure 10). As a result, although various combinations of soil type, fire history, and grazing history are represented across the preserve, they are confounded with each other to varying degrees within pastures.

The only nongrazed fields are the Dozier and Docents units, with a combined total of 16 transect segments on a single soil type (San Ysidro sandy loam). A relatively low grazing intensity is represented in only one pasture (Eucalyptus), which includes transect segments on only two soil types. The most recent burn (2001) included some transect segments on all four soil types, but segments on San Ysidro sandy loam and Antioch-San Ysidro complex are the most common. Most segments burned in 2001 represented the highest recent (5 year) grazing intensities at the preserve. In addition to these singularities, overall grazing intensity since at least 1993 varies by soil type (Figure 11), and grazing intensity in each pasture varies considerably from year to year. Generally no grazing occurs on pastures in the year after they are burned.

The confounding of soil type, fire history, and grazing history limits the types of analyses that can be performed to investigate the effects of these factors on the vegetation outcomes measured during monitoring. While it is useful to examine differences between pastures overall from a management standpoint, it is important to remember that differences in soil type (Figure 10), topography, and surrounding vegetation (and hence possible seed influx) that exist between pastures need to be accounted for before attempting to attribute differences or changes to the management regime alone.

We ran repeated measures analysis of variance by pasture on rank sums for both natives and target weeds in 2001 and 2002. The analyses showed highly significant effects of pasture, year, and the pasture by year interaction for both native plant rank sums and target weed rank sums ($P \leq 0.0001$ for all factors except $P = 0.0162$ for effect of year for weeds). Mean rank sums for both years by pasture are shown in Figure 12. Overall, cover rank sums for natives were higher and rank sums for weeds were lower in 2002 than in 2001. Deviations from this overall trend in certain pastures account for the significant year by pasture interactions.

In both years, transects in Corral, S of Calhoun Cut, and the northernmost pastures (Dozier, NE and NW Barker, and Eucalyptus) had higher populations of target weeds and lower cover of monitored native species than transects in other pastures (Figure 12). From Figure 10, it is apparent that the transects represent a range of soil types (though San Ysidro sandy loam predominates (except Corral), past grazing intensities, and fire histories. In contrast, transects in the southwestern pastures (Buck, North of Barn, Norris) had below average weed populations and relatively high cover of monitored native species in both 2001 and 2002. All three of these pastures have been grazed at relatively high intensities over the past 5 years and soils other than San Ysidro sandy loam are predominant or at least common in the transects.

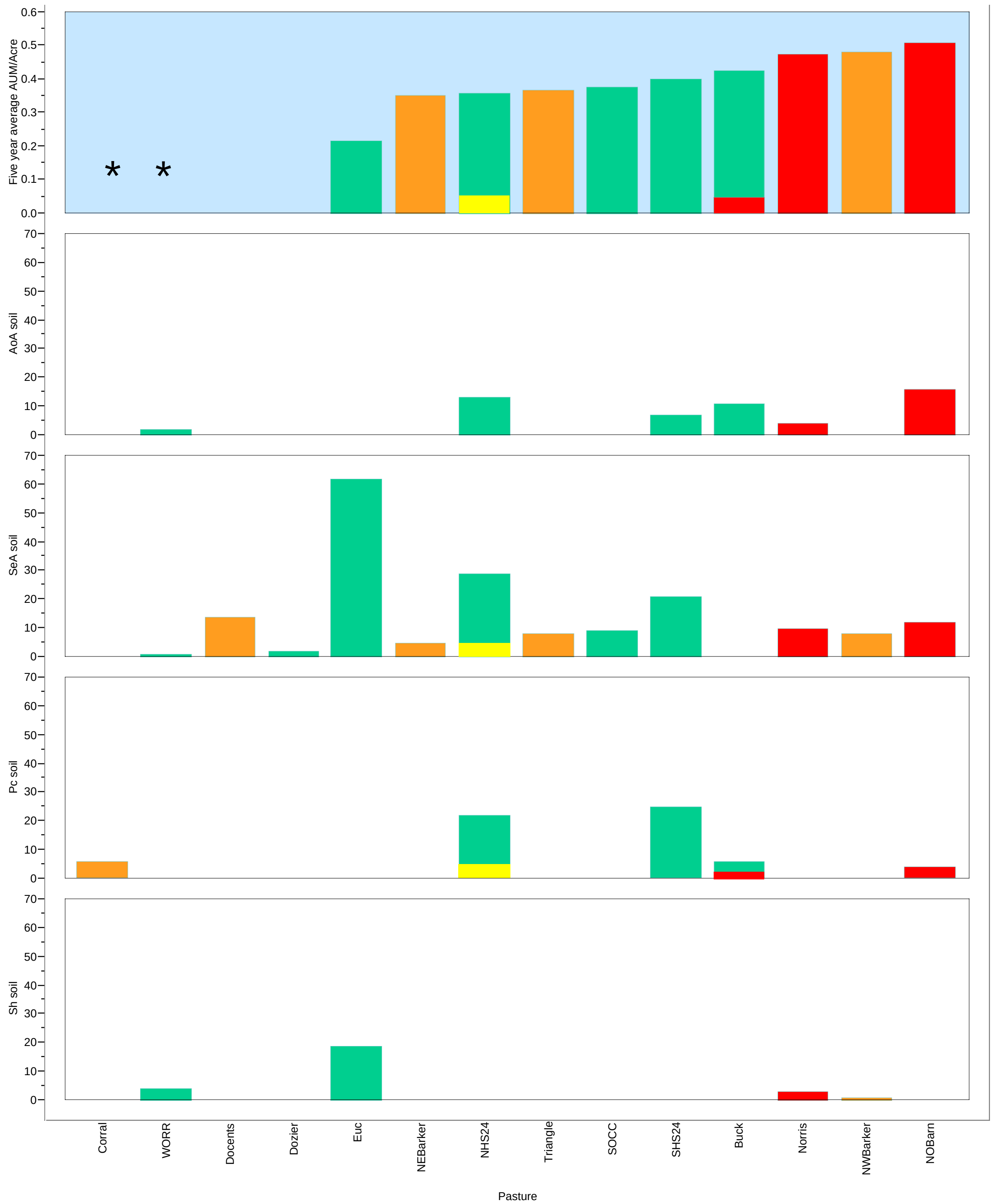

Figure 10. Recent grazing intensity July 1996-June 2001 (top graph), soil types (4 bottom graphs), and fire history (color coding) by pasture at Jepson Prairie Preserve. Corral and WORR pastures (asterisks in top graph) are grazed but AUM/acre data are unavailable. Bars for soil types represent the number of transect segments on each soil type (AoA=Antioch - San Ysidro complex, Pc=Pescadero clay loam, SeA=San Ysidro sandy loam, Sh=Solano loam). Fire history is denoted by color: red=burned in 2001; orange=burned in 2000; yellow=burned in 1999; green=not burned within the past 6 years.

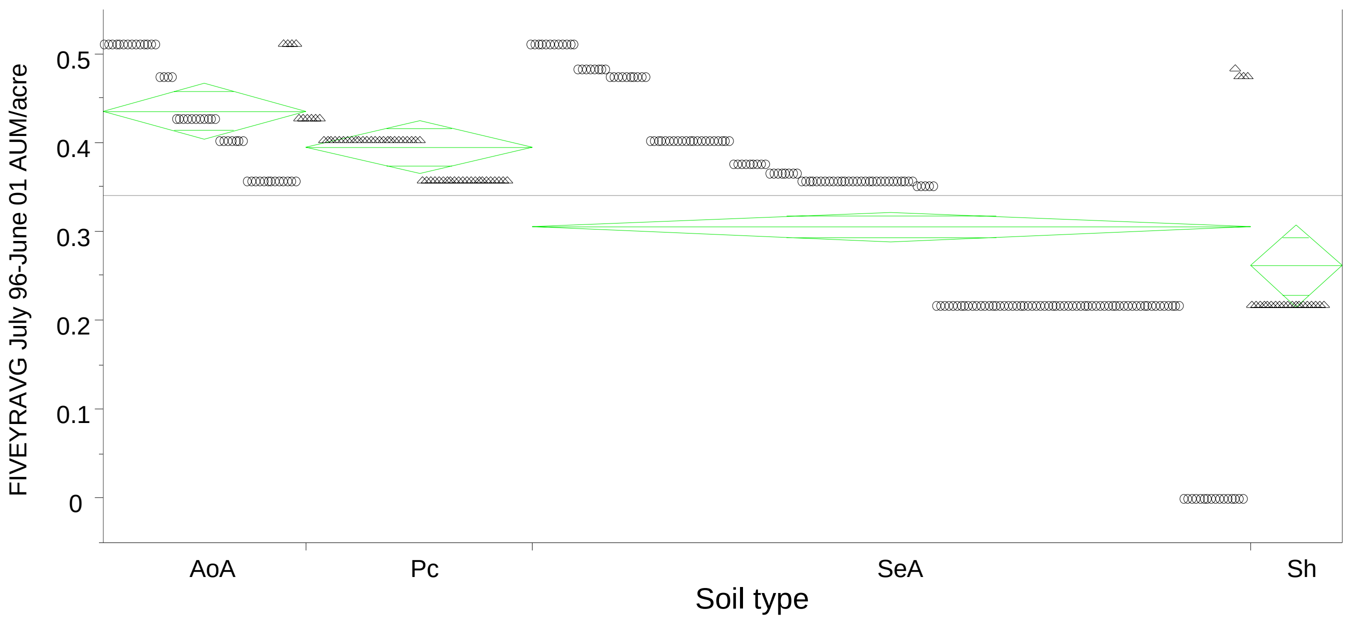

Figure 11. Average AUM/acre for each transect segment by soil type at Jepson Prairie for the period July 1996 to June 2001. Circles or triangles represent the values present for each transect segment, and alternate for clarity. The horizontal line represents the overall average. The center line of each diamond represents the mean for the soil type; the vertical extent of each diamond represents the 95% confidence interval based on a pooled variance for all segments. The horizontal spread of each diamond is proportional to the number of transect segments on each soil type. Soil types: AoA=Antioch - San Ysidro complex, Pc=Pescadero clay loam, SeA=San Ysidro sandy loam, Sh=Solano loam.

Soil type and the distribution of target exotic and native species

We previously reported that the cover of several of the monitored species showed significant associations with soil type (Swiecki and Bernhardt 2001). These included the natives *A. millefolium, Lasthenia* spp., *N. pulchra,* and *V. pedunculata,* and the exotics *C. pycnocephalus, Erodium* spp., *L. serriola,* and *T. caput-medusae.*

Two of the four soil types represented in the transects, Pescadero clay loam (Pc) and Solano loam (Sh), may be slightly to highly saline (ECe=4-8 and 2-10 dS/m, respectively; Bates 1977). Pescadero clay loam has an alkaline soil surface (pH 7.9-9.0+) whereas Solano loam's surface soil is acidic (pH 5.1-6.5). San Ysidro sandy loam (SeA) and Antioch - San Ysidro complex (AoA) are nonsaline soils with slightly acidic (pH 5.6-6.5) surface horizons. Areas mapped to Solano loam and Antioch-San Ysidro complex can contain small amounts of the other soil types (Bates 1977). In the species distribution plots at the end of this report (Figures 13-26), saline soils are gray shades and nonsaline soils are green shades.

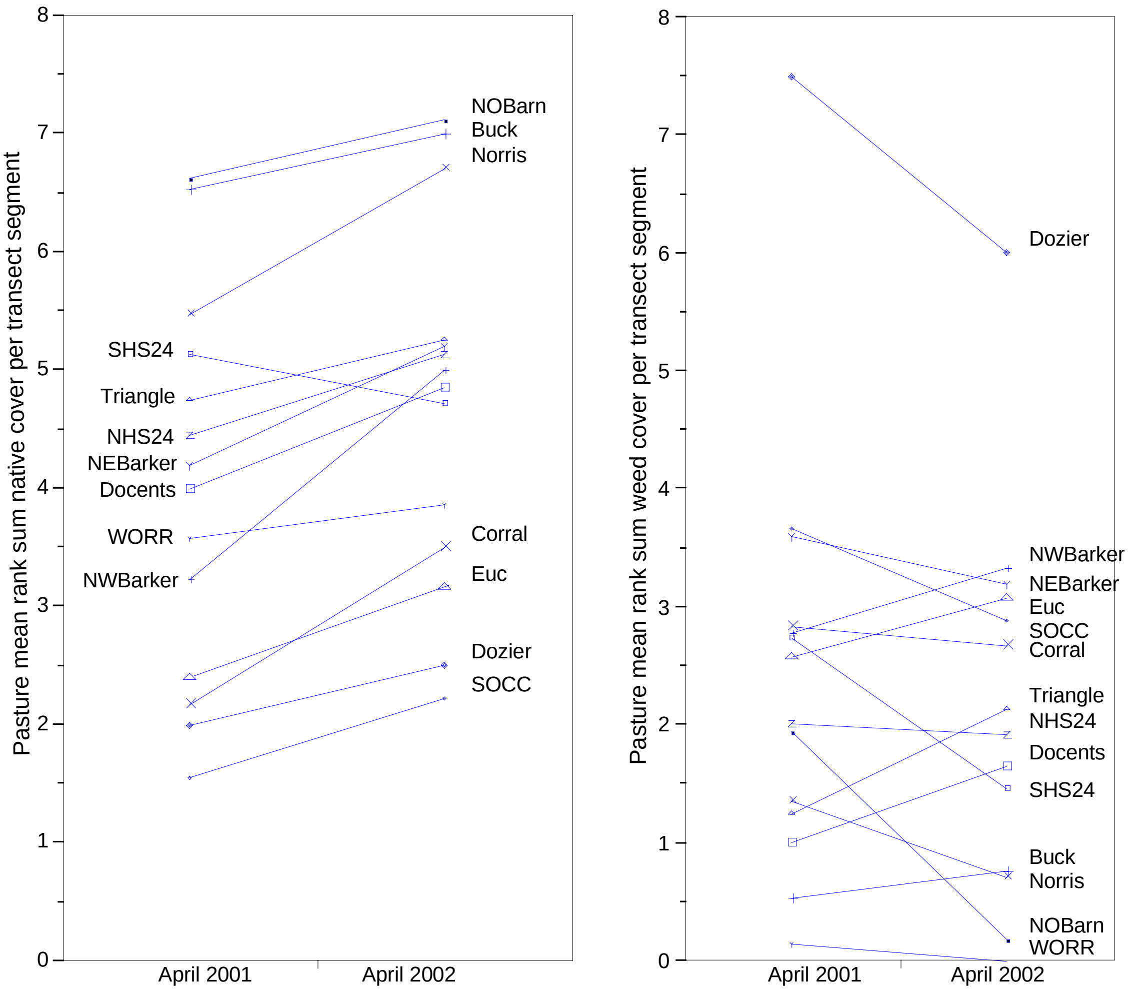

Figure 12. Average cover rank sums per transect segment for native species (left) and target weed species (right) for 2001 and 2002 by pasture. *Erodium* cover is not included with either the native or target weed cover rank sums.

We used the mapped soil types as a first approximation for the distribution of saline (Pc or Sh) and nonsaline (SeA or AoA) soils. This binary soil salinity variable and recent grazing intensity were tested in logistic regression models to predict the presence of monitored species in transect segments in 2002. We excluded from the analysis segments that had burned within the past 2 years. The significant logistic regression models are shown in Table 11. Four species were less likely to occur in segments mapped to the saline soil types. In contrast, *Lasthenia* spp. were more likely to occur in these areas. This result is consistent with our field observations that *Lasthenia* spp. were capable of growing in areas with visible efflorescence, a sign of high soil salinity.

Table 11. Model and parameter significance levels (effect likelihood ratio χ^2 test) for nominal logistic regression models for native and exotic species occurrence in transect segments which were not burned in either 2000 or 2001 and for which grazing data are available (n=222). The two segments in the Dozier field were also excluded from these analyses.

Species	Overall model likelihood ratio P>χ^2	Predictor variables Likelihood Ratio P>χ^2 (effect direction)	
		Saline soil type (Pc or Sh)	5 year average AUM/acre 1996-2001
Natives			
Achillea millefolium	<0.0001	<0.0001 (-)	<0.0001 (+)
Deschampsia danthonioides	0.0006	0.5511	0.0001 (+)
Lasthenia spp.	<0.0001	0.0232 (+)	0.0003 (+)
Nassella pulchra	0.0012	0.8829	0.0003 (+)
Viola pedunculata	0.0001	<0.0001 (-)	0.1265
Exotics			
Carduus pycnocephalus	<0.0001	<0.0001 (-)	0.0104 (-)
Lactuca serriola	<0.0001	0.0024 (-)	<0.0001 (-)
Taeniatherum caput-medusae	0.0071	0.4626	0.0017 (-)

We previously noted (Swiecki and Bernhardt 2001) that soil salinity is likely to play a major role in the distribution of plant species at Jepson Prairie. Only salt-tolerant species are able to colonize areas with highly elevated salinity levels. Salt-tolerant species may also have a competitive advantage over salt-sensitive species in areas where soil salinity is only somewhat elevated. In soils where high salinity occurs along with high levels of exchangeable sodium (saline-sodic soils), soils will tend to be deflocculated, resulting in slow drainage and longer periods of ponding in the winter and spring.

Variation in soil salinity is only crudely represented by mapped soil types. Better characterization of the variation in soil salinity within transects and across the preserve could be used to better assess the relative salt sensitivity of various native and exotic species present and would aid in the interpretation of vegetation dynamics at the preserve.

Effects of grazing on target exotic and native species

Several analyses in our previous report (Swiecki and Bernhardt 2001) showed relationships between recent grazing intensity (expressed at AUM/acre) and the cover of various monitored species. These analyses showed positive relationships between grazing intensity and the cover of the native species *D. danthonioides, Lasthenia* spp., *N. pulchra* and *T. eriantha*. In addition, higher grazing intensities were associated with reduced cover of the target weeds *C. pycnocephalus* and *C. solstitialis*. Table 11 shows similar relationships between recent past grazing intensity and the presence of several native and exotic species in non-burned pastures.

Many pastures have been grazed at similar average intensities over the past 5 years (Figure 10). Hence, any interpretation of grazing effects is necessarily restricted to the rather narrow range of grazing intensities represented at the preserve. Furthermore, grazing intensity expressed in terms of AUM/acre does not fully describe all of the impacts of grazing. A given grazing intensity could have different effects on vegetation depending on the seasonal timing of pasture use. Also, since annual plant biomass and composition may vary with rainfall amount and timing, a given grazing intensity can have different impacts in different years. While analysis of transect monitoring data can provide some information on grazing effects, well-designed and controlled studies are needed to provide a more detailed picture of how grazing patterns influence the cover of various native and exotic species at the preserve.

Effects of fire on target exotic and native species

Analyses in Swiecki and Bernhardt (2001) indicated that overall cover rank sums for both monitored natives and target weeds were significantly associated with controlled burns in 1999 and 2000. For transect segments on San Ysidro sandy loam soil (SeA), cover class ranks of several native and exotic species were positively associated with burning, and cover of *T. caput-medusae* was negatively associated with burning (Swiecki and Bernhardt 2001).

The impact of fire on *T. caput-medusae* cover is readily apparent from Figure 24. *T. caput-medusae* was reduced to undetectable levels in the year following fire in the North of Barn, Docents, Triangle, and Northwest Barker pastures. In the latter three pastures, *T. caput-medusae* has remained undetected in transects into the second spring after burning. However, some *T. caput-medusae* was present in the southern portion of Norris and in the Northeast Barker and Corral pastures in the first spring after burning. In the latter two pastures, *T. caput-medusae* was present in all transect segments both one and two years after burning. By compiling fire data for effective and ineffective burns (e.g., date/plant phenology, fire characteristics, completeness of combustion), transect monitoring data could provide a way to pinpoint factors that are most important for efficacy of controlled burns.

T. caput-medusae was the only monitored species that was clearly eliminated by fire. Because changes in cover of other species were not so strongly affected, statistical analyses are necessary to determine whether changes observed for other monitored species are significant. Because we have matched prefire and first-season postfire data for transects that were burned in June 2001, we can directly assess how fire influenced populations of monitored species in these burned pastures.

To compare the differences in cover ranks between 2001 and 2002 for burned and nonburned transect segments, we adapted an approach suggested by Levin and Serlin (2000). The analysis uses Fisher's exact test to compare the cells that show change in a 2 x 2 contingency table of paired ratings in each year. This 2 x 2 contingency table is composed of the two discordant pairs cells from two other 2 x 2 tables, one for burned and one for nonburned segments. The discordant pairs data (i.e., transect segments that had different cover ranks in the two years) and overall test for differences are presented in Table 12. We also used McNemar's test to for overall changes between the two years within the burned and nonburned segments. The nonburned control population was selected from the 273 segments that were not burned in 2001 using cluster analysis. We used hierarchical clustering on grazing (5 year average and 2000-2001 AUM/acre), soil type, and fire history (2000 and 1999 burns only) to identify clusters. The segments burned in 2001 were distributed in five of these clusters, and the remaining non-burned segments in these five clusters were used as the comparison population.

C. solstitialis, *C. calictrapa*, and *L. latifolium* did not occur in transects in the pastures that were burned in 2001. No significant changes in the cover of *A. millefolium* and *Lasthenia* spp. were detected for either burned or nonburned segments. The species listed in Table 12 showed significant changes in cover ranks between 2001 and 2002 in burned and/or nonburned segments according to McNemar's test. Four species (*T. eriantha, V. pedunculata*, *Erodium* spp, and *C.*

pycnocephalus) showed a differential change in burned compared to nonburned segments indicative of a fire effect (Table 12). Cover ranks of *T. eriantha* and *V. pedunculata* increased overall from 2001 to 2002 in burned segments, but did not increase in nonburned segments (Table 12). For *Erodium* spp., nonburned segments decreased in cover ranks in 2002 compared to 2001, but cover ranks in burned segments did not decrease. Hence, fire had a positive effect on *Erodium* cover. *Carduus pycnocephalus* cover ranks increased from 2001 to 2002 in nonburned segments, but were unchanged in burned segments (Table 12). Thus, the overall effect of fire was to prevent an increase in the cover of *C. pycnocephalus.*

Fire effects on monitored species are likely to vary not only with the timing and characteristics of the burn, but also with the distribution and density of plant biomass, the status of the seedbank, and other factors. Hence, the fire effects that we detected though statistical analyses (Table 12) should be considered tentative unless they can be shown to be repeatable in different years.

Table 12. Burned (in May 2001) and matched nonburned transect segments showing changes in cover ranks between April 2002 and April 2001 monitoring surveys.

	Burned in 2001 (n=51)		Matched segments not burned in 2001 (n=155)		Burned vs nonburned
	Transect segments with cover rank changes: higher rank in 2001 higher rank in 2002	Significance of change McNemar's test P	Transect segments with cover rank changes: higher rank in 2001 higher rank in 2002	Significance of change McNemar's test P	Significance of difference in changed segments Fisher's exact test P
Natives					
Deschampsia danthonioides	18 17	NS	13 28	0.0288	NS
Nassella pulchra	9 2	NS	35 10	0.0003	NS
Pleuropogon californicus	2 19	0.0005	4 50	<0.0001	NS
Triphysaria eriantha	0 11	0.0026	18 28	NS	0.0115
Viola pedunculata	0 10	0.0044	13 7	NS	0.0011
Exotics					
Carduus pycnocephalus	3 3	NS	1 26	<0.0001	0.0136
Erodium spp.	6 10	NS	63 16	<0.0001	0.0013
Lactuca serriola	5 5	NS	19 46	0.0013	NS

Long-term trends and status of target weed species

In addition to the transect monitoring data from 2001 and 2002, two other sources provide information on short and long-terms trends in weed populations at the preserve. In both 2001 and 2002, we used the weed polygon monitoring protocol described in the methods to map and characterize spot populations of various rarely-occurring target weeds. The points and polygons mapped in the two years are shown in Figure 26 along with transect-based cover data for *Centaurea calcitrapa, Cirsium vulgare, Silybum marianum,* and *Foeniculum vulgare*. Transect and polygon data for *L. latifolium* are shown in Figure 24.

Transect monitoring alone is insufficient to document the distribution and spread of rarely-occurring weeds. Polygon data collected to date show that many of the uncommon weed species are present in pastures where they were not detected through transect monitoring. However, weed polygon data are not complete and are largely based on chance observations made in association with monitoring activities over the past two years. Some target weeds of interest, notably *Aegilops cylindrica,* have neither been mapped as polygons or detected in transects to date but are known to occur at Jepson Prairie. A more systematic application of the polygon monitoring protocol would be helpful for assessing both the current distribution and future spread of the uncommon weed species.

In addition to the data we have accumulated through this project, some historical data on the distribution of various exotics is available from a survey conducted in October 1995 (The Nature Conservancy 1996). The 1995 survey followed a monitoring approach analogous to that described in this report, although the 1995 survey was less quantitative and involved a much smaller sampling rate. The 1995 survey included only qualitative weed cover ratings made on one 20 ft radius circle (about 0.03 acre) per 10 acres. Based on the distribution maps included in the 1996 report, that survey omitted the pastures north of Barker Slough, south of Calhoun Cut, and the south half of Section 24. Nonetheless, data from the 1995 survey constitute the oldest baseline data available for assessing the spread of target weeds at the preserve.

We have summarized information about the status and apparent spread of the main target weeds below.

Italian thistle - *Carduus pycnocephalus*

C. pycnocephalus is the third most common target weed (Figures 8 and 9) and showed the highest relative increase in transect segments from 2001 to 2002 of the major monitored weeds (Table 10). Almost all segments that had *C. pycnocephalus* in 2001 also had this species in 2002, but the weed was also detected in many new segments in 2002 (Figure 20). Both cover ranks and the overall proportion of segments with this species were significantly greater in 2002 compared to 2001 (Table 10). In part, the general increase in *C. pycnocephalus* in 2002 may be associated with rainfall (Figure 7). Early fall rains favor establishment of *C. pycnocephalus* (J. DiTomaso, Weed Ecologist, UC Davis, personal communication).

In comparing the 1995 distribution map for *C. pycnocephalus* (The Nature Conservancy, 1996) with Figure 20, it seems very likely that this species has increased in total cover and distribution since the 1995 survey even if the differences in survey methodology are taken into account. In particular, the 1995 map shows no occurrences of *C. pycnocephalus* in the Triangle, northern Eucalyptus, Norris, or North of Barn pastures, all of which had sizeable populations of this weed in 2002.

As discussed above, burning in 2001 appears to have prevented an increase in *C. pycnocephalus* populations (Table 12), although there was no correlation between burning and cover ranks reported in 2001 (Swiecki and Bernhardt 2001). The distribution of *C. pycnocephalus* may also be limited by soil salinity (Table 11). Especially in the South half of Section 24 pasture, *C.*

pycnocephalus is absent from the saline Pescadero clay loam but occurs on adjacent nonsaline San Ysidro sandy loam and Antioch - San Ysidro complex soils (Figure 20).

Options for managing *C. pycnocephalus* populations are limited. Herbicides are not a viable option due to the widespread and dispersed nature of *C. pycnocephalus* populations. Grazing (Swiecki and Bernhardt 2001) and burning (Table 11) may have the potential to reduce populations somewhat, but more controlled studies are needed to determine how to optimize suppression of *C. pycnocephalus* with these tools. A weevil, *Rhinocyllus conicus*, is widely established in California and provides some biological control of *C. pycnocephalus*. The weevil is most destructive in the larval stage and attacks the seed head. It may also attack stems and adults may partially defoliate plants. A photo of the weevil, which has a short snout and is about 5 to 6 mm long, is available at http://mtwow.org/musk-thistle-information.htm. Monitoring for the weevil and timing activities, where possible, to minimize impacts to the weevil may be useful for conserving this biocontrol agent.

Purple star-thistle - *Centaurea calcitrapa*

C. calcitrapa was not detected in transects in 2001, although an isolated plant was mapped just beyond a transect segment in 2001 near the visitor parking area. An infestation of this species that was known to exist in the Corral pasture was partially mapped in 2002, and *C. calcitrapa* was also detected in a nearby transect segment (Figure 26). This infestation may be related to the one noted on the southeast side of the Corral pasture in the 1995 survey (The Nature Conservancy, 1996). It appears that some localized spread of this species has occurred since 1995. The 2000 burn of the Corral pasture failed to eliminate the *C. calcitrapa* infestation.

More complete mapping of this infestation using the polygon protocol and targeted eradication are recommended to prevent further spread of this species. For small infestations, hand removal may be an option. Spot application of a selective (e.g., clopyralid [Transline®]) or nonselective (e.g., glyphosate [Roundup®]) herbicide to plants in the rosette stage is likely to be the most viable management option for larger areas. Using a wick applicator or backpack sprayer with a narrow spray pattern will minimize the total amount of herbicide needed and damage to nontarget species.

Yellow star-thistle - *Centaurea solstitialis*

C. solstitialis populations apparently did not change substantially in the past year (Table 10, Figure 21). The highest concentration of *C. solstitialis* is in the areas adjacent to Cook Lane north of Olcott Lake and in the three northernmost fields along Hwy 113 (NW and NE Barker, Dozier). A few scattered populations of *C. solstitialis* are present in fields south of Olcott Lake. Although the 1995 report did not monitor the NW and NE Barker pastures, the current distribution of *C. solstitialis* populations in the remainder of the preserve appears similar to that reported in 1995 (The Nature Conservancy, 1996).

The management of *C. solstitialis* is a topic of ongoing research. At the preserve, an integrated control strategy is clearly necessary. At minimum, grazing and burning will be involved in this strategy, but mowing, hand removal, herbicide use, and conservation of biological control agents should also be considered in at least some situations. To be effective, management actions need to be rather precisely timed and integrated into a multi-year program. The UC Davis Weed Research and Information Center website provides extensive resources related to *C. solstitialis* management (http://wric.ucdavis.edu/yst/index.html). Research by Joe DiTomaso on the use of fire to control *C. solstitialis* has yielded inconsistent results, but in some instances burning stimulates *C. solstitialis* by removing competition.

Monitoring data from 2001 (Swiecki and Bernhardt 2001) indicates that *C. solstitialis* cover on San Ysidro sandy loam soil decreased with increasing grazing intensity, although this relationship is somewhat confounded with the spatial distribution of *C. solstitialis* on the preserve. *C. solstitialis* was detected in the year after burning in three of the four fields burned in 2000 and in all four of these fields two years after burning (Figure 21). While *C. solstitialis* was clearly not eradicated by these burns, the actual impact of these fires on *C. solstitialis* populations cannot be assessed due to a lack of prefire data. Because *C. solstitialis* was not present in transects of the pastures that were burned in 2001, the monitoring data collected to date do not allow us to directly assess the of effects of fire on *C. solstitialis* cover at the preserve.

Bull thistle - *Cirsium vulgare*

C. vulgare was detected in one segment in 2001 and in two different segments in 2002 (Figure 26). Several scattered occurrences of *C. vulgare* have also been mapped. The current density and distribution of *C. vulgare* across the preserve does not appear to be substantially greater than that reported in the 1995 survey (The Nature Conservancy, 1996). Because the 1995 transect and the current transects are not directly superimposed, we cannot tell whether small *C. vulgare* populations have persisted in the areas where they were found in 1995. Followup monitoring of transects and polygons will provide information on the longevity of localized populations of this species.

Although this species has not shown a strong propensity to spread, spot treatment of bull thistle would be prudent in disturbed areas where this biennial tends to re-establish and persist. Hand removal before flowering is probably the simplest method of control. If plants are flowering, seedheads should be removed, bagged, and disposed of off-site when tops are cut. The upper 5 cm (2 inches) of taproot should be removed when plants are dug. Spot herbicide application can be used in lieu of hand removal if plants are treated before bolting.

Fennel - *Foeniculum vulgare*

F. vulgare was detected in the same single segment in the NW Barker pasture in both 2001 and 2002 (Figure 26). A number of *F. vulgare* plants have also been mapped in the northwest portion of the triangle pasture, the same area where some plants were noted in the 1995 survey. It appears that *F. vulgare* has spread somewhat since 1995 from this one area, although spread appears to be less rapid than anticipated by The Nature Conservancy's (1996) report.

The persistence of the *F. vulgare* population in the northern area despite grazing and burning indicates that these management activities have limited effects against this perennial. Eradication requires mechanical removal, including removal of the entire root crown area and 5 - 10 cm (2 - 4 inches) of taproot and/or spot application of herbicides (e.g., glyphosate [Roundup®]). Herbicide application may be more effective on large plants if tops are first cut and then allowed to resprout slightly. Control actions should be taken before seed is produced.

Prickly lettuce - *Lactuca serriola*

The number of transect segments with *L. serriola* increased greatly in 2002 compared to 2001 (Table 10, Figure 23). As discussed in our previous report (Swiecki and Bernhardt 2001), April is not the optimal time for assessing *L. serriola* populations because the rosettes are difficult to see from a distance. Because larger survey crews were used in 2002 compared to 2001, part of the increase in *L. serriola* populations could be due to increased efficiency of detection by the larger crews. The rainfall pattern in the 2001-2002 season (Figure 7) could also have been more favorable for the establishment of *L. serriola* than the previous season's rainfall. The distribution of *L. serriola* was not described in the 1995 report.

As shown in Table 11, *L. serriola* is likely to be limited by soil salinity and appears to be suppressed by grazing. The 2001 burn did not have a significant effect on *L. serriola* (Table 12), but because this species was uncommon in the burned fields, fire effects would be difficult to detect. At this time, it is unlikely that specific management actions will be taken against *L. serriola*, but grazing and burning treatments directed against other species may provide some control of *L. serriola*.

Perennial pepperweed - *Lepidium latifolium*

L. latifolium appears to have spread the most of all the target weeds documented in the 1995 survey. In 1995, only four small *L. latifolium* infestations were reported, although as noted above, the fields north of Barker Slough were not surveyed. Currently, extensive, dense patches of *L. latifolium* occur along Barker Slough and many smaller *L. latifolium* patches are found throughout NW Barker pasture. Populations of *L. latifolium* are also found throughout the Triangle pasture and isolated spot infestations are found in the Eucalyptus pasture, the small corrals north of the barn, and near Calhoun Cut (Figure 24). As expected, cover ranks of this perennial species did not differ significantly between the 2001 and 2002 surveys (Table 10).

L. latifolium is a rhizomatous perennial and is very difficult to control. It has a high potential for invading the flat and swale topographic positions throughout the preserve, and under favorable conditions can become the dominant cover through vegetative spread (a study showing rapid spread over six years is summarized at http://wric.ucdavis.edu/exotic/techtran/rate_of_spread.htm). Reproduction via seed is probably more important for the establishment of new infestations than the spread of existing populations.

Grazing may help reduce flowering and seed production of *L. latifolium* (Laws 1999), but grazing has clearly not prevented the spread of *L. latifolium* at the preserve. Monitoring data is consistent with Laws' (1999) finding that fire is ineffective at reducing established *L. latifolium* populations, and burning may actually favor spread if it suppresses competing vegetation. Although research is ongoing, control of *L. latifolium* is largely based on the use of herbicides. Imazapyr (Arsenal®) and sulfonylurea herbicides, including chlorsulfuron (Telar®) and metsulfuron (Escort®) are highly effective against *L. latifolium*, but use of these compounds is limited to areas away from water, in part due to their high toxicity to a wide variety of nontarget plants. Glyphosate and/or 2, 4-D have been used for control adjacent to water, but these compounds are less effective. Mowing or grazing tops to deplete carbohydrate reserves prior to herbicide application can improve herbicide efficacy. Current UC recommendations for *L. latifolium* management should be reviewed before undertaking management actions for this species.

Milk thistle - *Silybum marianum*

S. marianum (milk thistle) was not detected in any transects in 2001, but was detected in 2002 in an area where the Eucalyptus trees were removed during the summer of 2001 (Figure 26). Other isolated milk thistle plants have also been noted in several other areas around the preserve, particularly in disturbed areas and along fence lines. Milk thistle was not noted in the 1995 survey (The Nature Conservancy, 1996).

S. marianum generally prefers fertile soils and germinates best in disturbed, generally bare soils. Hence, areas where sheep congregate or linger, such as around eucalyptus stumps, are most susceptible to colonization by this species.

Medusahead grass - *Taeniatherum caput-medusae*

Unlike the other target weeds discussed above, *T. caput-medusae* is widespread throughout the preserve. The 1995 survey showed this species to be common or dominant throughout most of the preserve. Due to the suppression of *T. caput-medusae* in pastures that were burned in the past two years (Figure 25), current cover of *T. caput-medusae* is probably lower than levels present in 1995.

A regular burning program at the preserve is likely to keep populations of *T. caput-medusae* in check. Continued observations on recently burned pastures will help provide additional information on the length of time that *T. caput-medusae* is suppressed by an effective burn. As noted above, not all recent burns have been effective. By analyzing burn parameters and identifying control successes and failures through monitoring it should be possible to more clearly identify factors that are necessary for efficacy. In addition, pastures receiving ineffective burns should be scheduled for reburning sooner than pastures where good control was attained.

In fields that have not been burned recently, higher grazing intensity is associated with lower cover of *T. caput-medusae* (Table 11). Due to the confounding of these factors, information on the interaction of fire and grazing will be difficult to extract from monitoring data. Long-term controlled studies will be necessary to explore these interactions at the preserve.

Other species

As noted above, *A. cylindrica* (goat grass) has not been detected in transects. To date, no populations of this species have been mapped using the polygon protocol. *A. cylindrica* is not distinctive enough to recognize without the presence of inflorescences. Because *A. cylindrica* generally heads out too late to be recognized in spring surveys and seed may shatter by midsummer, efforts to map its distribution should be timed for late spring or early summer. This species was not mentioned in the 1995 survey, but it would have been difficult to recognize in October.

Xanthium strumarium (cocklebur) has only been observed to date in two locations in section 24 (Swiecki and Bernhardt 2001). It was not recorded in the 2002 survey.

Picris echioides (bristly ox-tongue) has been noted in several locations throughout the preserve, mostly near pasture edges (Figure 26). Although this species is not currently on the target weed list, it has the potential to spread more extensively in the preserve, based on observations from other similar areas. The presence of this species should be noted in future surveys in order to determine whether this species is increasing to the point that management should be considered.

CONCLUSIONS AND RECOMMENDATIONS

The combination of regular transect-based monitoring and point/polygon mapping for uncommon target weeds provides a means for monitoring certain native and invasive exotic plant species in the Jepson Prairie Preserve grasslands. We have demonstrated that the personnel, equipment, and time requirements to execute the transect-based monitoring are quite modest. If care is taken to ensure that all evaluators are adequately trained prior to monitoring and the survey is timed for optimal detection of monitored species, the measurement error associated with transect-based monitoring is acceptably low.

Ongoing monitoring is the key to an adaptive resource management program. Because the Jepson Prairie plant community is dominated by annuals, relatively large changes in the vegetation can occur from year to year. The monitoring data collected to date has clearly shown that burning provided nearly complete suppression of *T. caput-medusae* in some pastures, but that some burns were ineffective. Continued monitoring should show how long is required for *T. caput-medusae* populations to return to problematic levels. Increases in species such as the native *P. californicus* and the exotic *C. pycnocephalus* appear to be related to rainfall differences for the two years in which monitoring has occurred so far. Continued monitoring on an annual basis will be needed to develop a database that can be used to study the interaction between weather parameters and vegetation.

By comparing the current monitoring data with older baseline data, it appear that *C. pycnocephalus* and *L. latifolium* have spread substantially at the preserve since 1995. Consistent application of the current monitoring protocols will provide a clearer picture of the spread of these and other invasive exotics. Monitoring will also provide a means for objectively determining the success of management activities directed against exotic species. The inclusion of native plants in the monitoring protocol provides a way to assess the impact of these management activities on native species.

The monitoring system will work best if data is collected annually. GIS-based presentations of the data can be used to scan each year's data for obvious trends and new detections of uncommon exotics. More complete retrospective analyses of the monitoring data need not be conducted annually, but could be conducted every 4 to 5 years.

The value of the monitoring system will be increased if additional information that is collected at the preserve utilizes or includes the established transect system. For instance, a more detailed soil survey, including better characterization of soil salinity levels along the transects would provide a better basis for accounting for edaphic factors than the existing soil type polygons. If surveys for native species other than those included in the transect protocol were conducted using the same transect segments, relationships between a wider variety of native and exotic species could be explored and related to management activities.

In contrast, small manipulative studies, especially those involving manipulations of vegetation by grazing, burning, or other means, should generally not be conducted within the transect segments. Alternative management regimes that affect at most one or a few transect segments generally cannot be dealt with in statistical models and would result in the exclusion of data from the affected transect segments. However, when localized events occur in transect segments, such as herbicide treatments or spot fires, location data should be gathered using GPS receivers so that these factors can be taken into account prior to data analysis.

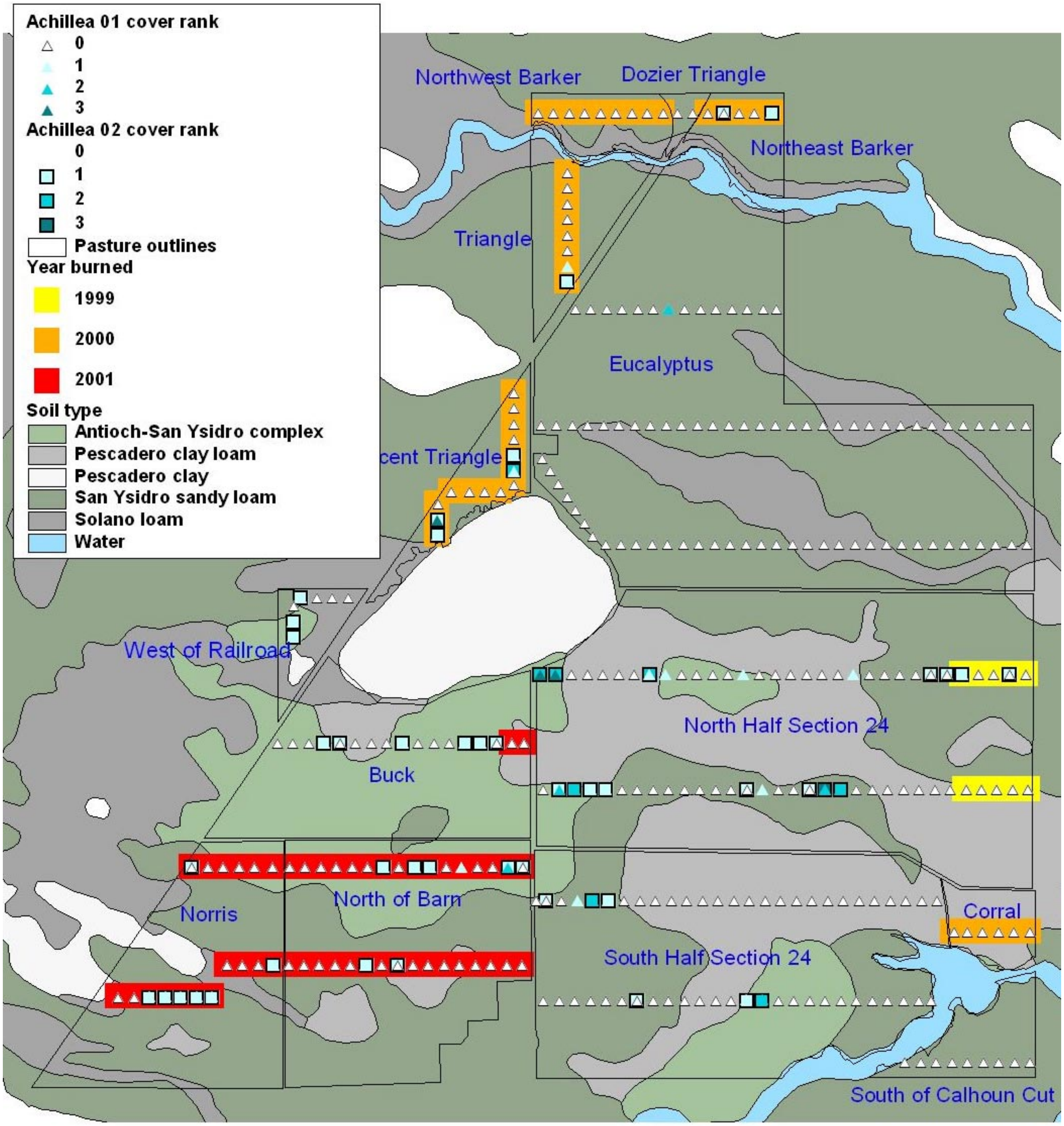

Figure 13. *Achillea millefolium* cover ranks in transect segments, April 2001 and 2002 Markers for transect segments are centered over the midpoint of the segment and are not to scale.

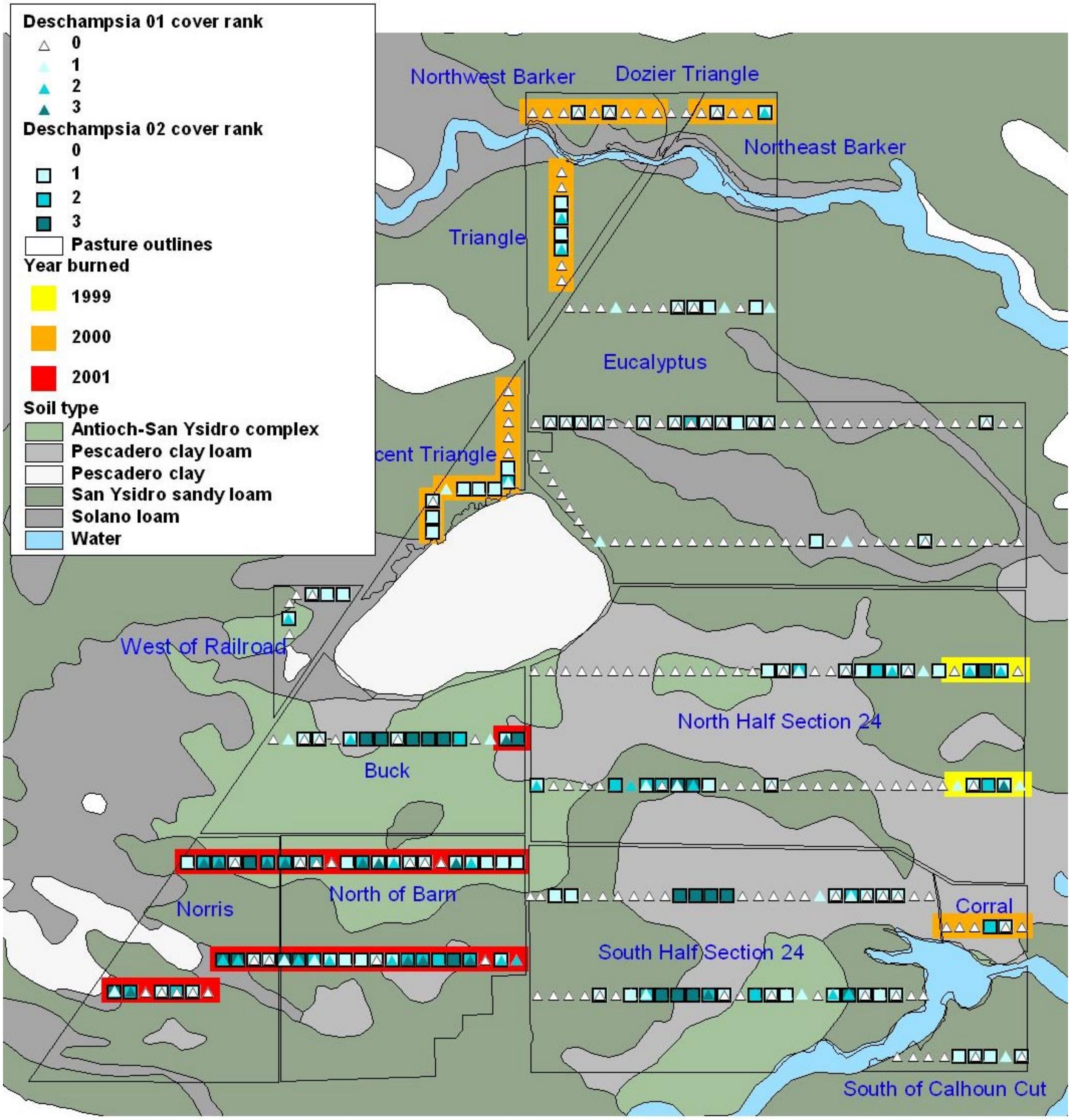

Figure 14. *Deschampsia danthonioides* cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

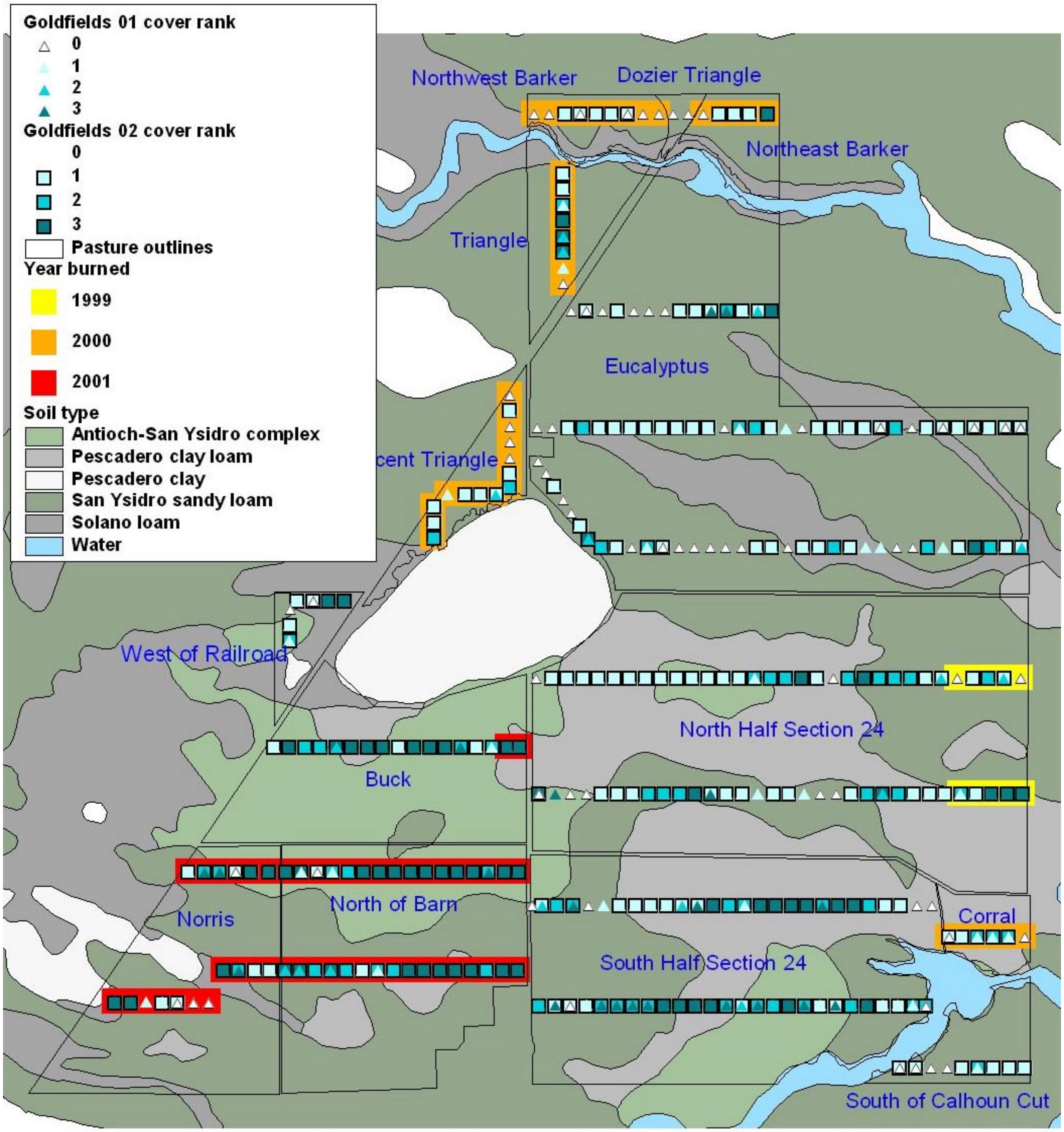

Figure 15. *Lasthenia* spp. (species with conspicuous ray flowers, including *L. californica* and *L. fremontii*) cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

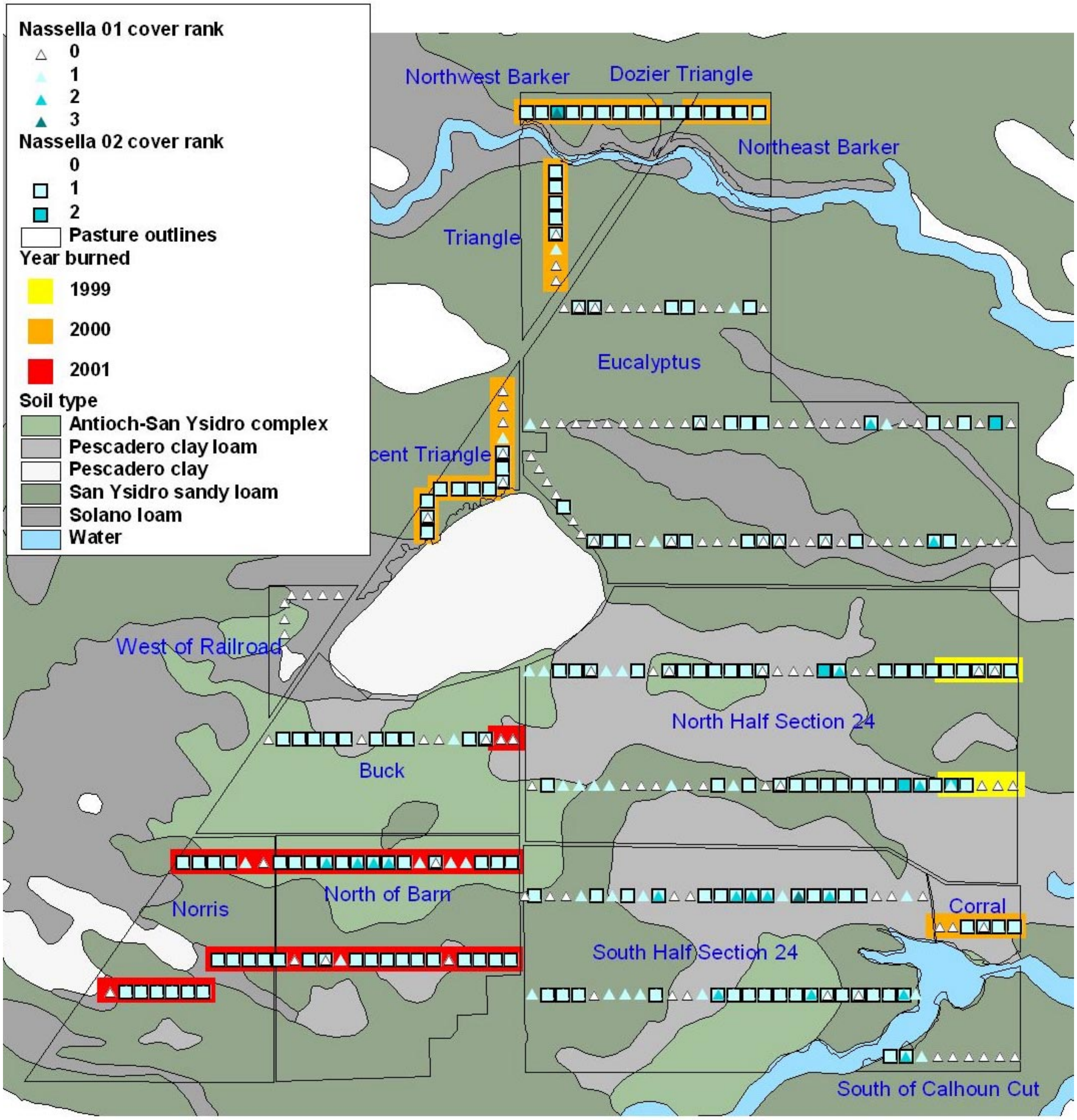

Figure 16. *Nassella pulchra* cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

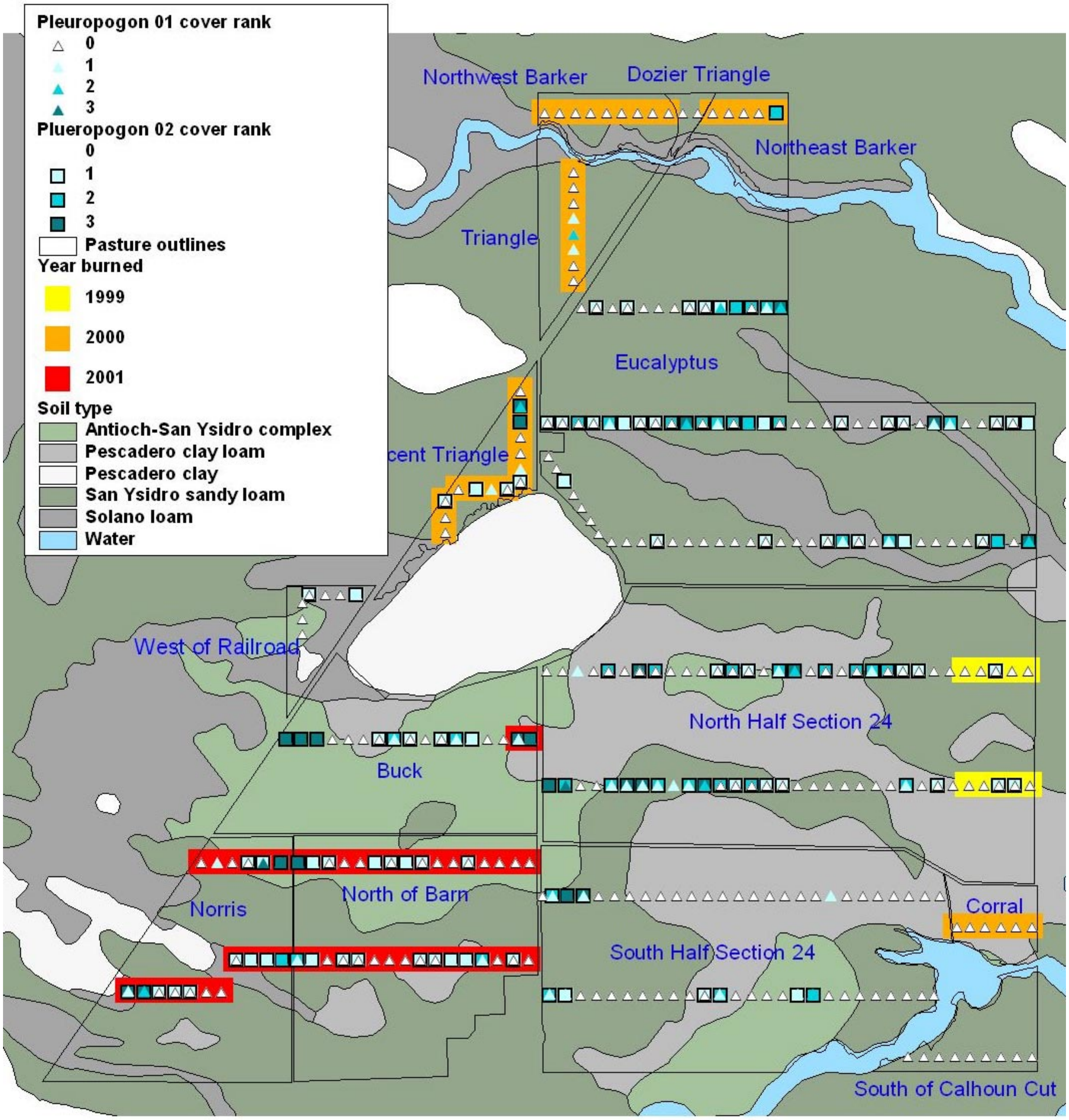

Figure 17. *Pleuropogon californicus* cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

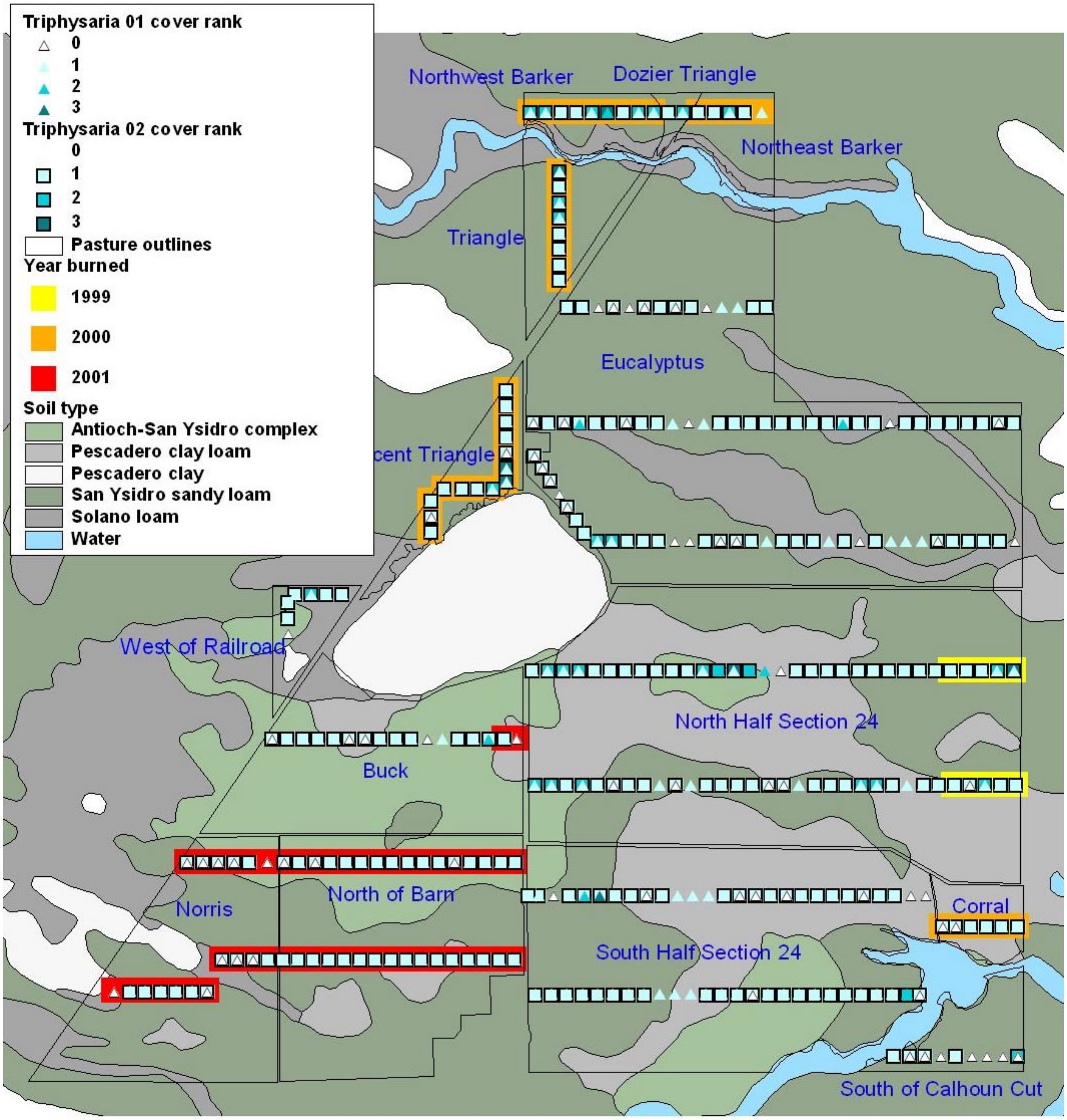

Figure 18. *Triphysaria eriantha* spp. *eriantha* cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

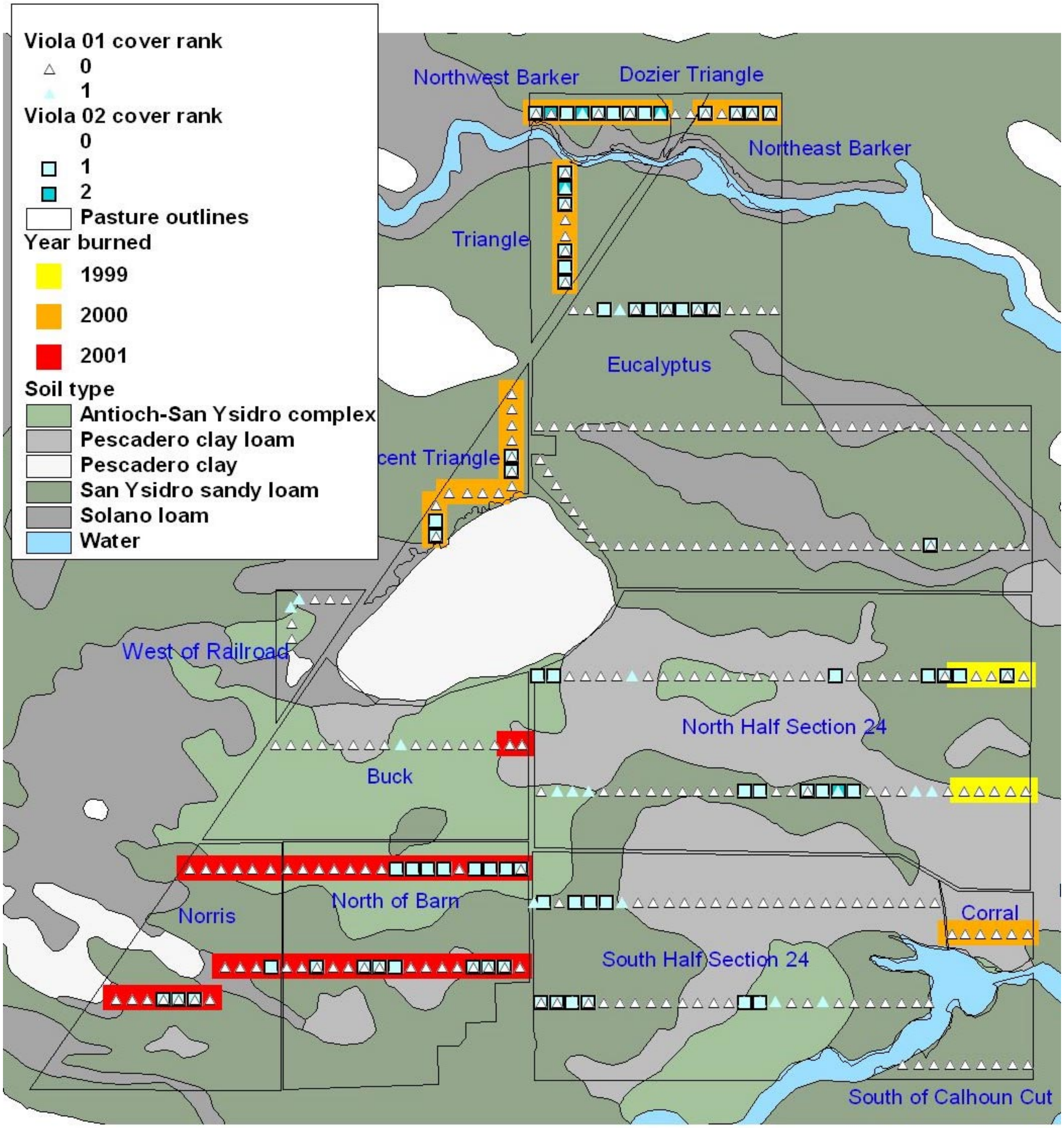

Figure 19. *Viola pedunculata* cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

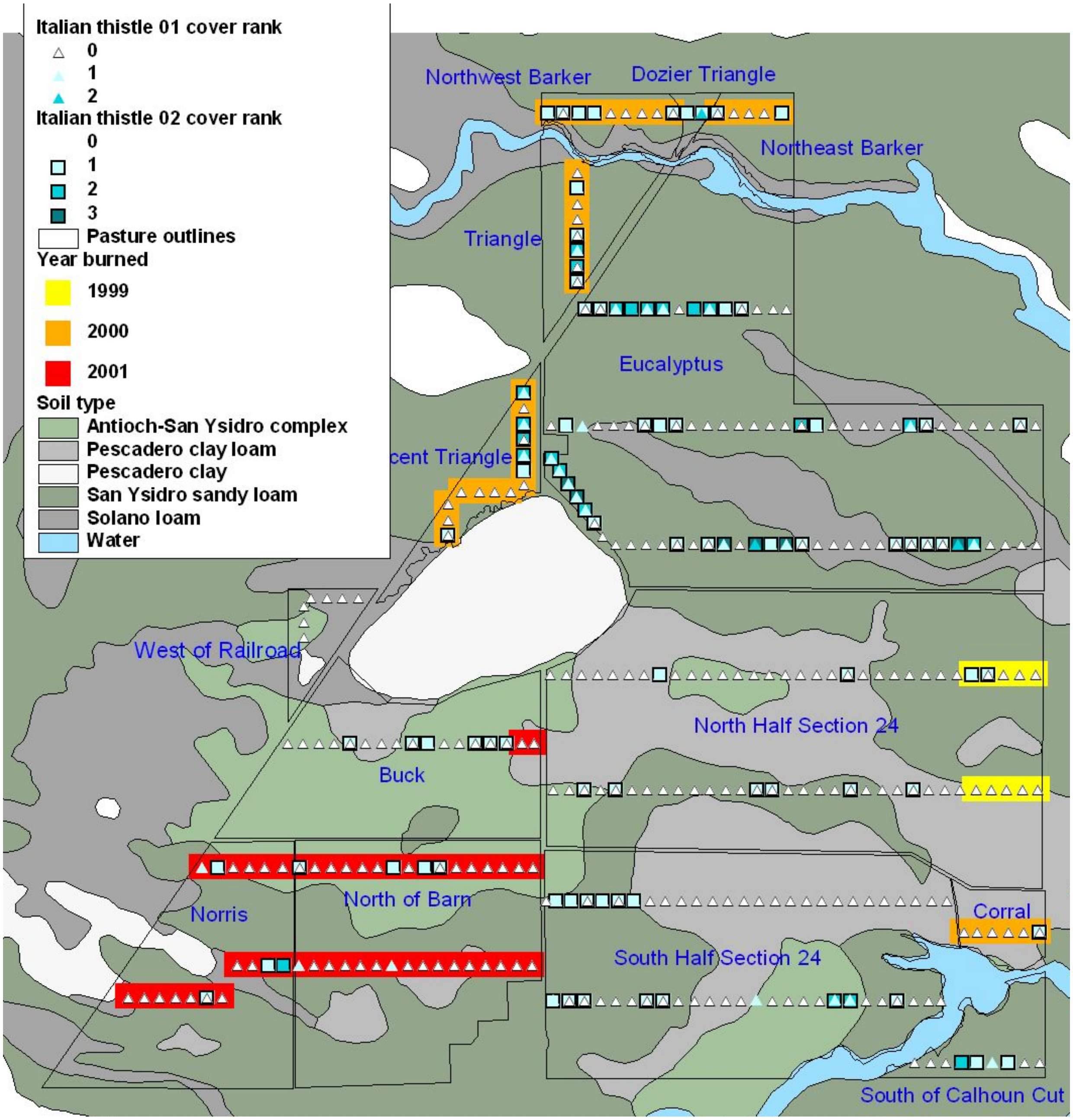

Figure 20. *Carduus pycnocephalus* cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

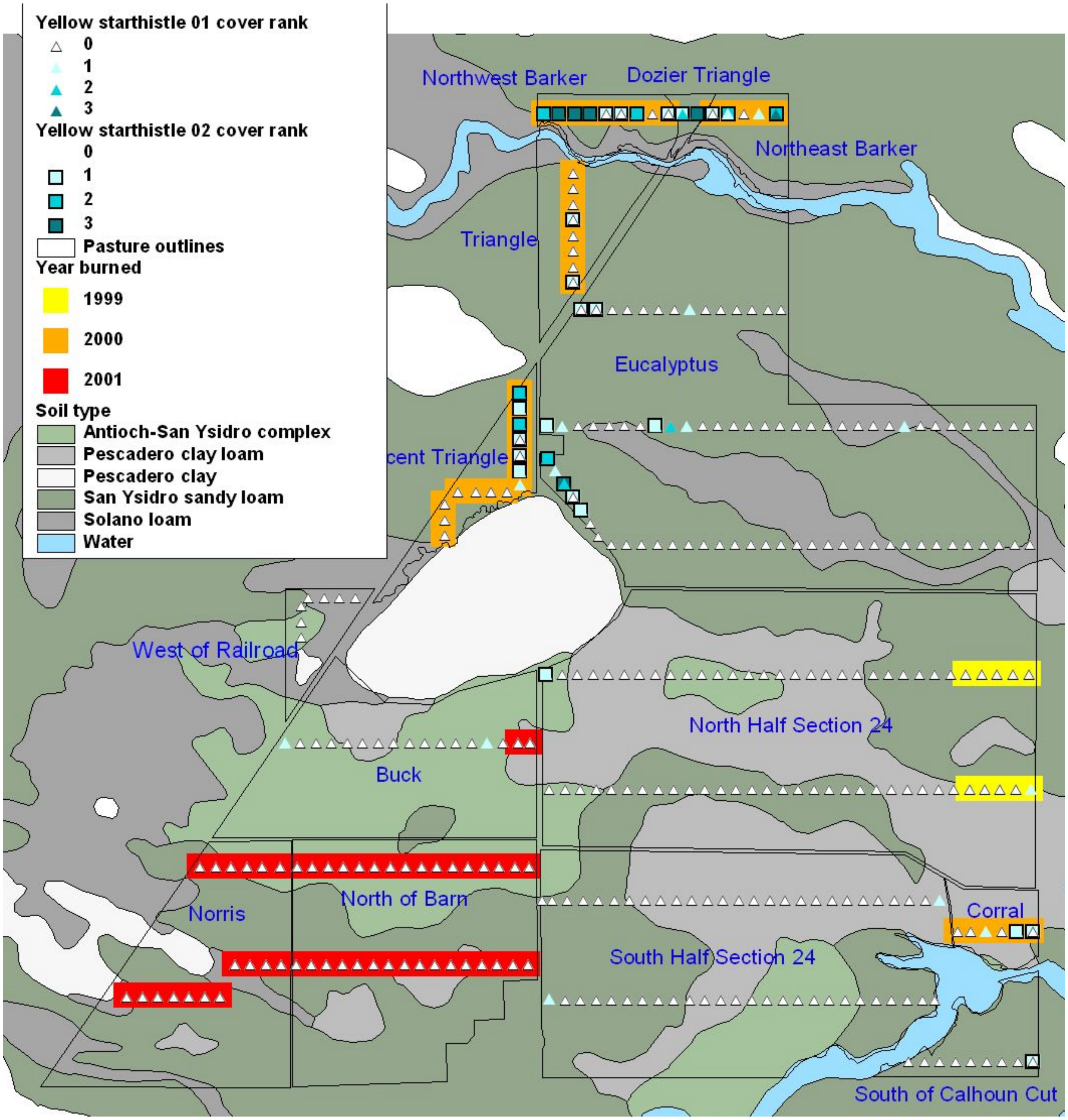

Figure 21. *Centaurea solstitialis* cover ranks in transect segments, April 2001 and 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

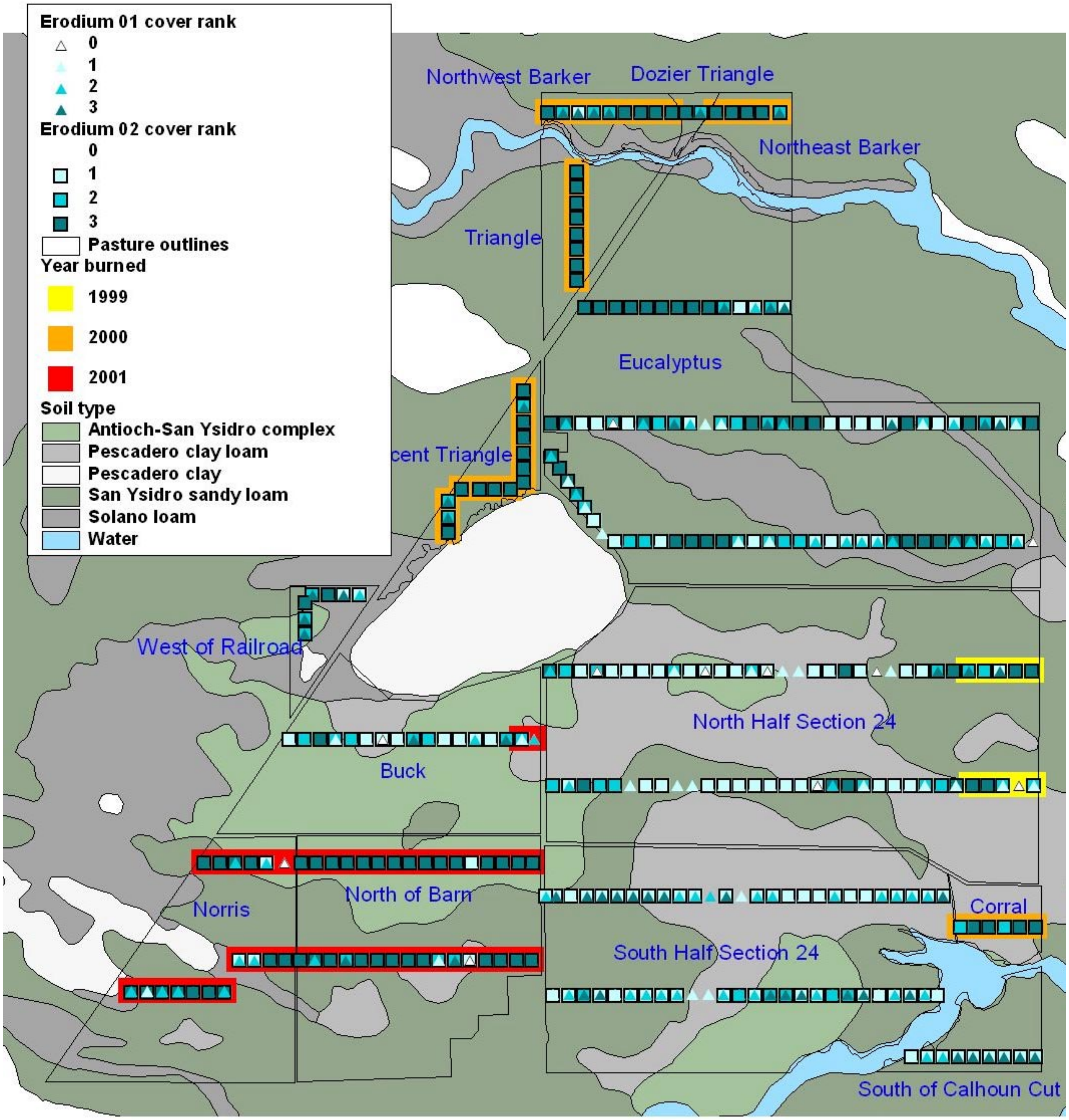

Figure 22. *Erodium* spp. cover ranks in transect segments, April 2001 and April 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

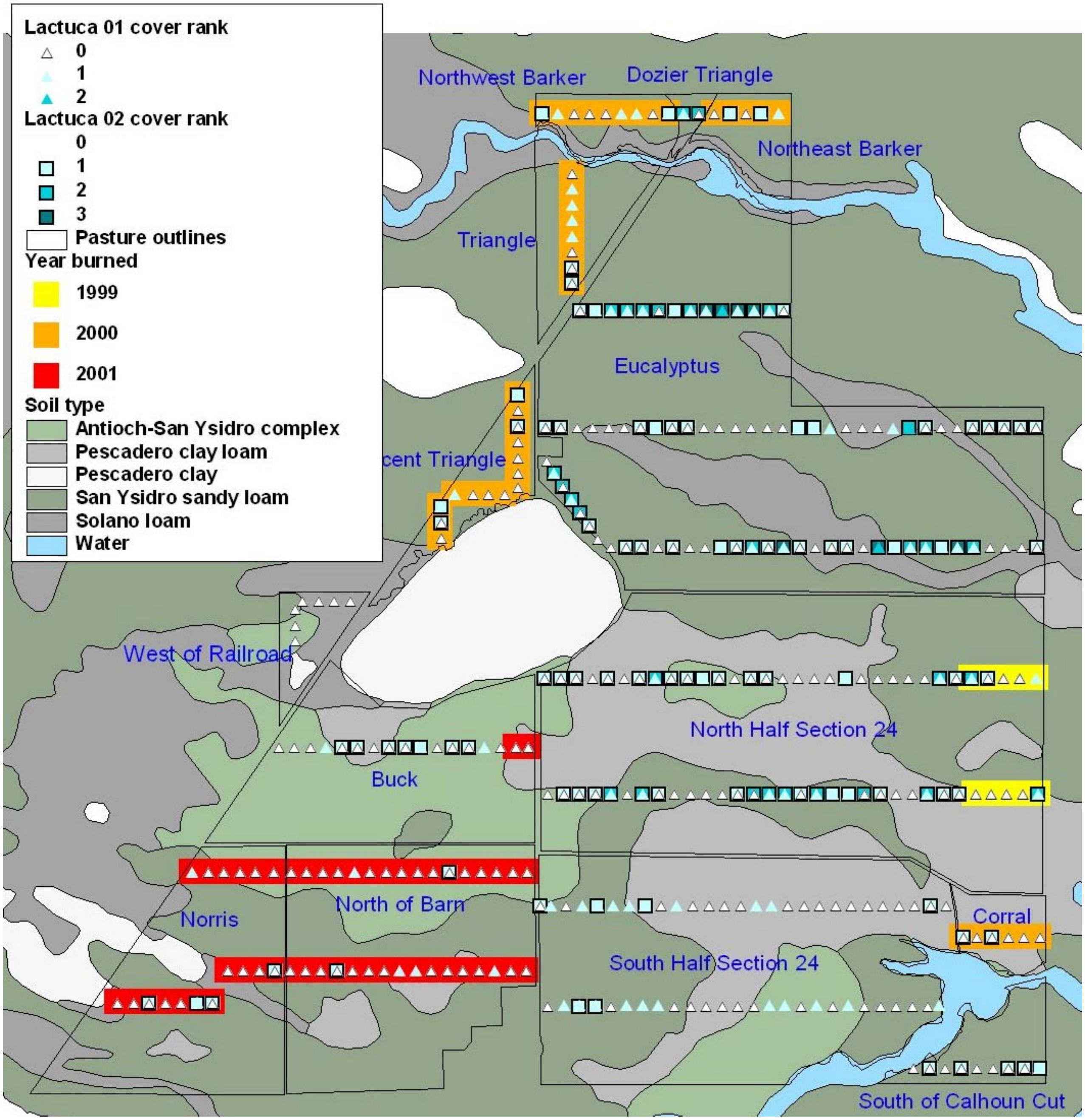

Figure 23. *Lactuca serriola* cover ranks in transect segments, April 2001 and 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

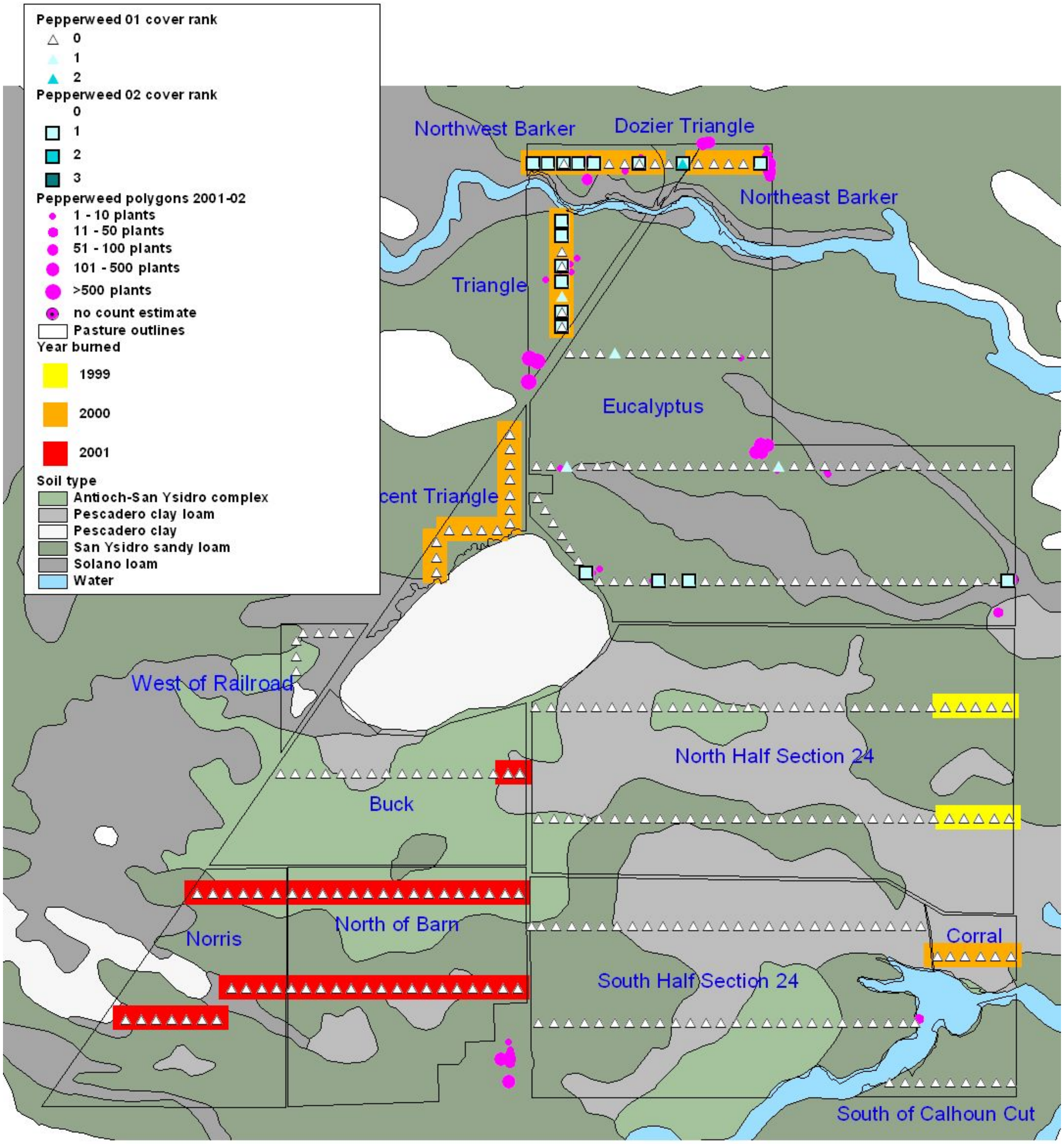

Figure 24. *Lepidium latifolium* cover ranks in transect segments (April 2001 and April 2002) and mapped point/polygon populations. Not all visible populations have been mapped in the heavily infested pastures north of Barker Slough. Markers for transect segments are centered over the midpoint of the segment and are not to scale. Point/polygon markers are at centers of points or edges of polygons. Marker size for all markers for a given polygon is scaled to match the weed population size class for the entire polygon.

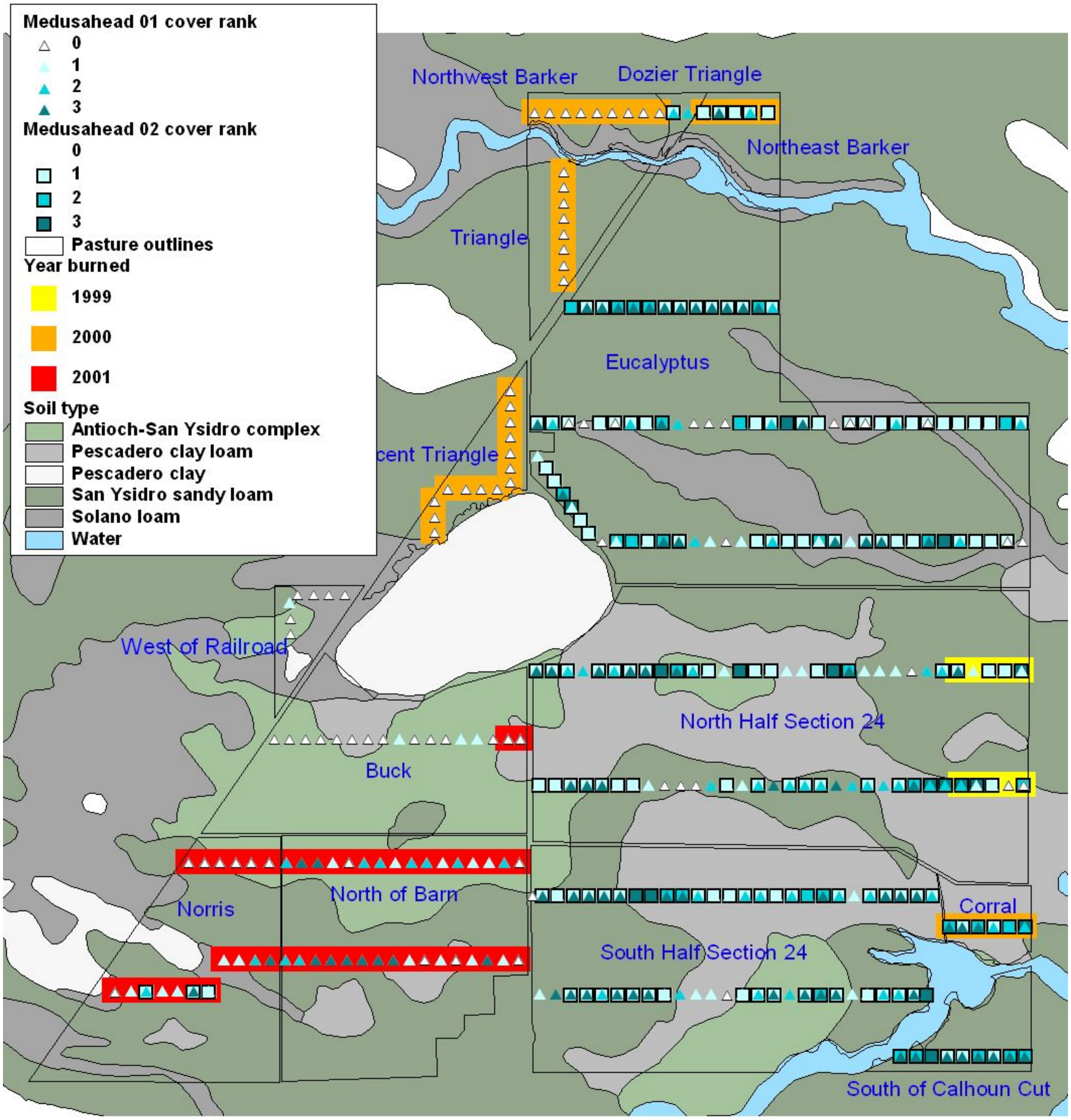

Figure 25. *Taeniatherum caput-medusae* cover ranks in transect segments, April 2001 and 2002. Markers for transect segments are centered over the midpoint of the segment and are not to scale.

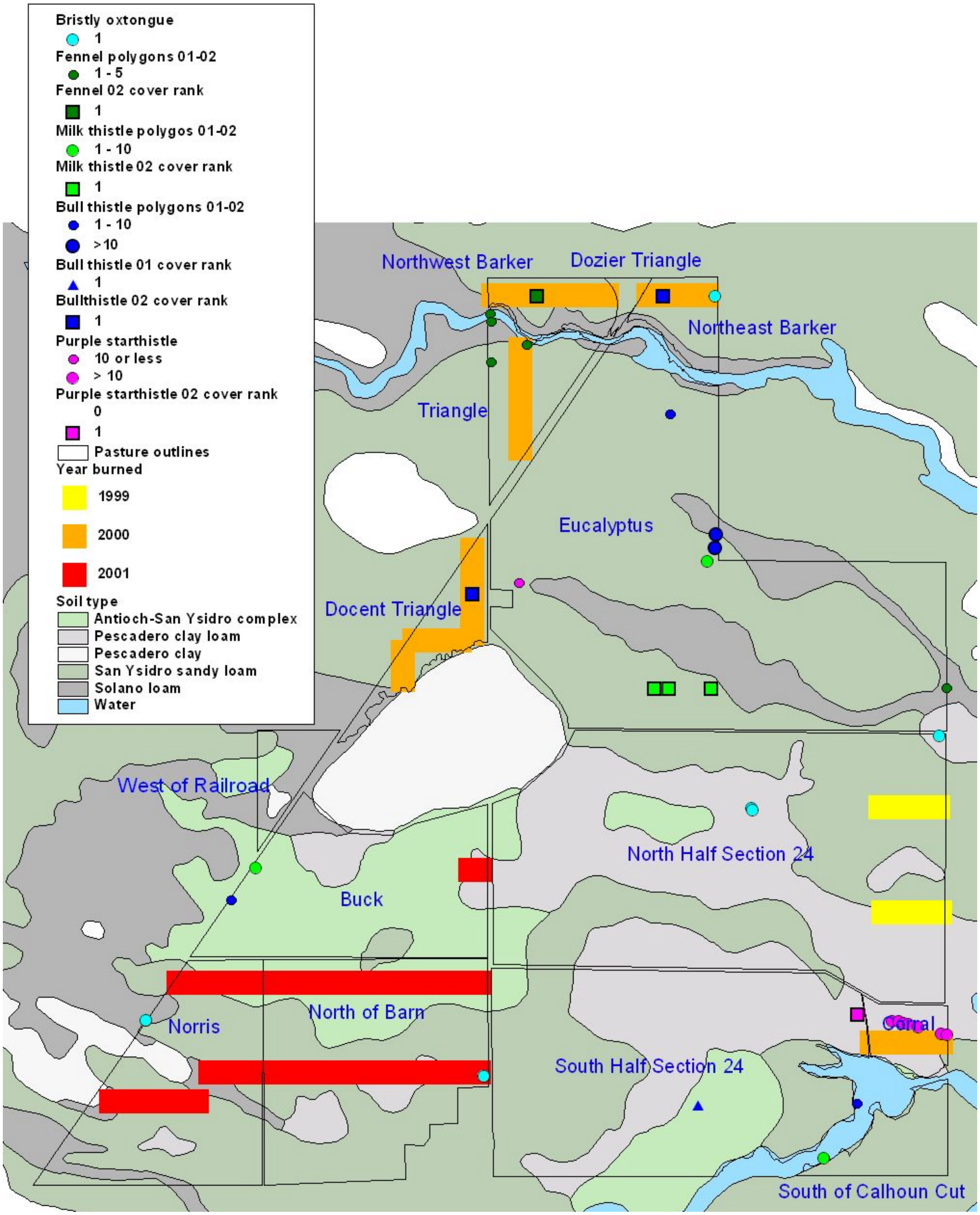

Figure 26. Rarely-occurring weeds noted during the transect monitoring in April 2001 (triangles) and April 2002 (squares) and mapped as weed polygons in April 2001 through April 2002 (circles). Bristly ox-tongue (*Picris echioides*) is not on the target list of weeds. Markers for transect segments are centered over the midpoint of the segment. Markers are not to scale.

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