Vernal Pool Ecology and Vernal Pool Landscape Management as Illustrated by Rare Macroinvertebrates and Vascular Plants at Vina Plains Preserve, Tehama County, California

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ABSTRACT

California Nature Conservancy's Vina Plains Preserve, in southern Tehama County, was used to develop an ecosystem approach to the study of vernal pools. Spring-aquatic observations (starting in March 1995) of select macroinvertebrates, were combined with summer-dry pool observations (extending through August 1995) of select plants from the same vernal pools. Rainfall, temperatures and pool conditions were recorded for this area.

A standard aquatic invertebrate collection technique was developed to determine a density index for macroinvertebrates, including the two special status species (*Lepidurus packardi* or vernal pool tadpole shrimp and *Branchinecta conservatio* or the Conservancy fairy shrimp). The *Lepidurus packardi* density index that included juveniles and adults ranged from 20 to 85 individuals per m^2 of pool floor. Collections that had adults only displayed an index of 10 individuals per m^2. Different life history patterns observed in different pools are illustrated by the number of generations (one or two), time of total adult mortality (April to June) and the maximum first generation carapace size (24 to 39 mm). The *Branchinecta conservatio* density index ranged from 3 to 99 individuals per m^3 of water sampled. Four pools had high densities and three had low densities. The synchronized development combined with a decrease in population density of this anostracan indicates that the most important cyst production occurs as adults first reach maturity.

Spring plant communities surveyed on single transects in 18 pools contained a total of 47 species (including the rare *Gratiola heterosepala* or Boggs Lake hedge-hyssop in one pool). Frequency determined for 47 species, and density for 20 species, documented differences among all pools. A series of summer transects was used in nine of these pools to determine frequency of the green and/or reproducing plants that were part of the dry pool communities. Four of these (the special status species *Chamaesyce hooveri*, or Hoover's spurge; *Orcuttia pilosa*, or hairy Orcutt grass; *O. tenuis*, or slender Orcutt grass; and *Tuctoria greenei* or Greene's tuctoria also had density determined with stratified/random sampling. This information was used to estimate total pool population size and produce detailed maps of each pool (for comparison in later years). The unique nature of each pool is illustrated by the number of rare species per pool, species densities, species patterns in pool basins, and total population sizes. *Chamaesyce*, in four pool populations, had variable frequencies (0.006 to 0.141) and variable densities (0.1 to 6 plants per m^2). The *Chamaesyce* patterns in different pools varied with individuals either predominantly in one part, scattered or present in a ring. *Orcuttia pilosa* was found in the same pools with *Chamaesyce*, and had a density of 45 to 474 plants per m^2, and was usually found throughout each pool. *Orcutti tenuis* was found in the southern half of a different pool. *Tuctoria* was found in restricted locations in five pools, with a density of 7 to 133 plants per m^2. Total pool populations ranged from 1,320 (*T. greenei*) to ~ 4 million (*O. pilosa*).

Density and pattern differences in vernal pool macroinvertebrates and plants mandate long-term monitoring. Although the macroinvertebrate and plant communities make each pool distinct, we consider these seasonally displaced species to be components of a single ecosystem.

Eight key ecological ideas about vernal pools (especially at Vina Plains) were developed using the single ecosystem premise. 1. Vernal pools are hydrologically independent ecosystems in landscapes that include a variety of pool types. 2. Initiation, intensity and duration of wet and dry seasons in pools can not be predicted from year to year. 3. Both animals and plants display specialized and synchronized pool populations that start growth from resistant cysts and seeds at select times throughout the entire year. 4. Pool populations vary in density, and their resistant propagules potentially result in overlapping generations. 5. Vernal pool populations are part of metapopulations displaced in time and space, with greater diversity shown in a pool landscape or region than in a single pool. 6. Pool dynamics can be influenced by exotic species and also by native species that may spend only part of their life cycle in the pool. 7. Summer and winter pool communities are interacting components of the same ecosystem. 8. The conservation of vernal pool ecosystems requires population and habitat preservation. Management recommendations developed from these eight ideas are presented.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1
INTRODUCTION

The object of this report is to present the research done during winter 1994 through spring and summer of 1995, on vernal pools and on several special-status vernal pool macroinvertebrates and vascular plants found at the Vina Plains Preserve, Tehama County, California. One objective of this report was to combine numerical data and observations from our studies to discuss vernal pool ecosystems and to discuss how ecological principles should be used to support preservation and management of vernal pools. A major focus of these studies was to provide information relevant to the preservation and management of vernal pools--pools occurring both on the Preserve and elsewhere in California.

Three special status species (Federal Register 1994) occur on the Vina Plains Preserve: *Brachinecta conservatio* , the conservancy fairy shrimp (federally endangered), *Brachinecta lynchii*, the vernal pool fairy shrimp (federally threatened) and *Lepidurus packardi* , the vernal pool tadpole shrimp (federally endangered). Work by Alexander (1976) as well as unpublished observations by Alexander (extending from 1964 to the present) at the Vina Plains Preserve and surrounding region have provided information that has set the stage for this research. The ecology of several vernal pool invertebrates was considered in student studies done from the late 1960's to the present, in the Vina Plains Region, under the direction of Alexander: Michener (1970) reported on major life history differences between two common vernal pool calanoid copepods, *Diaptomus* (now considered *Leptodiaptomus*) *tyrrelli* and *Diaptomus* (now considered *Hesperodiaptomus*) *eiseni* ; Wolt (1972) considered populations of *Cyzicus californicus* (listed as *C. mexicanus* in error) in one pool south of Chico and in four pools in the Vina Region including a population in what is now the largest pool on Vina Plains Preserve, and found it unable to reproduce during the drought of 1972; Lanway (1974) considered the importance of temperature and dissolved oxygen in controlling the hatch of crustacean cysts; Ahl (1983 and 1991) dealt specifically with the tadpole shrimp, and found that the cyst bank was enchanced by the second generation in one season; Patton (1984), considering fairy shrimp distribution and development, found that hatching is synchronized and early development occurs over a brief period; Gallagher (1992, 1993) found that a mimimum size was required before vernal pool snails, *Fossaria (Bakerilymnaea) sonomensis*, could successfully aestivate and considered the population plasticity between adjacent pools; Syrdahl (1993) found the invertebrate community composition and physical factors of the 14 largest pools on Vina Plains Preserve produced 14 unique communities; Ballantyne (1994) used field-preserved animals examined under the scanning electron microscope to establish the importance of the detritus food chain in the feeding of a vernal pool copepod, *Hesperodiaptomus eiseni*; and Eads (1995) found high heterozygosity and genertic similarity between *Brachinecta conservatio* on Vina Plains Preserve and Jepson Prairie Preserve in Solano County that were statistically unique.

Five special status plants (Skinner and Pavlik 1994) occur in pools on the Vina Plains Preserve: *Chamaesyce hooveri* , Hoover's spurge (federally threatened); *Gratiola heterosepala*, Bogg's Lake hedge-hyssop (California endangered), *Orcuttia pilosa,* hairy orcutt grass (endangered for California, federally endangered); *O. tenuis,* slender orcutt grass (endangered for California, federally threatened); and *Tuctoria greenei,* Greene's tuctoria (rare for California, federally endangered). Schlising has studied a vernal pool endemic, *Sidalcea hirsuta* (1989), and has 11 years of observations on *Chamaesyce hooveri* . Griggs (1974 and 1980) studied *Orcuttia* and *Tuctoria* species throughout the state, and some of his information on these plants was obtained from what is now the Vina Plains Preserve. Broyles (1983, 1987) studied the vascular plant flora of the Preserve, and offered some details on the plants in pools, including especially the rare species. She provided information for specific pools that has served as the starting point for some aspects of the present work. Ikeda (1982), in considering *Navarretia* reproductive biology in northern California, provided some information on *N. leucocephala* for the Preserve. Stone et al. (1988) included Vina Plains Populations of *Chamaecyse, Orcuttia* and *Tuctoria* in their Central Valley surveys of these rare plants. These and other populations from the Vina Plains area are included in the California Natural Diversity Data Base (California Department of Fish and Game 1995).

Chapter 2
THE VINA PLAINS STUDY AREA

This study was restricted to the Main Tract of Vina Plains Preserve in Tehama County (Figure 2.1). The vernal pools of Vina Plains Preserve are found on an alluvial fan produced by the river system that is now called Deer Creek. This alluvial fan is part of a piedmont bench system between the Sacramento River Floodplain and the foothills. The pools are found between dissected drainage channels on a relatively level bench system that is higher in the north and lower in the south (King 1992). The topography of the preserve is illustrated in Figure 2.2.

RAINFALL AND AIR TEMPERATURES

In the fall of 1994, volunteers placed and monitored a series of simple tube rain gauges in a variety of locations on the preserve. The funnels on these fenceline gauges were constantly impacted by raptors and wind. As a result the rainfall totals were derived from composite information. In January of 1995, volunteers carefully mounted a United States standard rain gauge in the center of the Preserve, and all the following readings were taken with this gauge. Rainfall was recorded on an irregular basis, when conducting biological surveys in adjacent pools. Figure 2.3 provides the rainfall totals that occurred between observation dates, using small gauge data before installation of the standard gauge. Figure 2.4 presents the cumulative percent rainfall for the entire season. A maximum-minimum thermometer mounted on a fence post near the rain gauges provided the air temperature extremes between visits (Figure 2.5).

POOL CHARACTERISTICS

Pool numbers and general geomorphology

Through the years, individuals have developed numbering and naming systems for the pools (e.g., Broyles 1983). These were replaced by a numbering system devised by King (1992). He numbered all the pools observed that were over 30 m^2 in surface area (Figure 2.6). Although pools are numbered independently, some of these pools interconnect during high rainfall events in seasons with heavy rain. Examples include Pools 29 and 30 connected by a saturated clay (vernal wetland), and Pool 17 draining into Pool 16. Figure 2.7 illustrates the surface area calculations by King (1992) for the pools that we used. Most of the pools are located between Sheep Camp Ditch and the next major drainage to the east (called Singer Ditch by Broyles, 1983). There are only three major pools west of Sheep Camp Ditch, Pools 1, 14 and 39. Pool 1 has the largest surface area and is located on a junction between the Anita Clay and Tuscan Loam soils according to the Soil Survey of Tehama County (U. S. Department of Argrculture 1967).

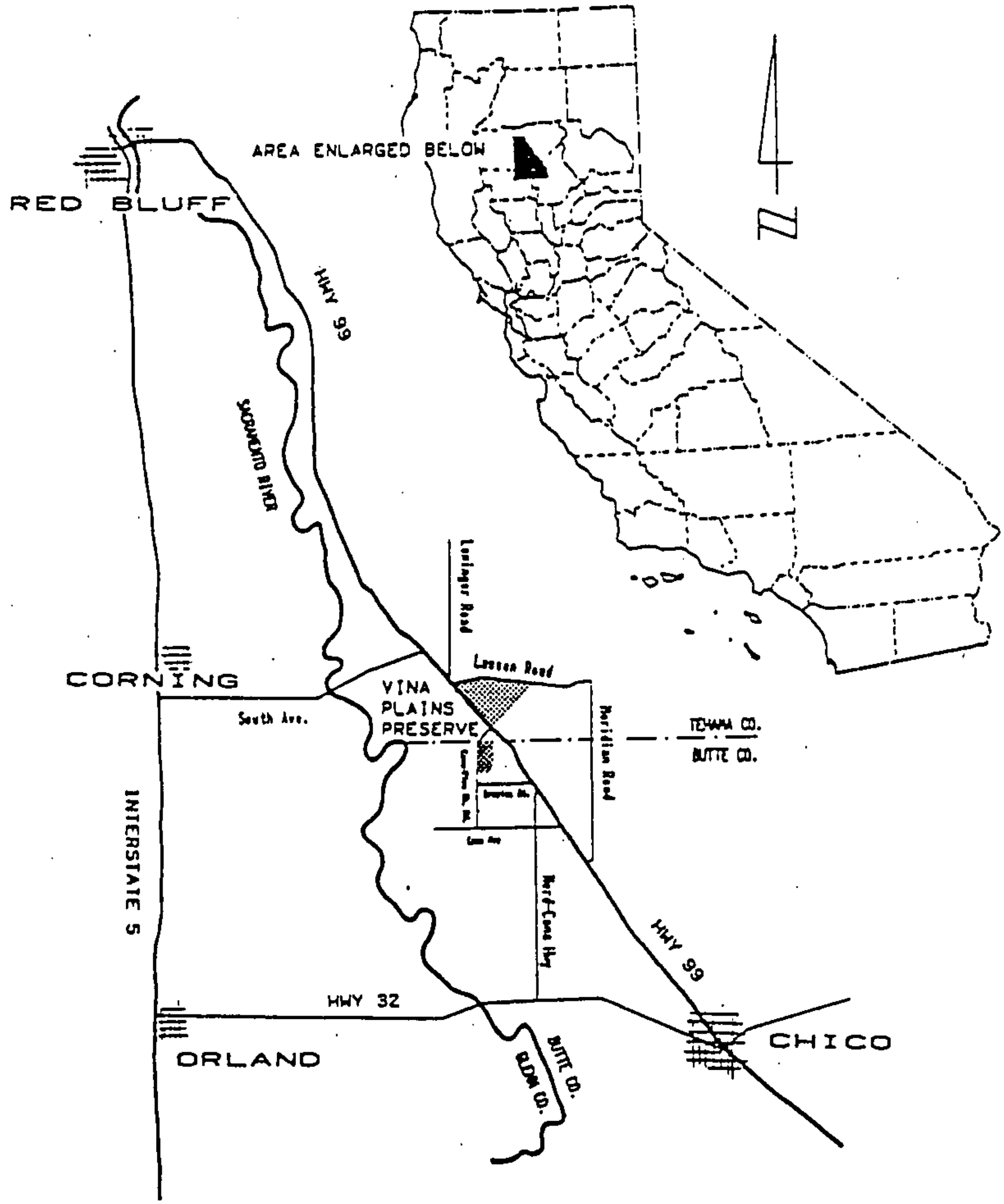


Figure 2.1. Location of Vina Plains Preserve (from a figure provided by J. White for the Dynamic Master Plan for Vina Plains Preserve) and found in: Oswald, V. H. 1989. Survey of the vascular plants of Vina Plains Preserve, Wurlitzer Unit. Unpublished pamphlet, Department of Biological Sciences, California State University, Chico.

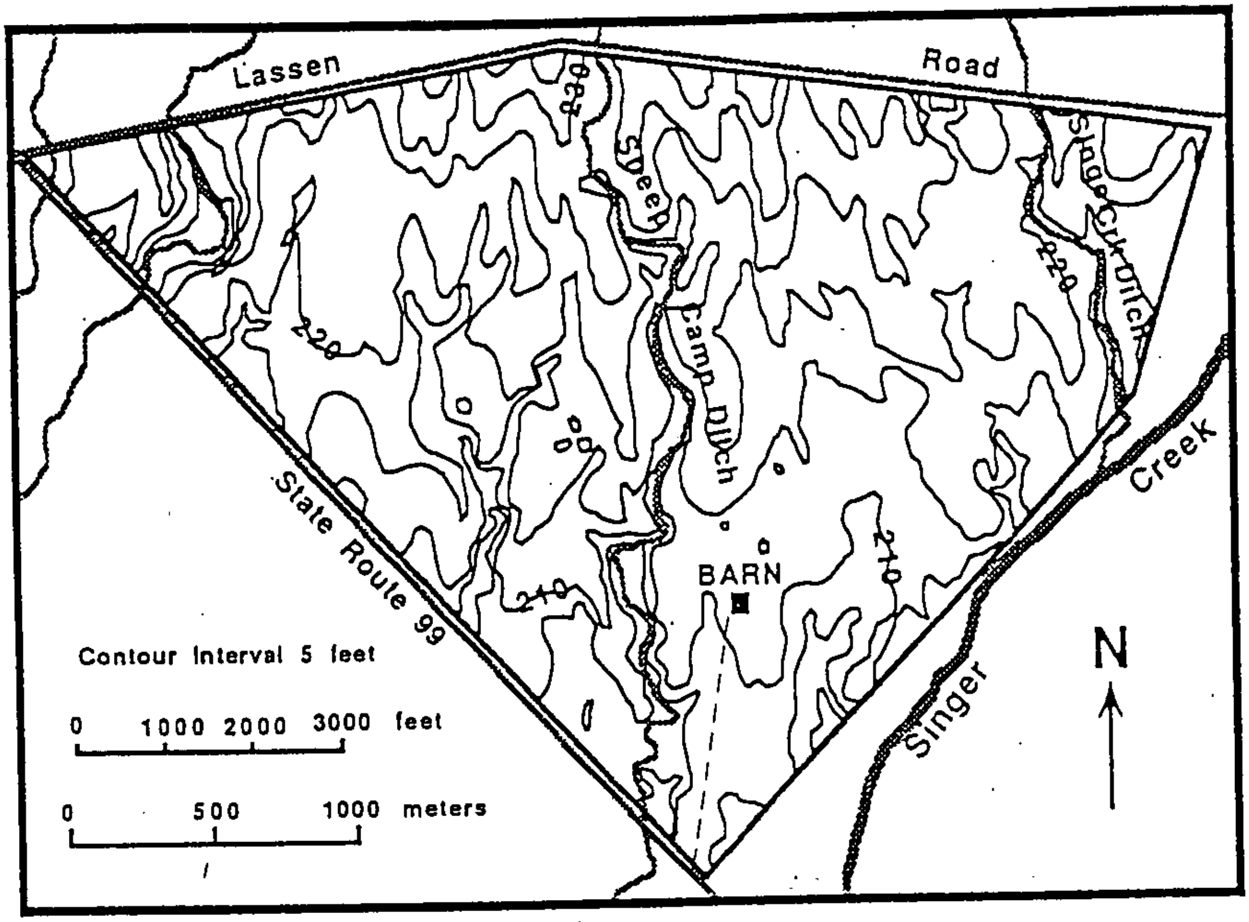


Figure 2.2. Topographic map of Vina Plains Preserve, Main Tract, from King (1992).

Total rainfall between observations Vina Plains Preserve October 1995 to June 1995
(789 mm of rain)

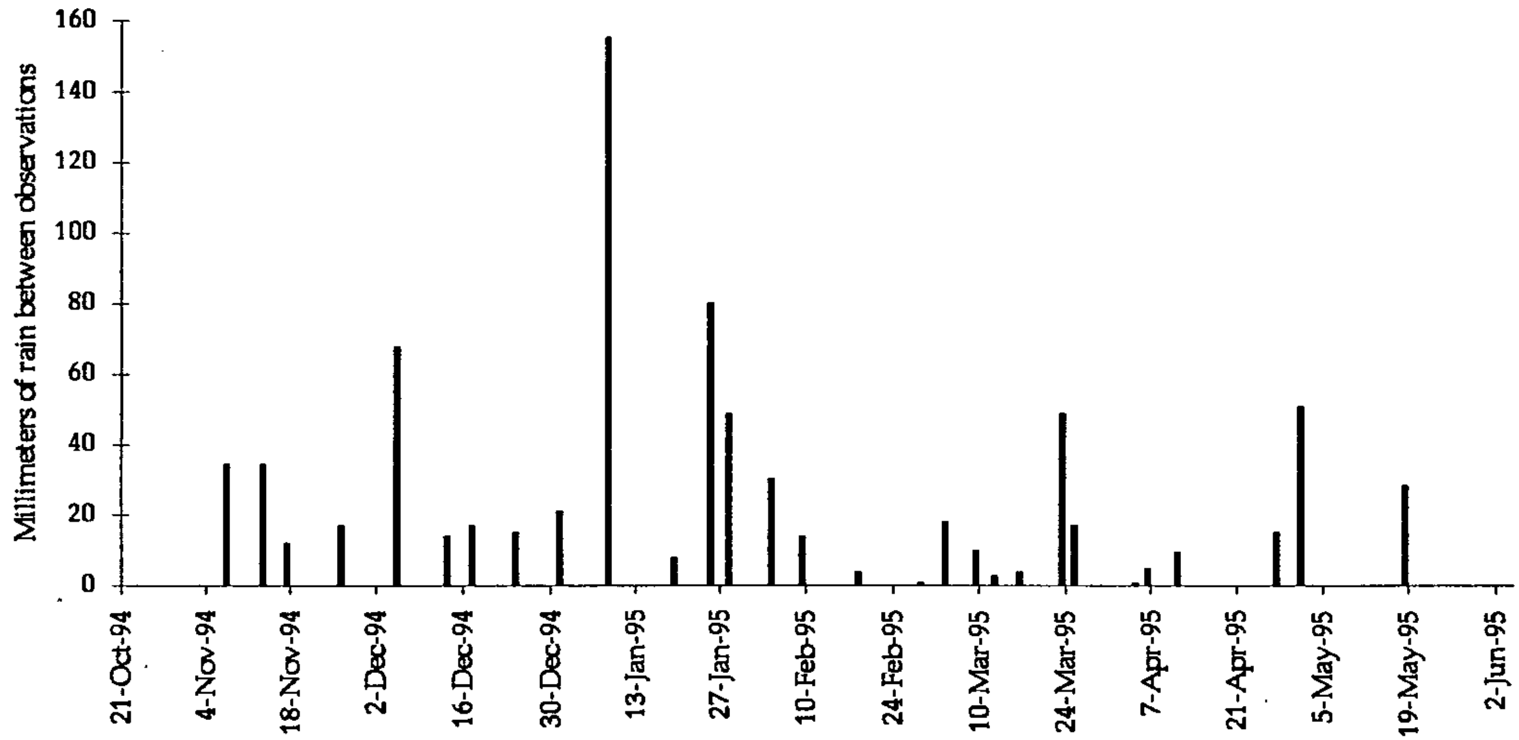


Figure 2.3. Rainfall totals for the 1994-1995 season as measured in the center of Vina Plains Preserve. Rainfall values represent the measured total that accumulated between visits.

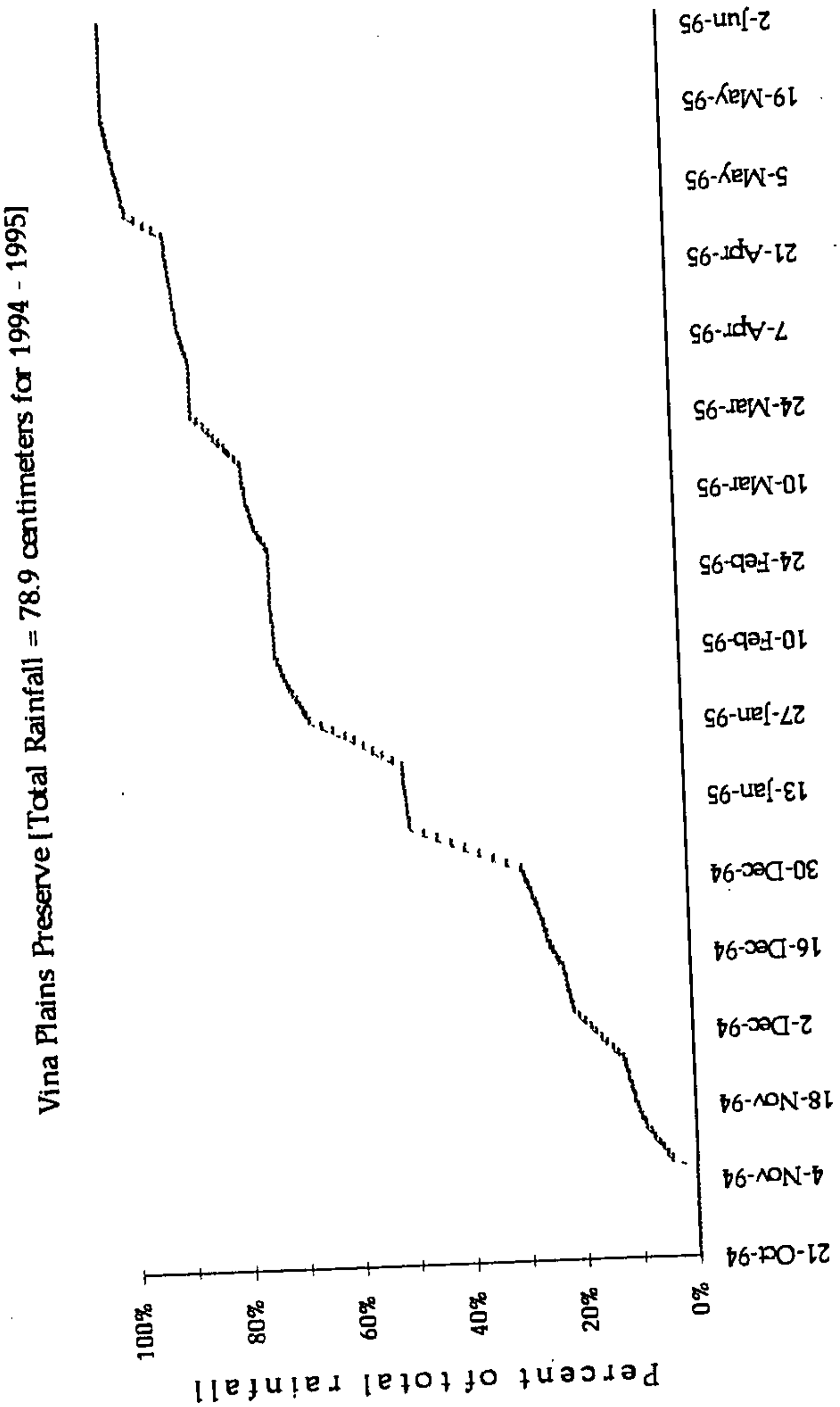


Figure 2.4. Cumulative percent rainfall for the 1994-1995 season, Vina Plains Preserve

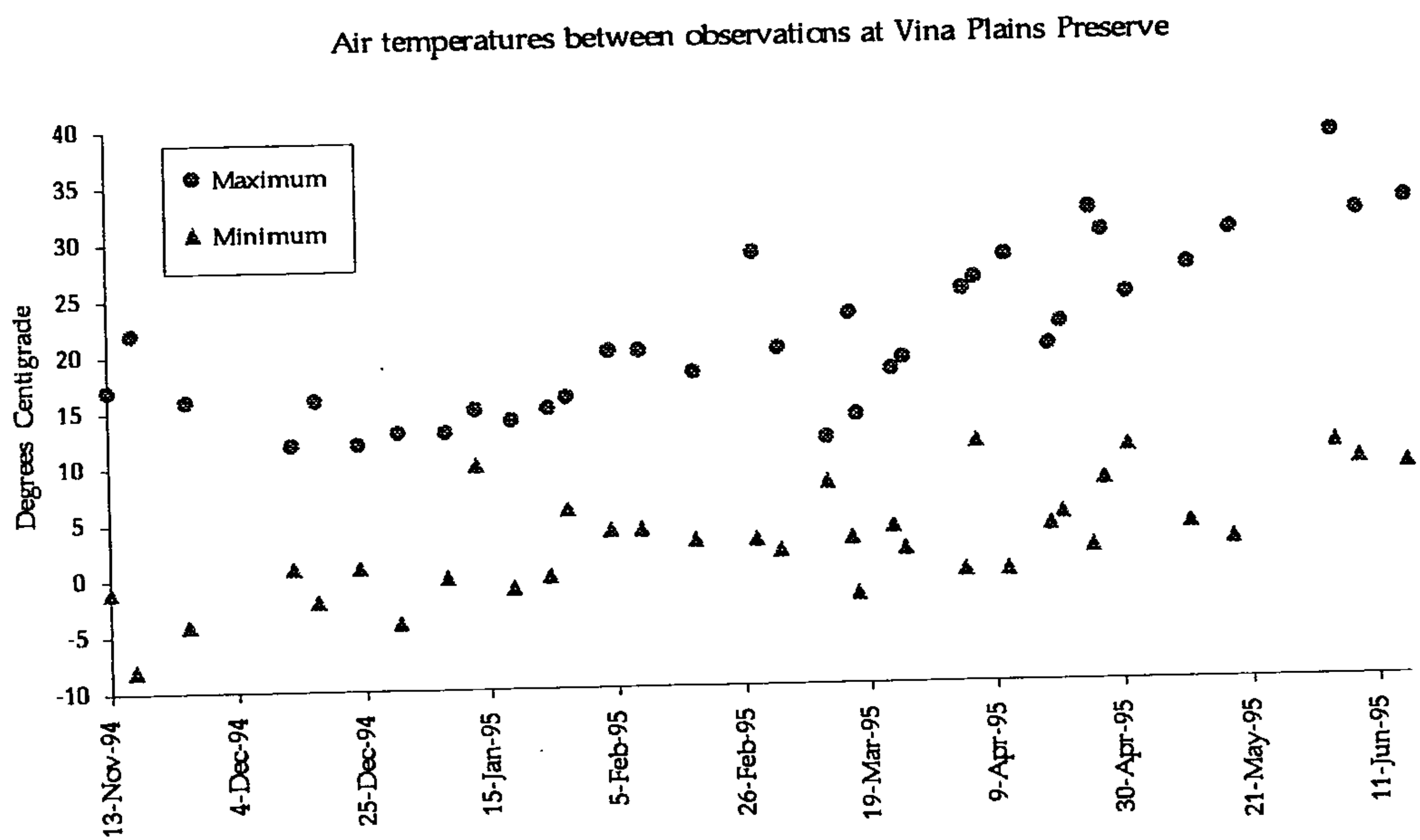


Figure 2.5. Maximum and minimum air temperatures between observations at Vina Plains Preserve during the 1994-1995 season.

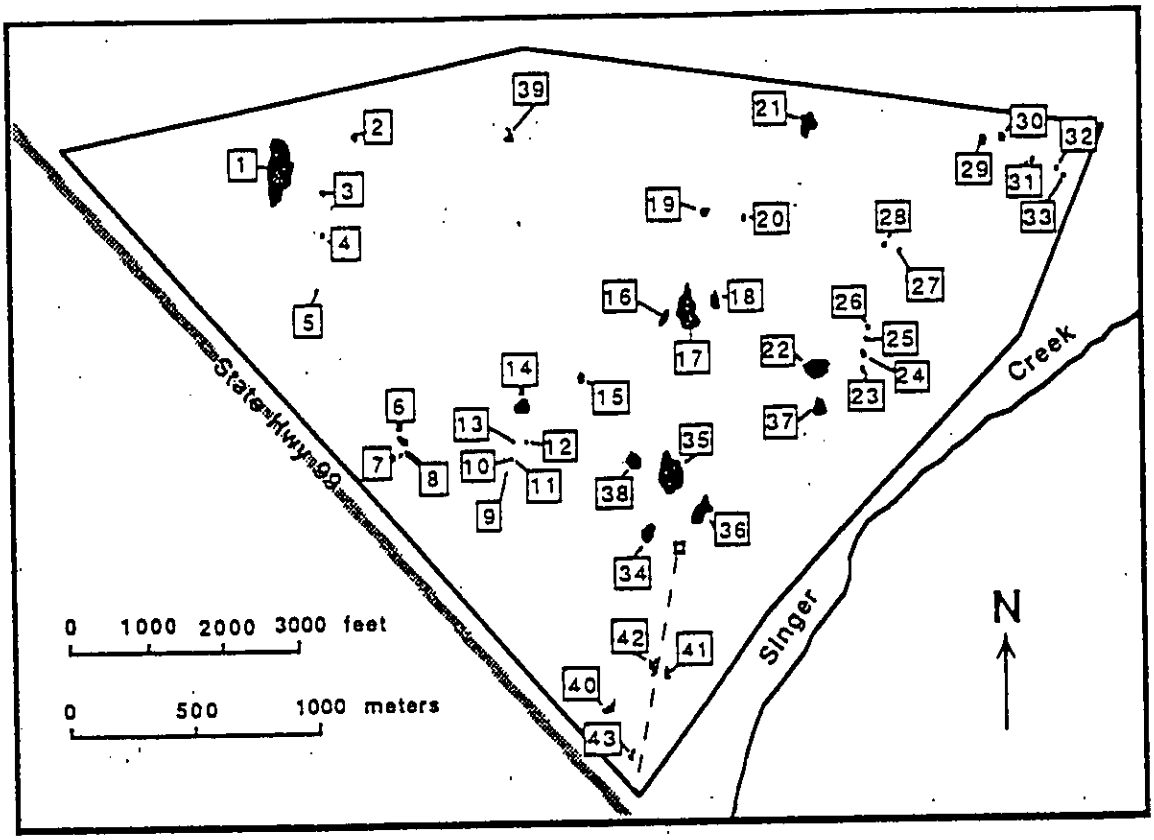


Figure 2.6. The vernal pool numbering system established by King (1992) for vernal pools 30 square meters or larger found on the Main Tract of Vina Plains Preserve.

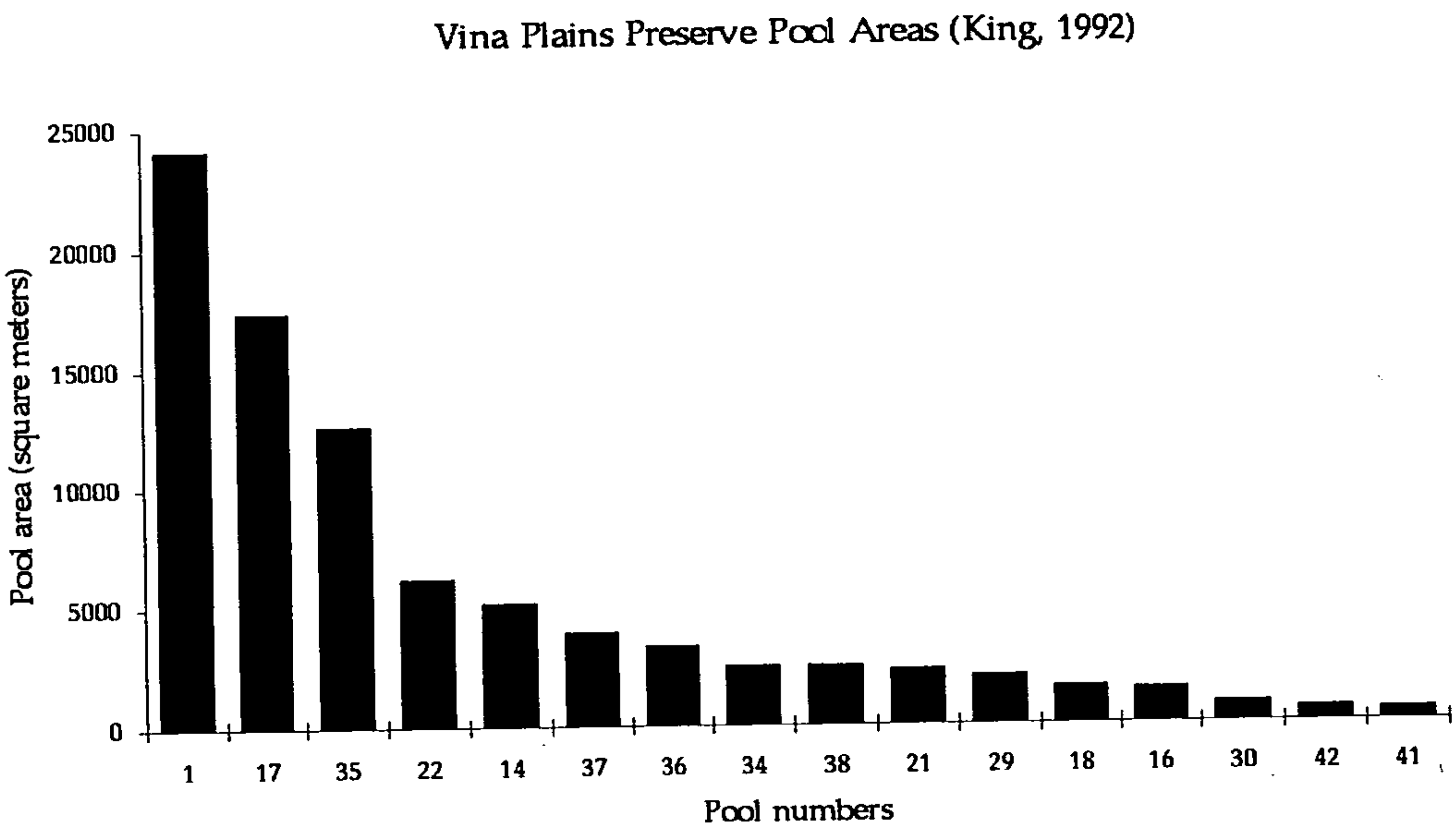


Figure 2.7. Maximum surface area calculations of select larger pools found on Vina Plains Preserve (King 1992).

There may have been a larger pool above Pool 14 that has been drained (personal communication, Guy King). A delta-like extension into Pool 14 at the discharge by a temporary stream draining the past pool area and the extensive mud soils on the south side of this pool further support this hypothesis. Pools 29 and 30 are the only large pools on the existing preserve east of Singer Ditch (there is another large pool located beyond the eastern edge of the preserve toward Singer Creek). The remaining large pools (Pools 41, 42, 34, 36, 35, 38, 37, 22, 16, 17, 18, and 21) are located in a band, between the existing drainage systems, extending from the entry gate on the south to Lassen Road on the north. Pools 41 and 42 appear to have been a single isolated pool that was bisected by the gravel road from the gate to the barn (Figure 2.6). Pool 22, divided by internal fencing, is just north of the shallow pool 37. Pool 21 is an isolated pool easily accessible from Lassen Road. The rest of the pools form two clusters:

1. In the north, Pool 17, a very large pool, has Pool 18 to the east and Pool 16 to the west. Pool 16 receives surface water from Pool 17 during very high rainfall years (e.g., spring 1995) and Pool 18 is isolated by a low ridge. Pool 18 represents a pool formed in the headwaters of a temporary drainage. Pool 17 has a relatively small watershed in relation to the pool size, receiving some water from a small drainage that occasionally provides surface water from the north. Other than the high water discharge into Pool 16, Pool 17 appears to provide subsurface water into a clay dominated drainage to the south.

2. Pools 34, 35, 36 and 38 form a second cluster, to the south. These pools are just north of the barn. Pool 35 is the largest, and like Pool 17 (and Pool 1) has a relatively small watershed with a large pool surface area. All three have a small "temporary-inlet" that drains surface water from the north. At full water, Pool 35 is more than 1-meter higher than the water level of Pools 34, 36 and 38. Although adjacent to Pool 35, Pools 36 to the south-east and 38 to the west appear not to have a surface or subsurface connection with Pool 35. Pool 38 is located within the Sheep Camp Ditch floodplain and, although it did not connect with the flooding Sheep Camp Ditch in March 1995, the water level was within 10 to 15 cm of this connection. Pool 36 has an irregular shape, with a smaller lobe that is disconnected from the main pool at low water. The early season flooding of this pool is assumed to reflect a larger watershed in relation to the surface area of the pool. Pool 34, located to the south-west of Pool 35, is partially dependent upon a water seepage through clay soils forming a wetland connecting these pools. When the soil is saturated, the tail of this wetland contains a surface water channel that runs into the west side of Pool 34. The delayed flooding of Pool 34 reflects the importance of this water source.

Chronology of flooding and dry down

Most of the pools on the preserve dried down in April 1995. The remaining larger pools represented areas which were of special interest to our research. A few of the larger pools dried down in May (Pools 34, 22 and possibly 14). The remaining three largest pools dried down in June (Pools 35 and 1) and July (Pool 17). Although Pool 17 has a smaller surface area than Pool 1, it is deeper and held water longer.

Differences in the pattern of input (mainly rainfall) and output (mainly evaporation) will result in different pool flooding and drydown patterns from one year to the next. We have information on the changes in the water level of Pools 34, 35, 36, and 38 during the 1994-95 season (Figure 2.8). Table 2.1 illustrates a calculation of changes in the pool surface area of the 14 larger pools in 1992 (Syrdahl 1993). These values were determined by measuring the changing size of the two major hemiaxes of each pool and considering the pools as ovals. Although some of these maximum values do not agree with King (1992), the ranking of the pools is similar. This 1992 pool chronology divides the pools into different groups. Pool 29 flooded very early. Pools 14, 16, 18, 21, 29, 36, and 39 were at maximum capacity in the first weeks of flooding (late December and early January). Pools 1, 17, 22, 34, 35, 37, and 38 did not reach full size until February and March. Syrdahl observed the drydown of most pools in April, with four pools holding water into May and one into June.

Pool chemistry

Very little effort was placed on pool chemistry. The measurements taken were done with equipment purchased for class use many years ago at California State University, Chico. A series of disconnected water temperature, dissolved oxygen, and conductivity readings were made in the four pools just north of the barn (Pools 34, 35, 36, and 38). Some of these readings are presented in Table 2.2. Individual pool measurements are not representative of other pools in the cluster because of the differences in hydrology, volume and biotic composition of adjacent vernal pools. The analysis of these point values of physical factors such as dissolved oxygen, temperature, pH is not appropriate because these values fluctuate greatly with diurnal and climatic changes as well as seasonal changes in biotic activity.

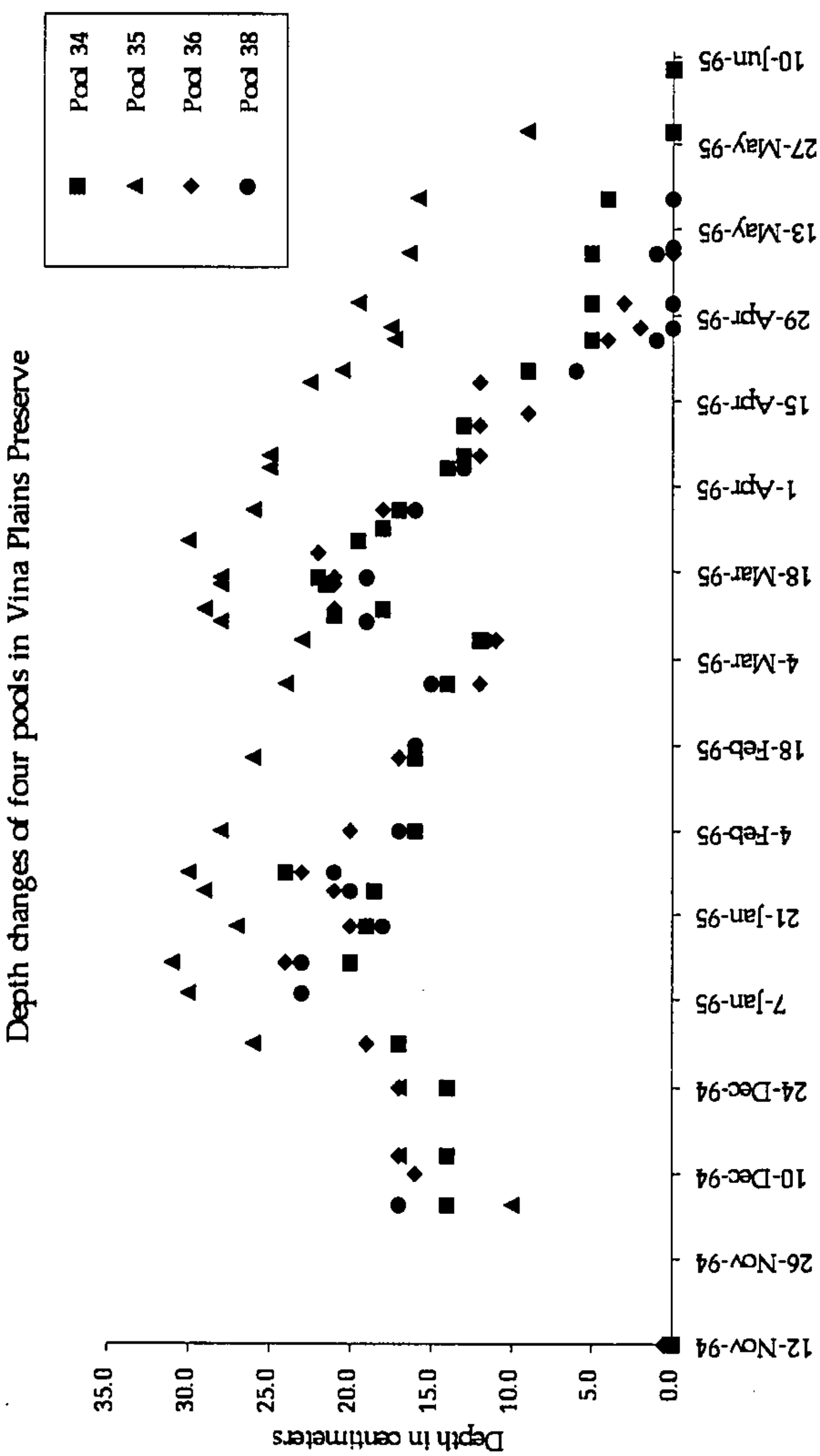


Figure 2.8. Depth changes in Pools 34, 35, 36 and 38 for the 1994-1995 season. The water levels were taken from a standardized depth stake in a deep part of the pool.

Table 2.1. Chronology of 14 pools including the week of flooding, the week of drydown and select pool areas in square meters calculated in 1991-1992 by Syrdahl (1993). The double lines indicate the time of flooding and drydown. The boxed number is the maximum area observed.

Week	Dates	Pool 1	14	16	17	18	21	22	29	34	35	36	37	38	39
48	Nov 26 - Dec 2								dry						
49	Dec 3 - Dec 9								flooded						
50	Dec 10 to Dec 16								?			dry		dry	
51	Dec 17 to Dec 23		dry			dry	dry		?		dry	flooded	dry	flooded	
52	Dec 24 to Dec 31*	dry	flooded	dry	dry	flooded	flooded	dry	?		flooded	?	flooded		dry
1	Jan 1 to Jan 7	26902	?	**2395**	17899	**1890**	**5711**	flooded	**3097**	dry		?			**2127**
2	Jan 8 to Jan 14		**9291**					6450		3840	13179	**5727**	4349	2177	
3	Jan 15 to Jan 21	24705	9225	2304	19474	1138	4790	6213	2138	3743	12777	5420	3213	1764	1664
4	Jan 22 to Jan 28														
5	Jan 29 to Feb 4	26268		2341		1764	5143		2273						1907
6	Feb 5 to Feb 11		9270		19325			6350		3776	12942	5513	3921	1793	
7	Feb12 to Feb 18	30307		2337	26829	1875	5365		2391						1085
8	Feb 19 to Feb 25		9234					6694		3744	**13654**	5647	**4571**	**2255**	
9	Feb 26 to Mar 4*	29513	9056	2250	28184	1424	4793	6638	2138		13503	5479	3822	1855	1700
10	Mar 5 to Mar 11									3864					
11	Mar 12 to Mar 18	**30362**	8754	2291	**28817**	1738	5475	**6731**	2479		13635	5626	4274	2033	1993
12	Mar19 to Mar 25									**3975**					
13	Mar 26 to Apr 1	30265	8477	2161	28493	960	4754	6342	2001	3751	13421	5286	2040	1685	1499
14	Apr 2 to Apr 8														
15	Apr 9 to Apr 15	30244	7788	1942	28109	520	4349	6363	1749	3548	13315	4908	0	1405	601
16	Apr 16 to Apr 22			0		0						0		0	0
17	Apr 23 to Apr 29	29564	2009		25800		0	5150	0		12470				
18	Apr 30 to May 6		0							0					
19	May 7 to May 13	27477			23231			0			0				
20	May 14 to May 20														
21	May 21 to May 27				19049										
22	May 28 - June 3	0													
23	June 4 to June 10				0										

Table 2.2 Select water chemistry values for some Vina Plains vernal pools, spring 1995. Pool 36-H represents the smaller pool connected to the north-east of Pool 36.

Date	Pool	Time	Conductivity (mmho/cm)	Temperature (water)	Temperature (air)	DO (ppm)	pH
16-Feb	34	PM	71	10			
16-Feb	34	PM	80				
16-Feb	34	PM	88				
16-Feb	36	AM	55				
16-Feb	36-H	AM	71				
16-Feb	36-H	AM	90				
16-Feb	36-H	AM	77				
16-Feb	38	PM	80				
4-Mar	35	AM	40	12		11	
4-Mar	35	AM	48	16		11	
14-Mar	34	AM	46	11		17	
16-Mar	34	PM	50	20		9	
16-Mar	34	PM	68				
16-Mar	34	PM	64				
16-Mar	35	AM	59	19		11	
21-Mar	35	PM	29				
21-Mar	36	PM	44				
21-Mar	36-H	PM	48				
23-Mar	34	AM	51	5		13	
23-Mar	35	AM	43	10		11	
6-Apr	35	PM	47				
13-Apr	35	PM	48				
27-Apr	34	AM	50				
9-May	34	AM	66	13		11	
9-May	38	AM	153	14		12	
9-May	35	PM	equipment error	16		11	
23-May	1	PM		24	22	7	11
25-May	17	AM		20	21	7	11
25-May	17	PM		27	25	7	11
25-May	35	PM		30	29	7	12
29-May	35	AM		24	22	7	12
29-May	35	Noon		29	28	7	10
8-Jun	17	PM		21	21	7	8
8-Jun	35	Noon		27	25	11	7
13-Jun	1	PM		24	21	8	8
16-Jun	17	PM		23	22	8	9
23-Jun	1	AM		17	21	7	5
7-Jul	17	Noon		28		7	7

Chapter 3
VERNAL POOL MACROINVERTEBRATES OF SPECIAL STATUS

This chapter summarizes the field activity considering the ecology of select vernal pool invertebrates on Vina Plains Preserve. The objectives established at the start of this grant included a documentation of the seasonal life history sequences of the listed crustacean species found in the larger pools on Vina Plains Preserve. This was to include an attempt to determine population density changes through the 1995 season. This macroinvertebrate information was to be combined with a study of the summer rare plants. The scientific research on these species was to be directed toward applied information important to the preservation and management of vernal pool preserves.

On 2 March 1995, Alexander received a four year permit (PRT -- 797266) to study *Branchinecta conservatio* (the conservancy fairy shrimp), *Branchinecta lynchi* (vernal pool fairy shrimp) and *Lepidurus packardi* (vernal pool tadpole shrimp). Following this, Alexander also obtained the necessary local approval from the regional U. S. Fish and Wildlife Service office in Sacramento. The Department of Fish and Game permit # 2097 issued to Alexander by the state of California, also covers this research.

This paper documents population level dynamics in select pools of a single vernal pool complex. This activity observed all major populations of *Branchinecta conservatio*, the larger and long lasting populations of *Lepidurus packardi* and collections of *Linderiella occidentalis* (California linderiella) and *Cyzicus californicus* (California clam shrimp) found with the first two species. At the time research was initiated (early March), the bulk of the *Branchinecta lynchi* populations would have completed development (Gallagher 1996). If the permission had been granted earlier, this study could have been expanded to include more pools, estimated densities of *Branchinecta lynchi* , and estimated densities of other species' developmental stages. It is likely that the small pools at Vina could have supported more than one population of *Branchinecta lynchi* as as a result of multiple flooding as Gallagher (1996) observed in previous years in the Chico region.

This paper documents population level dynamics in select pools from the pool complex found on Vina Plains Preserve. The invertebrate observation program started on 4 March. Field observations were made twice a week, typically on Tuesday and Thursday from early March to early June, with two additional collections in mid June and early July in the longer lasting pools. This total collection sequence involved 31 field observations (ranging from 6 to 10 hours) over a period of 125 days. During many of these days Shelly Kirn was conducting an associated research program in some of the pools. Her study (in partial completion of the requirements for a masters degree) considered the foraging success of *Notonecta kirbyi* (a backswimmer) on *Linderiella occidentalis* (California Linderiella) and Corixidae (waterboatmen) in vernal pools.

METHODS

Several field techniques were tested during the initial week. Only larger branchiopods collected after 4 March on select vernal pools of Vina Plains Preserve were included. This resulted in the development of a procedure that allowed a simultaneous, nondestructive estimate of *Branchinecta conservatio* and *Lepidurus packardi* densities. Some observations were made on *Linderiella occidentalis* (California linderiella) an unlisted fairy shrimp and a few individuals of *Cyzicus californicus* (California clam shrimp) were collected. The technique developed is most appropriate for repeated sampling in larger vernal pools. Density estimates and general pool observations were made in a series of collections from 7 March to 7 July. The three largest pools (1, 17 and 35) were visited six to nine times. A series of intermediate size pools (16, 22, 34, 36 and 38) were visited two to five times. During 30 March to 6 April, eight additional pools (14, 18, 21, 29, 37, 40, 41 and 38) and a cluster of four small pools (including 42) in the flood zone of Sheep Camp Ditch were visited one time. The total spring collection activity considered of over 500 two meter plankton net tows that were used for quantitative catch-and-release observations.

The initial collection activities followed collection methods used previously by Alexander. This collection technique used an open ended can (area 0.9 m^2) placed vertically into the pool to isolate a water column. The lower edge of the can was sealed in the soft mud and all the water was dished out and poured through a plankton net to remove the organisms. At the end of this process, the pool floor was examined for organisms (before there was a major break in the mud seal) and the organisms collected were counted and returned to the water. (In previous years, a fine screen was used and this sample was preserved for laboratory analysis.) The advantages of this technique centered on the ability to make a representative sample of numerous organisms from the pool surface to the pool floor regardless of pool depth. This provided information on community composition and was necessary when considering organisms that are different in size as well as those that have small free living early developmental stages. There were a variety of disadvantages with this technique: 1. It was time consuming. 2. Some pool floor conditions do not allow the continued maintenance of an appropriate seal to keep out pool water. 3. It was hard on the investigator, the organisms collected and the vernal pools. 4. The relatively small samples do not generate enough population density estimates for the study of macroinvertebrates, especially when their density is low. Attempts to reduce the column size in order to obtain more replicates in the same time were unsuccessful because of the above problems and the difficulty of removing water from the container.

This community sampling procedure was immediately replaced with a net collection system that allowed field counts of individuals with a minimal impact on the populations. A system was developed pulling a standard round plankton net through the water. A one millimeter net mesh allowed numerous smaller crustaceans to pass through before capture, with the net fabric collecting the larger invertebrates and water flow washing these into a large collection jar on the end of the net. The invertebrates remaining on the net were washed directly into an enamel pan and combined with the contents of the pond water. A complete collection of *Branchinecta conservatio* was possible because synchronized development had passed the individuals through the small early season free-living stages. The smallest *Lepidurus packardi* collected (2-3 mm carapace length) represent recently hatched individuals. A small plywood platform mounted on a post was used as a stand to hold the enamel pan, allowing the collections to be placed in the pan, examined and immediately returned to the water at the point of capture. These macroinvertebrates survived this collecting technique without negative impacts. Individuals were rarely out of the water and they were returned to the pool in less than 10 minutes. The presence of tadpole shrimp was also determined in some pools by partial exoskeletons on the water surface. This capture and release technique required the following equipment: chest waders, a small enamel pan, a meter stick, a small clear millimeter ruler attached to the collector's wrist, a sorting platform nailed to a 130 cm wooden post that acts as a leg (the small wooden platform had side restraints to support the pan), a small tape recorder (fastened within the waders), a zooplankton net (a 1 millimeter mesh net with a 25 mm diameter opening and a screw receptor accommodating a large plastic bottle at the narrow end of the net). The information dictated into the tape recorder was personally transcribed to hand notes before another fieldtrip and generally within 24 hours of the field activity. This information was converted to computer programs.

Macroinvertebrate collection transects that bisected the pool were established in the intermediate size pools (16, 22, 34, 36 and 38) and the largest pools (1, 17 and 35) had two transects generally on an east-west line. The transects were marked with yellow-flagged wire pins on each side of the pool. These transects were parallel to the spring plant transects marked with white-flagged wire pins. The first collection was made 1-1.5 meters from the edge of the pool. The time available for collecting and the size of the area determined the number of steps between samples (ranging from 5-15 steps or roughly 4-12 meters). This number was kept constant during that collection sequence any one day. This distance between collections roughly controlled the number of locations sampled on the transect and where the transect was finished. The changing pool size resulted in most repeat collections in following weeks being taken at different locations along the same transect. Collections on the same transects were repeated in different weeks up to nine times in long lasting pools.

The following numbered listing of collection activities performed at each pool is provided because this is a newly developed technique potentially useful in monitoring vernal pool invertebrates. This technique was developed to monitor changing life history dynamics and is unnecessary if the objective is to determine presence or absence.

1. Transects were established with flagged wire pins placed on each side of the pool before entering the pool.

2. Equipment was assembled so that the collection sequence could be made from one side of the pool to the other side of the pool in one continuous effort.

3. The pool was entered from one edge (east or west) walking toward the pins on the opposite edge. The first collection was made in water deep enough to move the net, generally 1-1.5 meters from the edge.

4. After arriving at a collection location, the platform on a single post was placed into the pool floor approximately one-half of a meter to the right. (Initially, a three legged tripod was used but this was found to be cumbersome. If the mud was not deep enough, the platform was stabilized with one hand or the body.)

5. A meter stick was stuck into the sediments one meter from the initial mark going from right to left. When the water was shallow or the meter stick would not stay in the sediments a rock or emergent vegetation was used as a marker.

6. The round plankton net was placed vertically into the water next to the right edge of the 1-meter unit. The net was then quickly pulled the 1-meter unit. Selective pressure was used by holding the net by the edge, to keep the net in contact with the pool floor and to move it over cobbles and through vegetation. (The edge of the net was reinforced several times during the spring collecting period.) The net was pulled in a rapid continuous motion and taken vertically out of the water after the one meter path had been traversed. The first net pull was quickly followed by a second net pull placed in a new location. The collector had to lean forward to make the second sample in undisturbed water. (This second collection would be difficult for individuals with short arms. Initial surveys found that the second collection was necessary to include a logical number of organisms and reduce the number of collections without organisms. The option to reduce this collection pattern to a single meter was used only once in pool 42 when the number of *Linderiella occidentalis* was very large. The option to combine more than 2 meters of collected water was rejected for statistical reasons and was not possible without special permission due to U. S. Fish and Wildlife Service directives.)

7. As the net was pulled along the bottom of the pool, it potentially also picked up sediments, bits of living and dead vegetation and even small rocks. The net was examined in the water and larger organisms observed in the net were washed directly into a small amount of pond water in the enamel pan. Although the system picked up a few small rocks, restricting the pull to two meters reduced the chance for these physical objects to harm the delicate bodied organisms in the net. When large bits of vegetation and rocks were observed in the net they were removed quickly by reaching into the net as the net was held in the water. All of these objects were washed carefully in the pan to remove any organisms attached to their surface. Any activity that would roll rocks in the net and damage macroinvertebrates was avoided. Fine clay caught in the net was washed out with an unhurried rocking motion.

8. After removing the larger organisms and large objects the remaining net contents were washed into the attached large plastic jar by a verticle motion that does not allow any water into the net opening. This was done before the net was pulled out of the water. A complete vertical washing procedure is required to insure organisms caught on the net are in the bottle before it is removed from the adaptor. The contents of the net collection jar were placed directly into the enamel pan with pool water. If the net or the jar was not completely clean, the jar was re-screwed onto the net and the net was cleaned by back flushing pond water. Under conditions of high density of macroinvertebrates, only a subsample of the contents was poured into the pan. The bottom of the net, with the jar attached, was carefully kept in the water during subsample counting.

9. The enamel pan on the stand platform was an important aid when counting and measuring individual organisms. The number of macroinvertebrates observed in the enamel pan was recorded with the tape recorder. As the contents settled in the pan, the movement of individual organisms aided detection. The contents of the pan were counted more than one time to insure a complete count. The tadpole shrimp carapace lengths were measured in the water with the clear millimeter rule that was attached to the wrist. These records were dictated directly into the tape recorder that was attached to the bib of the chest waders. As counting was completed the animals were returned directly to the pool in the area of capture. The collecting and recording sequence was conducted quickly, and animals never left the water. This technique allowed animals to be examined and returned with minimal impact (typically under five minutes and never more than ten minues). Although heavy wind reduced the efficiency, it was possible to make these collections under a variety of environmental conditions from bright sun to heavy rain. (The technique described

above is much harder on the collector's back and knees but results in minimal impact to the animals. It should be noted that most net collecting often involves pulling the net out of the water. This technique requires finding organisms stranded on the net in the air.)

10. The depth of the water was measured in three locations within the area the plankton net was pulled. This was done by placing the meter stick vertically in the water, but avoiding footprints and rocks.

11. The plankton net was cleaned by back flushing several times before moving to the next location.

12. After re-assembling equipment after one sample, the investigator moved along the line established by the flagged wire pins. A single individual in a muddy pool cannot measure a distance but can move a given number of pool steps. Although the collector will potentially sink into the soft mud of the pool sediments, there should be an attempt to move a known distance determined by pacing. Each collection along a pool transect was separated by five to fifteen steps (in this case, this was roughly 4-12 m). This spacing of the collections made it possible to collect in different locations on the same transect at different dates. However, repeatedly walking the transect in the larger pools (1, 17 and 35) resulted in a noticeable track across the pool floor and some deeper radiating cracks from these tracks in the dry summer.

13. The distince from the final sample to the pool edge was also recorded in paces.

14. Before moving from one pool to the next, all equipment and waders were carefully washed. During the winter this was easy; however, as the pools dry this became very difficult and collections were restricted to one pool to allow time to return from the field and clean equipment. At the end of every collecting trip, all equipment and waders were very carefully washed with a garden hose.

The net collected animals suspended in the water of the shallow pools and picked up benthic organisms where it was in contact with the pool sediments. If all the individuals were collected were observed, this field collection system provided an estimate of aquatic macroinvertebrate densities relative to collection effort (pool floor sampled or water volume collected). Any single collection provided a density index of both tadpole shrimp and fairy shrimp. Because individuals were collected and returned to the pool in viable condition, it is conceivable, but highly unlikely, that the same individuals were recollected on subsequent collection dates.

Clam shrimp are not effectively sampled this way because effective collections require repeated net sweeps at one location to pull individuals out of the pool sediments (Wolt, 1972).

The millimeter length of the carapace of each *Lepidurus packardi* was measured using a short transparent rule placed beside the animals in the shallow water of the enamel pan. Lengths were determined using any appropriate intermediate number that was next to the leading edge of the carapace, as opposed to attempting to put the end of the animal at the end of the ruler. All individuals 10 mm or larger were also examined for the presence of cysts in the egg sacs. A more detailed differentiation of male and female *Lepidurus packardi* was not possible, considering the conditions and the time available.

Problems of identification of juvenile individuals were avoided, because observations were initiated late in the season after development was generally complete. The field identification of *Branchinecta conservatio* mature females is reliable. The field identifications of *Branchinecta conservatio* populations were made from sequential observations from any one pool that always contained mature females. Mature females were observed in the first collection allowing a high confidence in all field identifications. Although it is possible that individual males could have been *Branchinecta lynchi,* this is highly unlikely in the pools considered. Collections in pools used by both *Branchinecta conservatio* , and *Branchinecta lynchi* would require the use of a field microscope to verify species identifications. Some pools also contained *Linderiella occidentalis* and the red eyes and red tails of these generally smaller individuals helped differentiate them from the generally dark eyed *Branchinecta conservatio*.. Furthermore, male antennae and female egg sacs of *Linderiella occidentalis* are distinctive.

The total number of individuals observed, and the number of individuals with cysts in egg sacs were recorded. This field identification system only differentiated mature females, the difference between the number of mature females and the total represents males, immature females and females not carrying cysts in the egg sac.

A few dead individuals of *Branchinecta conservatio* and *Lepidurus packardi* and moribund individuals of *Lepidurus packardi* were collected. Although most dead individuals were decomposing corpses, individuals with no movement were considered dead. Inanimate individuals generally also displayed fungal growth on their exoskeletons. The collection of corpses of recently deceased individuals indicated the net collection technique could collect inactive as well as active individuals. Because these soft bodied individuals decompose quickly, this must represent recent mortality.

Individuals were returned to the water dead or alive. General field comments were also recorded about insects and some representative insects were preserved late in the season. None of the insect observations are included in this report.

All collections were placed on a time scale using standard weeks with the first week of the year as week one and all weeks numbered following this. Although collections made at different days in the same week should be pooled, the collection sequence in 1995, resulted in no multiple collections in the standard weeks.

Density Indices

The collection system that allowed the development of density indices was repeated more than 530 times from 7 March to 7 July (Table 3.1). During this time, more than 40 individual pool surveys were conducted in 20 different pools and one set of adjacent small pools. These surveys ranged from a single collection in a low water pool to 29 different collections made in one pool in a single day.

Tadpole shrimp (*Lepidurus packardi*) density index

The net contact with the pool floor was determined to be five centimeters wide. The total standard collection at one location resulted in a pool floor sample of ten centimeters by one meter or one-tenth of a square meter. Because of this, the tadpole shrimp numbers were multiplied by 10 to produce a density index of individuals per square meter of pool floor sampled.

This density index was used to reflect changes in population size. A rapid collection system was conducted to counter net avoidance by tadpole shrimp. Changes in the numbers of tadpole shrimp collected are also influenced by size (age) class changes, changes in the size of the pool (that concentrates or dilutes the individuals) and changes in collection efficiency.

The movement of individuals of all sizes in the pan sediments made it difficult to miss any living organisms. The smallest individuals had a three millimeter carapace length. These small individuals were used as an indication of a recent cyst hatch. Although great care was taken, some of the smallest individuals could have been accidentally lost from the count especially in collections that contained detritus.

Ahl (1983) considered individuals below 10 mm carapace length as prereproductives and no individuals below 10 mm carapace length carrying cysts were observed.

Table 3.1. Quantitative collections for vernal pool invertebrates made in 1995. A number of collection techniques were tested from 4 March to 11 March. The number of 2 meter quantitative net tows taken in each pool is indicated. Pools are ranked by the total number of 2 meter quantitative collections taken.

	Pool number (according to King 1992)																
	17	1	35	36	22	34	16	14	21	29	37	38	41	42	18	30	40*
4-Mar			**														
7-Mar				9													
11-Mar						10						6					
14-Mar						8											
16-Mar			17														
21-Mar				13													
23-Mar							9										
28-Mar	23																
30-Mar					5						9		7	7			10
4-Apr		10							12	10						6	
6-Apr								14							6		
13-Apr			8	12													
18-Apr	21																
20-Apr					4												
25-Apr		10				9											
27-Apr			8		9												
2-May	16						7										
4-May		13															
9-May			29			3						1					
11-May	14				10												
13-May		14															
18-May	13		16		5	2											
23-May		22															
25-May	18																
29-May			10														
4-Jun		17															
8-Jun	18																
13-Jun		13															
16-Jun	12																
23-Jun		14															
7-Jul	8																
TOTAL	143	113	88	34	33	32	16	14	12	10	9	7	7	7	6	6	10

* A group of small pools.

** Observations but no standard quantitative collections.

Fairy shrimp (*Branchinecta conservatio* or *Linderiella occidentalis*) density index

The volume of water sampled was used to determine a fairy shrimp density index. The net area intercept was determined with the help of Dr. Stephen BeMiller, Department of Math and Statistics, California State University, Chico (Figure 3.1).

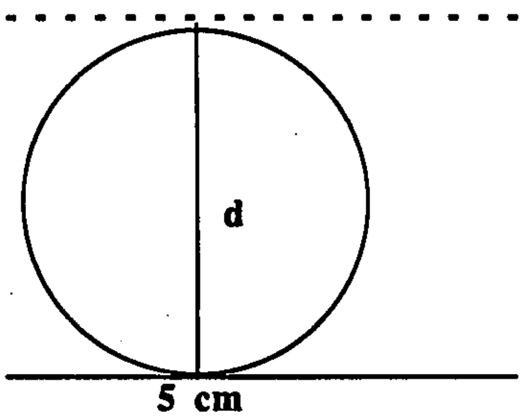
If the pool was deeper than 25 centimeters, the total net area sampled the water. This resulted in a sample with a surface area of 491 cm^2 and a length of 2 m. This column of water sampled had an area estimated to be almost 1/10 of a cubic meter (0.098 m^3). If the collection depth averaged less than 25 centimeters, the area of water intercepted by the net was calculated. When the water depth was 12.5 centimeters (one-half the net diameter) the collection represented 1/5 of a cubic meter (0.049 m^3).

The surface area of the net intercepting the water was calculated differently if the water level was above or below 12.5 centimeters. The surface area of a sector and the area of the right angle triangle formed below or above the water level (with the hypotenuse of this triangle consisting of the net radius)was determined. The hypotenuse and one side adjacent to the right angle could be determined using the water depth and net diameter. This allowing the determination of the area of the triangle using the cosine of the angle of this triangle formed at the center of the net. If the water was deeper than 12.5 centimeters, the area of net in the air was calculated as two times sector "B" less the areas in the two triangles "b" that represent the part of the net (and part of the sectors) in the water (Figure 3.1). This area of net in the air was subtracted from the total area of the net to obtain the area of the net in the water. If the water was less than 12.5 centimeters in depth, the area of net in the water was two times the area of sector "C" less the areas in triangles "c" which, in this case, are the parts of the sector in the air (Figure 3.1).

The surface area of the net in the water was then multiplied by the two meters of net pull, producing the cubic meters of water sampled. Individual collection numbers were converted to individuals collected per cubic meter of water to produce a density index for fairy shrimp. Ten individuals collected in a fully submerged net represented 102 individuals per cubic meter.

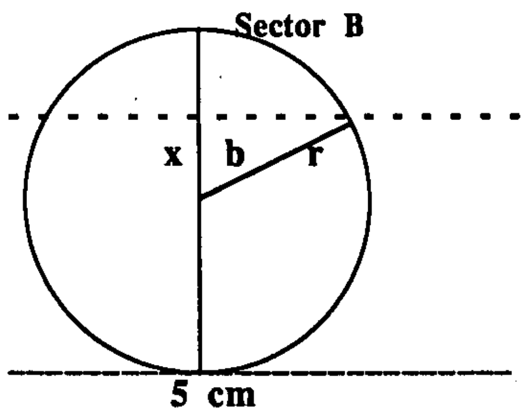
This density index was used to reflect changes in population size. Changes in the numbers of fairy shrimp collected are also influenced by changes in the size of the pool and changes in collection efficiency. If fairy shrimp have a significant ability to avoid this net collection system (which is doubtful), it is assumed that different collections have the same proportional error. We also assumed that the turbid nature of the pools combined with the rapid collection technique minimized differential behavioral effects produced under different climatic conditions.

A. Net totally submerged



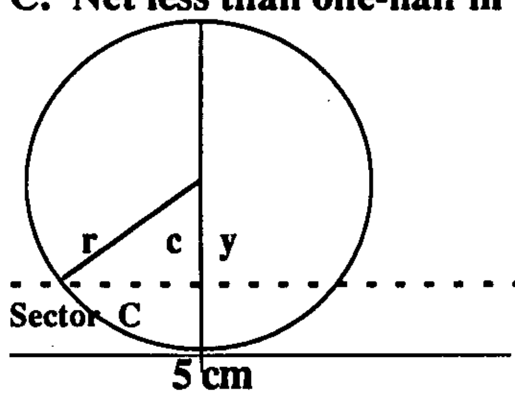
water depth > 25 cm
d = diameter = 25 cm
Area of net in water =
A = 492 cm^2
Length of pull = 2 meters
(pull length constant)
Volume of sample = 0.098 m^3
Volume considered = 1 m^3

B. Net more than one-half in the water



12.5 < water depth < 25 cm
x = 25 - water depth
Area of net in water = A - a
a = air Area of net in air
= 2 (area of Sector B -
area of triangle b)
r = radius = 12.5 cm

C. Net less than one-half in the water



Area of net in water =2 (area
of Sector C - area of
triangle c)
r = radius = 12.5 cm
y = r - water depth

12.5 < water depth < 25 cm

Figure 3.1 Method of determining sample volume to determine Anostraca density index. A. Net totally submerged. B. Net more than one-half in the water. C. Net less than one-half in the water. Volume of water sampled was equal to the net area times 200 cm. Net contact with the pool floor remains 5 cm wide regardless of pool depth.

RESULTS

Table 3.2 illustrates the average pool transect collection depths as well as some information about changes in pool conditions. Several of the smaller pools dried up in early April and only five pools (Numbers 1, 17, 35, 22, and 34) were deep enough to include in this collecting system after the first of May. A shallow collection in Pool 38 (that did not contain Branchiopods) is not considered because this pool reflooded after drydown. Only two pools (Numbers 17 and 1) had surface water in June. The only collection in July was the last collection made in Pool 17 on 7 July and this collection did not contain any Branchiopods.

Lepidurus packardi

Density index

Table 3.3 provides a summary of the density indices for all collections of *Lepidurus packardi*. *Lepidurus packardi* was collected in ten pools and indirectly determined to be present in three additional pools. The density indices range from over 80 to under 10 individuals per square meter of pool floor sampled.

Size class analysis

Lepidurus packardi carapace measurements (used to reflect age class differences) were grouped to represent individuals under 3.5 mm, and in 2 mm categories starting with 3.5. This meant that individuals estimated to be 9.5 or larger were considered adults. Although the same collections were used to estimate density, individuals collected with other methods could be included in this analysis. The size class distributions of collections for individual pools were placed in standard weeks. This system considers the resolution of the week to be more effective than individual days.

Table 3.4 illustrates *Lepidurus packardi* carapace measurements for Pool 36. The break in the size classes on week 10 is assumed to indicate a division between the first and second generation individuals. The small individual collected in week 12 represents a late first generation hatch and the bulk of this collection represents the second generation. The final collection on week 15 is assumed to represent 100% second generation adults. This pattern was observed in scattered observations of April drydown pools (including pool 16, see below).

Tables 3.5 and 3.6 illustrate *Lepidurus packardi* carapace measurements for Pools 22 and 34. In combination these collections indicate a first generation generally mature by the 10th week and followed by a second generation that was dominantly mature on the 20th week. On May 18, Alexander observed living individuals in the pools before noon and a total mortality by 17:00. Measurement of dead individuals on the surface indicate that more than 98% of these individuals were greater than 9.5 mm in carapace length. At this time, the

Table 3.2. Average depth for all two meter quantitative collections made for vernal pool invertebrates on Vina Plains Preserve in 1995. Pools ranked with the highest estimated surface area by King (1992) to the left.

	Pool																
	17	1	35	14	22	21	36	34	29	37	16	38	18	40	42	41	30
7-Mar							10										
11-Mar								20				21					
14-Mar								23									
16-Mar			26														
21-Mar							20										
23-Mar											20						
28-Mar	43																
30-Mar					18					10				13	13	10	
4-Apr		34				13			9								5
6-Apr				17									6		M	M	
13-Apr			21				8								M	D	
18-Apr	40														D		
20-Apr					15												
25-Apr		25					M	8			M	M	M				
27-Apr			19		8												
2-May	40						M				7	M			M		
4-May		28															
9-May			16				D	6				7					
11-May	38				7						M	D					
13-May		26									M						
18-May	38		15	M	7			4			M		D				
23-May		22			D			M									
25-May	35																
29-May			10														
4-Jun		15															
8-Jun	26		D														
13-Jun		8															
16-Jun	22																
23-Jun		7															
7-Jul	9	D															
14-Jul	M																

M Pool floor with mud (if water present it was very shallow)
D floor dry

Table 3.3. Density index for Lepidurus packardi. Density is given in individuals per square meter of pool floor. Density was determined by estimating the surface area of pool floor sampled. Pools with the highest single density are ranked to the left. The population dynamics were distinctive in different types of pools. This species was not observed in Pools 18, 43 and the series of pools including Pool 40. The double line box indicates times of observed total natural mortality. The single line box indicates times of observed partial natural mortality.

	Pool														
	22	36	35	34	42	1	38	16	17	41	29	30	37	14	21
4-Mar															
7-Mar		45													
11-Mar				22			13								
14-Mar				9											
16-Mar			22												
21-Mar		33													
23-Mar								12							
28-Mar									2						
30-Mar	82				20					1			*		
4-Apr						8					*	*			*
6-Apr														*	
13-Apr		7	16												
18-Apr									7						
20-Apr	48														
25-Apr				12		7									
27-Apr	7		8												
2-May								*	8						
4-May						11									
9-May			9	3			0								
11-May	9								10						
13-May						14									
18-May	[[6]]		3	[[5]]					5						
23-May						11									
25-May									6						
29-May			[5]												
4-Jun						4									
8-Jun									3						
13-Jun						[1]									
16-Jun									2						
23-Jun						[**]									
7-Jul									*						

* exoskeletons in the water indicate individuals were previously in these pools

** individual observed, none collected in quantitative samples.

Table 3.4 Carapace lengths of Lepidurus packardi collected in Pool 36, Vina Plains Preserve, spring 1995. The numbers represent individuals of a given length collected during any day in the standard week that identifies the column. Density index represents individuals collected per square meter of pool floor.

			March			April			
	Standard week >		10	11	12	13	14	15	TOTAL
	Carapace length								
	MIN	MAX							
	37.5	39.4							
	35.5	37.4							
	33.5	35.4							
	31.5	33.4							
	29.5	31.4							
	27.5	29.4							
	25.5	27.4							
	23.5	25.4							
	21.5	23.4							
	19.5	21.4							
	17.5	19.4			1				1
	15.5	17.4	4		1			1	6
	13.5	15.4	3		6			1	10
	11.5	13.4	4		6			4	14
ADULT	9.5	11.4			2			2	4
JUVENILE	7.5	9.4	1		13				14
	5.5	7.4	12		13				25
	3.5	5.4	12						12
	UNDER 3.5		1		1				2
	Total measured >		37		43			8	88
	Density index >		45		33			7	

Table 3.5 Carapace lengths of Lepidurus packardi collected in Pool 22, Vina Plains Preserve, spring 1995. The numbers represent individuals of a given length collected during any day in the standard week that identifies the column. Density index represents individuals collected per square meter of pool floor. The individuals collected week 20 (18 May) were all dead.

			March			April					May			
	Standard week >		10	11	12	13	14	15	16	17	18	19	20	TOTAL
	Carapace length													
	MIN	MAX												
	37.5	39.4												
	35.5	37.4												
	33.5	35.4												
	31.5	33.4												
	29.5	31.4												
	27.5	29.4												
	25.5	27.4												
	23.5	25.4												
	21.5	23.4												
	19.5	21.4				1								1
	17.5	19.4				2						1		3
	15.5	17.4				3			1					4
	13.5	15.4				4			2			4	2	12
	11.5	13.4				1			2			3	1	7
ADULT	9.5	11.4				3			10	3		1		17
JUVENILE	7.5	9.4				16			2	1				19
	5.5	7.4				8			1					9
	3.5	5.4				3			1					4
	UNDER 3.5													
	Total measured >					41			19	4		9	3	76
	Density index >					82			48	7		9	6	

Table 3.6 Carapace lengths of Lepidurus packardi collected in Pool 34, Vina Plains Preserve, spring 1995. The numbers represent individuals of a given length collected during any day in the standard week that identifies the column. Density index represents individuals collected per square meter of pool floor. One living individual was collected on week 20 (18 May) before noon, all others died between noon and 17:00 that day.

			March			April					May			
	Standard week >		10	11	12	13	14	15	15	17	18	19	20	TOTAL
	Carapace length													
	MIN	MAX												
	37.5	39.4												
	35.5	37.4												
	33.5	35.4												
	31.5	33.4												
	29.5	31.4												
	27.5	29.4												
	25.5	27.4												
	23.5	25.4												
	21.5	23.4												
	19.5	21.4												
	17.5	19.4	1										1	2
	15.5	17.4											4	4
	13.5	15.4	3							1			30	34
	11.5	13.4	2							1			20	23
ADULT	9.5	11.4	8	4								1	2	15
JUVENILE	7.5	9.4	1							8			1	10
	5.5	7.4	2	1						1				4
	3.5	5.4	6	2										8
	UNDER 3.5													
	Total measured >		23	7						11		1	58	100
	Density index >		2.3	0.9						1.2		0.3	0.5	

average length of these first generation individuals was around 13.5 mm carapace length with no first generation individuals collected.

Table 3.7 illustrates *Lepidurus packardi* carapace measurements for Pool 35. The smallest individual probably represents a first generation hatch; however, we cannot be completely certain this is not a late first generation hatch. The development of the second generation is clearly illustrated in the collections after week 13 and it appears that no first generation individuals were collected after this date.

Table 3.8 illustrates *Lepidurus packardi* carapace measurements for Pool 1. This is similar to the pattern observed in Pool 35 and it includes a very large first generation individual collected on week 18.

Table 3.9 illustrates the combined Lepidurus *packardi* carapace measurements for Pools 16 and 17. These were combined because the pools were connected by high water and the only collection from Pool 16 was week 12. Pool 17, the deepest pool, also contained a very large first generation *Lepidurus packardi* collected during week 18.

The carapace lengths of single date collections of *Lepidurus packardi* from Pools 38, 41 and 42 are not been presented in tabular form.

Mortality

Sixty-two dead *Lepidurus packardi* were measured during this study and two disarticulated corpses were observed. On 18 May, Alexander observed living individuals in Pool 34 at noon and fresh mortality in Pool 22 at 16:30. Because of this mortality observation, Pool 34 was reexamined at 17:00 and large numbers of dead individuals were observed on the pool surface. Fifty-nine individuals were selected out of the hundreds of dead individuals on the surface of this pool to determine a size class distribution at the time of death (Table 3.6). This sample consisted of one juvenile, 49 non cyst carrying adults and nine individuals carrying cysts. Shore birds were actively observed feeding on these dead individuals before sunset on that day.

Two of the remaining three individuals collected as dead on different days had mold growing on their exoskeletons. The third individual was collected dead from the surface of Pool 1 on 23 June. This individual appeared very similar to those collected on May 18. Some reduced active soft or gray individual *Lepidurus packardi* were also observed on several different dates in different pools.

Table 3.7 Carapace lengths of Lepidurus packardi collected in Pool 35, Vina Plains Preserve, spring 1995. The numbers represent individuals of a given length collected during any day in the standard week that identifies the column. Density index represents individuals collected per square meter of pool floor.

			March			April					May				June		
	Standard week >		9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	TOTAL
	Carapace length																	
	MIN	MAX																
	37.5	39.4																
	35.5	37.4																
	33.5	35.4																
	31.5	33.4																
	29.5	31.4																
	27.5	29.4																
	25.5	27.4			1													1
	23.5	25.4	1		1													2
	21.5	23.4			3													3
	19.5	21.4	1													1		2
	17.5	19.4			2				1				1	1				5
	15.5	17.4	2		3								3	1		3		12
	13.5	15.4	5		3				2		1		12	2				25
	11.5	13.4	6		11								1	1		1		20
ADULT	9.5	11.4	6		7				1		1		4					19
JUVENILE	7.5	9.4	1		2				1		2		5					11
	5.5	7.4			1				1		1		1					4
	3.5	5.4	1		4				1		1							7
	UNDER 3.5				3				6									
	Total measured >		23		41				13		6		27	5		5		111
	Density index >		*		22				16		8		9	3		5		

* Collections made March 4 did not use the standard technique to estimate the density index

Table 3.8. Carapace lengths of Lepidurus packardi collected in Pool 1, Vina Plains Preserve spring 1995. The numbers represent individuals of a given length collected during any day in the standard week that identifies the column. Density index represents individuals collected per square meter of pool floor.

			March			April					May				June				
	Standard week >		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	TOTAL
	Carapace length																		
	MIN	MAX																	
	37.5	39.4																	
	35.5	37.4																	
	33.5	35.4																	
	31.5	33.4																	
	29.5	31.4									1								1
	27.5	29.4												1					1
	25.5	27.4												1					1
	23.5	25.4										2		1				1	4
	21.5	23.4										1				1			2
	19.5	21.4					2					2		2					6
	17.5	19.4					1				1	5		7			1		15
	15.5	17.4					1				3	2		1		4			11
	13.5	15.4					4			3	2	1		2		1			13
	11.5	13.4										3		5					8
ADULT	9.5	11.4									4	1		3					8
JUVENILE	7.5	9.4									2	2							4
	5.5	7.4								1									1
	3.5	5.4								3	1								4
	UNDER 3.5																		
	Total measured >						8			7	14	19		23		6	1	1	79
	Density index >						8			7	11	14		11		4	1	*	

* Individual observed, no individuals collected in quantitative samples.

Table 3.9. Carapace lengths of Lepidurus packardi collected in Pools 16 and 17, Vina Plains Preserve, spring 1995. The collection on the 12th week is the only collection from pool 16. These pools were connected by high water just before this collection and pool 16 dried a few weeks following. The numbers represent individuals of a given length collected during any day in the standard week that identifies the column. Density index represents individuals per square meter of pool floor.

			March			April					May				June			
	Standard week >		10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
	Carapace length																	
	MIN	MAX																
	37.5	39.4									1							1
	35.5	37.4																
	33.5	35.4											1					1
	31.5	33.4							1									1
	29.5	31.4																
	27.5	29.4									3	2						5
	25.5	27.4							1		1							2
	23.5	25.4				1			1		1	1	1	2				7
	21.5	23.4										1		1		2	2	6
	19.5	21.4			2				1		1	1	2	3		1		11
	17.5	19.4			2							2	1	4		2		11
	15.5	17.4			1				2			1	1	2				7
	13.5	15.4			1				1		4	4						10
	11.5	13.4			1						1	2						4
ADULT	9.5	11.4			2						1							3
JUVENILE	7.5	9.4			1	1												2
	5.5	7.4			1	2			4									7
	3.5	5.4							3									3
	UNDER 3.5																	
	Total measured >				11	4			14		13	14	6	12		5	2	81
	Density index >				12	2			7		8	10	5	6		3	2	

Life history differences between pools

Table 3.10 illustrates some general life history features of *Lepidurus packardi* from the major 1995 collections.

Branchinecta conservatio

Density index

The density indices for all collections of *Branchinecta conservatio* are provided in Table 3.11. This species was identified in collections from seven pools. A more detailed analysis of these collections is presented in the performance curves for the three major collections in Pool 35 (Figure 3.2).

Proportion of mature females carrying cysts

The percentages of mature female *Branchinecta conservatio* carrying cysts in egg sacs in relation to the total collection are provided in Table 3.12.

Observed mortality

Two collections recorded the predation of *Branchinecta conservatio* by *Lepidurus packardi.* On 16 March, Alexander observed a male *Branchinecta conservatio* in the jaws of a 7 mm *Lepidurus packardi* collected from Pool 35. On 28 March, Alexander observed an individual *Branchinecta,* impossible to sex, in the jaws of a 25 mm female *Lepidurus packardi* collected from Pool 17. On the same transect a disarticulated *Branchinecta conservatio* corpse was observed that was assumed to have been killed by one of the tadpole shrimp in the same collection. An adult beetle was also observed feeding on a *Branchinecta conservatio* in another collection.

Life history differences between pools

Four of the pools contained well-established populations of *Branchinecta conservatio* (1, 17, 22 and 35). Observations of small numbers of *Branchinecta,* including *Branchinecta conservatio* females, were made in Pools 34, 38 and 16. At these low densities individuals could be missed in a spot survey. Seven of these nine individuals collected were females. A single male *Branchinecta* was collected from Pool 42. Although it is assumed that all these collections represent low density *Branchinecta conservatio* populations, it would have been more effective to examine these individuals in more detail with a field microscope.

Table 3.10. Some generalized life history dynamics of Lepidurus packardi determined during 1995 from select pools, in Vina Plains Preserve.

Pool	Second generation hatch	Density index (individuals/meter square) juveniles and adults	Density index (individuals/meter square) adults only (late season)	Maximum carapace size of adults/ date	Time of pool drydown
36	Before observations to late March	33 to 45	7	19 mm. / 21 March	mid April
22 and 34	Before observations to mid April	4 to 41	0.5 to 9	19mm. / 30 March	late May
35	Early March to mid April	9 to 22	3 to 5	27mm. / 16 March	early June
1	Mid April to early March	7 to 14	1 to 11	31mm. / 4 May	early July
17	Mid April to early March	7 to 12	2 to 10	39 mm. / 2 May	mid July

NOTES:
Pool 36 represented many other pools on the preserve. Tadpole shrimp killed by drydown (Table 3.4).
Pools 22 and 34 had total mortality on 18 May before pool dry down (Tables 3.5 and 3.6).
Pools 35, 1 and 17 have a generally similar pattern:
Pool 35 mortality on 29 May before dry down (Table 3.7).
Pool 1 mortality on 23 June before dry down (Table 3.8).
Pools 17 mortality late June. Living individuals collected 16 June and no living individuals collectred on 7 July (Table 3.9).

Table 3.11. Density index of Branchinecta conservatio given in individuals per cubic meter of water. This is determined by estimating the volume of water sampled. Pools with highest single density are ranked to the left. Collections made in pools 14, 18, 21, 29, 30, 36, 37, 40 & 41 did not contain this species.

	Pool							
	22	35	1	17	34	38	16	42
	*	*			*	*	*	* **
4-Mar		***						
7-Mar								
11-Mar					17	11		
14-Mar					10			
16-Mar		84						
21-Mar								
23-Mar							5	
28-Mar				31				
30-Mar	99							4
4-Apr			60					
6-Apr								
13-Apr		30						
18-Apr				3				
20-Apr	3							
25-Apr			35		0			
27-Apr	6	18						
2-May				9			0	
4-May			12					
9-May		0			0	0		
11-May	0			0				
13-May			3					
18-May	0	0		0	0			
23-May			0					
25-May				0				
29-May		0						
4-Jun			0					
8-Jun				0				
13-Jun			0					
16-Jun				0				
23-Jun			0					
7-Jul				0				

* Pools also contained Linderella occidentalis.

** A single Branchinecta male was observed and species verification was not possible.

*** Samples taken before the density technique was developed.

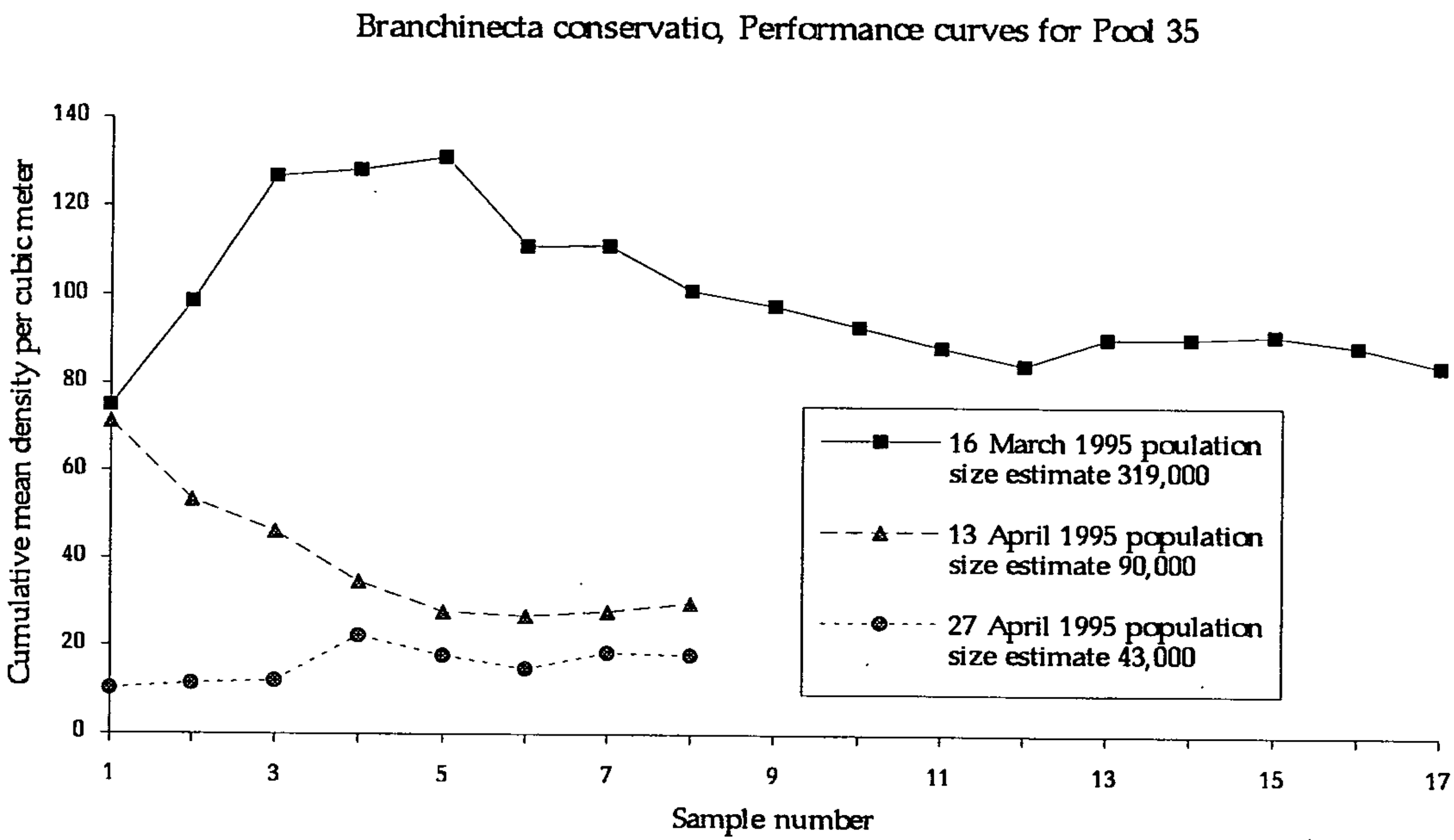


Figure 3.2. Performance curves for Branchinecta conservatio collected in pool 35, Vina Plains Preserve. As the cumulative mean levels out this indicates an appropriate sample number has been collected. Sample variability was still high. Total population estimates made using depth at the same depth stake used by Syrdahl (1993) and her pool volume estimates.

Table 3.12. The number and percent of mature female Branchinecta conservatio carrying cysts in egg sacs. Restricted to collections of ten or more individuals.

Date	Pool no.	n	percent mature female	females > .5 of total
16-Mar	35	139	48%	NS
28-Mar	17	71	48%	NS
30-Mar	22	36	53%	NS
4-Apr	1	59	78%	*
13-Apr	35	21	62%	NS
25-Apr	1	33	64%	NS
27-Apr	35	11	73%	NS
2-May	17	14	71%	NS
4-May	1	15	53%	NS

NS = not significant ($P>0.05$); * $P < .01$:

Linderiella occidentalis

Density index

The density indices for all collections of *Linderiella occidentalis* are provided in Table 3.13. A density index was determined from one or more collection from 11 pools. Additional observations made on a series of pools next to Sheep Camp Ditch, information from Shelly Kirn (*personal communication*), and records from previous years (Syrdahl, 1993 and Alexander's *personal observations*) indicate that four additional pools (14, 29, 30 and 40) potentially support *Linderiella occidentalis*. Pools 1 and 17 did not contain *Linderiella occidentalis* in 1995 and this species was not observed in these pools in collections made in past years.

Branchinecta compared

Individual *Cyzicus californicus* were observed in Pools 17 and 22. Although this collection technique does not develop a good density index for this species, the sequential collections were frequent enough to project this species as absent from the other pools considered. Table 3.14 considers the relative ability to produce cysts for the four species of large Branchiopods observed during spring 1995.

DISCUSSION

Lepidurus packardi

The *Lepidurus packardi* examined in the pan were in excellent shape. Activity often made it hard to obtain a measurement of the carapace length. Mature individuals appear strong enough to resist considerable manipulation during collection. Changes in exoskeleton coloration and rigidity may indicate the individuals are near death. The reduced active soft or gray individual *Lepidurus packardi* could be individuals that have freshly molted (*personal communication*, Sean Gallagher). If the collection system damaged individuals, these collections should have contained more damaged individuals. The collected individuals also did not display atypical movement of the appendages.

Because individuals were collected and returned to the pool in viable condition, it is conceivable but statistically unlikely that the same individuals were collected on more than one date. Collections displaced by weeks can be used to represent the continued growth through the season. This detailed analysis of length measurements displays unique life history differences that help identify hatching classes. These patterns produce different changes in size class distributions in different pools during one year and differences in the same pools during different years.

Table 3.13. Density index for Linderiella occidentalis. Density is individuals per cubic meter of water. Density was determined by estimating the volume of water sampled. Pools with the highest single density are ranked to the left. Pools 1 and 17 have never contained Linderiella occidentalis according to previous observations by Alexander and those reported by Syrdahl in 1992 (1993).

	Pool												
	42	22	16	38	35	21	41	36	34	18	37	14	40
4-Mar					*							**	
7-Mar								26					
11-Mar				111					12				
14-Mar									12				
16-Mar					70								
21-Mar								4					
23-Mar			124										
28-Mar													
30-Mar	847	149					29				3		*
4-Apr						50							
6-Apr										5		0	
13-Apr					102			6					
18-Apr													
20-Apr		82											
25-Apr									11				
27-Apr		73			13								
2-May			0										
4-May													
9-May				0	30				0				
11-May		4											
13-May													
18-May		0			1				0				
23-May													
25-May													
29-May					0								

* Observed but no quantitative values determined.

** Individuals observed in this pool in 1995 by Shelly Kim.

Table 3.14. Estimated relative cyst production of the Branchiopods collected from Vina Plains Preserve. These values were determined during 1995 from select pools.

Pool number	*Lepidurus packardi*	*Branchinecta conservatio*	*Linderiella occidentalis*	*Cyzicus californicus*
17	H	H-M	A	P
1	H	H-M	A	A
35	H	H	H	A
22	M	H	H	P
36	L	A	L	A
34	M	L	L	A
16	L	L	H	A
38	M-L	L	H	A
18	A	L	L	A

H High cyst production estimated for 1995.
M Medium cyst production estimated for 1995.
L Low cyst production estimated for 1995.
P Present (cyst production not estimated)
A Absent

First generation adults kept growing and a few representatives of the first generation were collected as the second generation individuals come into the collections. This allowed the production of very large individuals (Table 3.10). The number of cysts produced keeps increasing as individuals get larger. The so-called second generation could also represent a second hatch of cysts from the cyst bank. If this did occur it would be anticipated to be triggered by physical factors such as a heavy rain. Ahl (1983) demonstrated the ability of tadpole shrimp to produce viable cysts that hatch during the same pond cycle. Her laboratory experimentation illustrated a hatch strongly controlled by temperature with over 70% hatch at 10° C and around 10% hatch at 20° C. These observations by Ahl (1983) and the sequential nature of these observations support the second generation hypothesis.

Individuals with cysts were observed in all collections indicating there were at least some first generation adults depositing cysts before the collection system was initiated. The collection of small juvenile individuals was taken to indicate a time following cyst hatch. Depending on pool temperature and food availability, it is assumed to take a few weeks for these newly hatched individuals to reach minimum adult size.

The last prereproductives were collected in quantitative collections in Pools 35, 17 and 1 during the first week of May. One 9 mm individual (considered prereproductive) was observed out of 56 dead individuals measured during the day of total mortality in Pools 22 and 34. Although physical factors were not measured on that day, this population mortality was potentially caused by the low dissolved oxygen associated with higher water temperatures.

The late season collections in the three larger pools were dominantly second generation adults with a few large adults representing first generation individuals. Alexander observed surface mortality of a few individuals, similar to Pools 22 and 34, in Pool 35 on 9 June. One individual was collected from Pool 1 on 13 June and no individuals were collected with the same effort on 23 June, although one moribund individual was observed on the surface that day. Pool 17, the deepest pool, maintained a very low density through the collection of 16 June and no individuals were collected in July. It is assumed that the remaining individuals in these Pools (1 and 17) were eventually killed by similar environmental factors that caused the 18 May mortality in shallower pools and the mortality observed on 9 June in Pool 35. It is also assumed that the cysts on the dead individuals were viable.

These 1995 observations indicate that the pools can be grouped into three groups on the basis of *Lepidurus packardi* life history patterns: 1. The larger pools (1, 17 and 35) appear to have the largest cyst contribution by both first and second generation individuals. 2. The two medium pools (22 and 34) have smaller adults, and, most of the second generation became adults before mortality. 3. The smaller pools (36 and a number of other pools) have reduced cyst production by first and second generation adults.

Branchinecta conservatio

The *Branchinecta conservatio* populations disappeared from the pools before the water had completely evaporated. The last collection date involved only a few individuals with low density that could be missed in a spot survey. With the exception of Pool 42, which contained a single male *Branchinecta* in the sample, all these collections involved females as well as males. At late season dates, after the populations were gone, there was no way, other than by habitat characteristics, to determine if this species breeds in a pool. The highest density estimates were observed in early season collections in the same pools that contained individuals into late April or early May (Pools 1, 22, 35, and 17). This species was only observed after the first of May at low densities in two pools (Pools 1 and 17). Individuals were mature at the first collection in March and premature individuals were not collected. As a result, these populations did not receive any new individuals after the collection program was initiated. The drop in density represents mortality. In Pool 35, the density in late April was only 15% of the density in the first March collection (Figure 3.2). Although individuals are apparently continually producing additional cysts, the cyst production during the early high density periods will make the largest contribution to the cyst bank. The one collection without a 1:1 sex ratio (Table 3.12) potentially represents a collection made before all the females were mature enough to have visible cysts in the egg sac. The presence of cysts in all the other females, can be interpreted to indicate a rapid replacement of any cysts that are ejected into the pool water.

This collection effort concentrated on a limited number of pools and did not survey all the pools on the preserve. Syrdahl (1993) reported on *Branchinecta conservatio* in seven of the 14 pools she considered in 1992 and her collection records indicate that three of these contained only a few individuals. The observations with major populations in only four pools (1, 17, 22 and 35) supports these observations. The three pools that had low numbers of *Branchinecta conservatio* appear to be populations maintained by dispersal from the larger pools. These three pools (16, 34 and 38) are all located within 50 meters of the large pools. During 1995, there was a water connection between 16 and 17 (*personal communication,* Sean Gallagher) which may account for this dispersal. In 1992 Syrdahl did not observe any *Branchinecta conservatio* in Pool 16.

Special collections will be required to establish the presence of viable populations in many pools. It would be beneficial to have taken voucher specimens of the only two *Branchinecta* that were collected in Pool 38 because Syrdahl reported *Branchinecta lynchi* from this pool. However, this would have involved the preservation of the only two individuals (one male and one female) observed in this small pool, which is against good conservation principles. Field observations of the individuals, without microscopic aid, indicated that they were *Branchinecta conservatio.*; however, the collection analysis indicates that more specific care should be used. If this research is renewed, the observations made in midsize pools that should receive specific effort to eliminate this confusion.

Some of the dead *Branchinecta conservatio* were corpses with aquatic fungi forming a film on the exoskeletons, indicating they had been dead or dying before capture. It is unlikely that the collection technique facilitated the predation of *Branchinecta conservatio* by *Lepidurus packardi* because of the large number of individuals captured where no predation was observed. The two cases where predation was clearly observed involved large parts of the fairy shrimp already consumed. It is hard to believe that this level of consumption can be achieved in the minute or two time gap between collection and observation. However, the potential for the collecting system to facilitate a natural predation pattern cannot be completely removed.

General discussion

The Branchiopods considered in this study initiated their development after a cold-water flooding of pool basins. These species take several weeks to mature. The collections in this survey were initiated after the pools had eight to ten weeks of inundation. This aquatic phase previous to the collection program included an interstorm period with some solar warming of pools. As a result, this study did not have to contend with the collection and identification of early developmental stages.

The collection technique described allows a series of replicate collections where individual macroinvertebrates are retained in water samples, observed and returned to the pool in only a few minutes. Net mesh size, as well as population density, will determine how frequently a net should be examined. A course net is less likely to become jammed with organisms and non living material collected in the net. Although two meters is a good general value, common sense should be used to determine when a net is full because pool conditions will vary. Additional problems will develop if collections are made earlier in the year when collections of early developmental stages will require a finer mesh net. These collections will also have high density of other invertebrates such as copepods. Shallow pools with high algal growth, emergent vegetation, or large insect communities will also potentially require a modified collection technique.

The staggered collection times and the differences between pools make a statistical comparison of density indices suspect. A comparison of density indices between pools requires the difficult determination that the populations are at the same life history stage at the time of collection. Individual pools are different from each other because of a variety of factors including the more obvious differences in flooding history. This means that collections in a pool complex taken at the same date are actually examining population at different life history stages.

These populations have an aggregated pattern with large numbers in a few collections and numerous collections without individuals. This observation of aggregation indicates that reliable population estimates will require a very large number of samples. Beyond this problem, determining the number of individuals per collection effort is less effective unless the volume of the pond is also estimated. The astatic nature of vernal pools means that low densities can be caused by a rapid increase in pool volume. A test of this hypothesis would require detailed information on pool volume determined at the same time the collections were made. The irregular nature of many pool basins requires considerably more effort than simply determining pool depth and width in a few select locations.

The collection of corpses of previously deceased individual *Branchinecta conservatio* and apparently moribund *Lepidurus packardi* indicates that mortality occurs besides predation. The collection and observation of these inactive dead and moribund individuals attests to the efficiency of this collection technique

It is hard to find a common pattern when considering all species. The largest pools are the most important for both *Lepidurus packardi* and *Branchinecta conservatio*. Because the reproductive activity of *Branchinecta conservatio* is completed earlier in the season, Pool 22 is also important. The absence of *Linderiella occidentalis* from the two larger pools (1 and 17) is striking. The density differences of *Branchinecta conservatio* between the two populations with and without *Linderiella occidentalis* are not great but the two larger pools with only one Anostraca actually had lower observed densities. The observation of a water connection that could carry *Branchinecta conservatio* from Pool 17 to 16 is interesting because *Linderiella occidentalis* was not found in Pool 17. A partial explanation relates to the direction of water movement at the time of connection (from 17 to 16). If *Linderiella occidentalis* did move from 16 to 17 during the 1995 water connection, the density in Pool 17 was too low to detect. Considering the possibility of bird, as well as water transport, it appears that *Linderiella occidentalis* does not survive in Pool 17 (or Pool 1).

The Anostraca at Vina and elsewhere appear to form a series in terms of habitat selection. *Branchinecta conservatio* depends upon the larger pools, although it is also found in medium size pools. *Linderiella occidentalis* is found in medium size pools, and*Branchinecta lynchi* is found only in the smaller pools (Gallagher 1996, Syrdahl 1993)

These observations indicate the importance of considering life history dynamics of individual species in a variety of pool types when considering management and preservation strategies. The problem of estimating population size becomes fundamental to understanding the impact of specific species on energy flow and nutrient cycling. Population size information is also basic to determining the impacts of predation. These issues cannot be restricted to the consideration of single pools. Many vernal pool invertebrates form metapopulations with dispersal between pools and have the potential of hatching diapause stages produced years previously.

These large populations with their unique dispersal and diapause characteristics will be anticipated to have a very high heterozygosity and the problems of genetic restriction so common with endangered vertebrates will be unlikely. The large numbers of individuals indicate that the unique habitat characteristics are more important for species preservation than concern about individual organisms.

Chapter 4
VASCULAR PLANTS

Three major objectives were established prior to fieldwork: 1. to produce maps for all the known populations of rare plants (*Chamaesyce hooveri, Orcuttia pilosa, O. tenuis,* and *Tuctoria greenei*) on the main tract of the Vina Plains Preserve, and to provide population descriptions based on measures of frequency and density in these pools, 2. to numerically characterize the overall plant communities in these pools containing rare plants and in other selected nearby pools throughout the main tract of the Preserve, and 3. to coordinate information on the plants with information on the macroinvertebrates to produce descriptions of vernal pool communities and ecosystem function, and to use this synthesis to make management recommendations for vernal pools here.

METHODS

Pools chosen for study included nine pools known to contain populations of at least one of the four rare plant species (Broyles 1983), and nine additional pools spaced throughout the preserve. Rare plant populations were not ready for study until late spring and summer, but general vascular plant community analysis was started in March and continued through early August 1995. Work was carried out after each pool dried down and the plants within it were reproducing.

Spring plant communities

A single white-flagged transect crossing from east to west was used in each pool. This transect was subjectively placed near the center (north-south), where it would potentially cross through a deep or the deepest part of the pool, and it would not overlap with the yellow-flagged macroinvertebrate transect. Data collected on this transect are referred to as "spring transect data."

To obtain frequency for each species, a 0.01 m^2 wire sampliing frame was laid down as a quadrat at the beginning of each meter on the transect tape, and presence of all species was recorded on a field data sheet for each quadrat (Appendix 1, Field form for spring). Frequency for each species was then estimated for the pool, as the proportion of quadrats occupied on the entire transect. Additional species that did not occur in quadrats were recorded for each pool.

To obtain crude density for a species that had countable, individual plant bodies, all individuals were counted in the 0.01 m^2 quadrat, at each meter along the entire transect. Density was then estimated (for most species) by averaging the count in all 0.01 m^2 quadrats, and multiplying times

100, to give results in terms of mean plants per square meter. Counts of individuals were not made, and density was not estimated, for several species with sprawling plant bodies (e.g., *Callitriche* and *Marsilea*) or for species with potential vegetative off-sets below the soil surface (e.g., *Isoetes* and *Pilularia*).

The four rare species, if seen as pre-reproductives in the spring transects, were listed as being present but were not further analyzed or graphed to describe the spring plant communities. A more-detailed analysis was carried out for these rare species reproducing during the summer, after most other plants in the pool basins had dried up and the pool floors were surface-dry.

Summer plant communities containing the rare species

A series of parallel transects was used in the summer to determine frequency and density for rare plants. In the largest pools, parallel east-west running transects were laid down every 10 meters from north to south to cover the entire pool. In smaller pools, east-west transects were used every 5 meters (every meter in one case), and in several cases, only the portion of the pool containing the rare plants was sampled with transects.

To obtain frequency for rare plants, species presence was recorded in 0.05 m^2 quadrats, every meter along all transects in a pool (Appendix 2, Field form for summer). Frequency for each species was then estimated for the pool, as the proportion of quadrats occupied on all the transects in that pool. The transects and quadrats were recorded in the proper sequence on a worksheet in Microsoft Excel 5, to produce maps for each rare species in each pool.

To obtain density, stratified-random sampling was carried out, where a number from 1-10 (or 1-5 in smaller pools) was chosen randomly within each 10-meter segment (or 5-meter segment in smaller pools) of each transect. At each of these points all individuals of rare species were counted in the 0.05 m^2 quadrat. Counts in all 0.05 m^2 quadrats were averaged, and crude density for the pool was then estimated by multiplying times 20, to give results in terms of mean plants per square meter.

Mean plants per square meter was multiplied by the estimated total square meters in the pool bed to give an estimate for total population size for the pool. If a rare species occurred in a restricted portion of a pool, mean plants per square meter was multiplied by the size of that region for the estimate of total population size.

In addition, during the summer sampling of rare species, presence (but not density) was recorded for all late-flowering or still-green vascular plants (e.g., *Marsilea, Eryngium, Convolvulus, Xanthium*). Additional species that did not occur in quadrats were also recorded for each pool.

RESULTS

Summer plant communities containing the rare species

Since emphasis in this study is focused on the rare species, data on vascular plant communities in the nine pools sampled during the summer of 1995 are presented here first. Maps for the rare plants, and also for the most common associated species, are shown in Figures 4.1-4.27. All maps have north at the top of the page. Each dotted line represents the width of the pool at that location. All light and bold symbols are one meter apart east-west (horizontally). Maps for *Tuctoria greenei* in Pools 14 (Figures 4.5 and 4.6), 22 (Figures 4.13 and 4.14) and 37 (Figures 4.26 and 4.27) cover only the areas in these pool basins where this species was found. Estimates of density and total population size are given for the rare species (Table 4.1), and frequency measurements are given for both rare and associated species (Tables 4.2-4.3).

Locations in pools, and frequencies, for rare plant populations

Maps are presented for the nine study pools chronologically, by pool number. Each rare species has a map for it that shows the quadrats of occurrence on each of the pool transects, and is thus shown in relation to the total pool size (e.g., *Chamaesyce hooveri* in Pool 1, Figure 4.1). Then each of these maps for a rare species, and also a map for each major associated species is presented in a condensed form, where only the transects are shown and the intervening unsampled areas are omitted (see e.g., *Chamaesyce hooveri* in Pool 1, Figure 4.3). All of these smaller maps are to scale according to width of the pool, and are thus directly comparable as to transect length east to west (right to left). But these maps vary as to degree of "condensation" in the north to south direction (top to bottom); thus pool length is not directly comparable from pool to pool (in some cases the transects were separated by 9 m and other cases by 4 m, etc.). Frequency (as proportion of quadrats occupied) is listed on each map.

Chamaesyce hooveri was found more or less throughout the four pools where it occurred (Figures 4.1, 4.7, 4.17 and 4.21) in 1995. However, in Pool 1, the largest pool on the Vina Plains Preserve, C. *hooveri* was clearly most frequent in the northern half of the pool (Figures 4.1 and 4.3) whereas *Orcuttia pilosa*, the other rare species growing with it, was most frequent in the southern half (Figure 4.2 and 4.3).

Orcuttia pilosa tended to be widely distributed in pools where it occurred (see also Figure 4.8, 4.18 and 4.22).

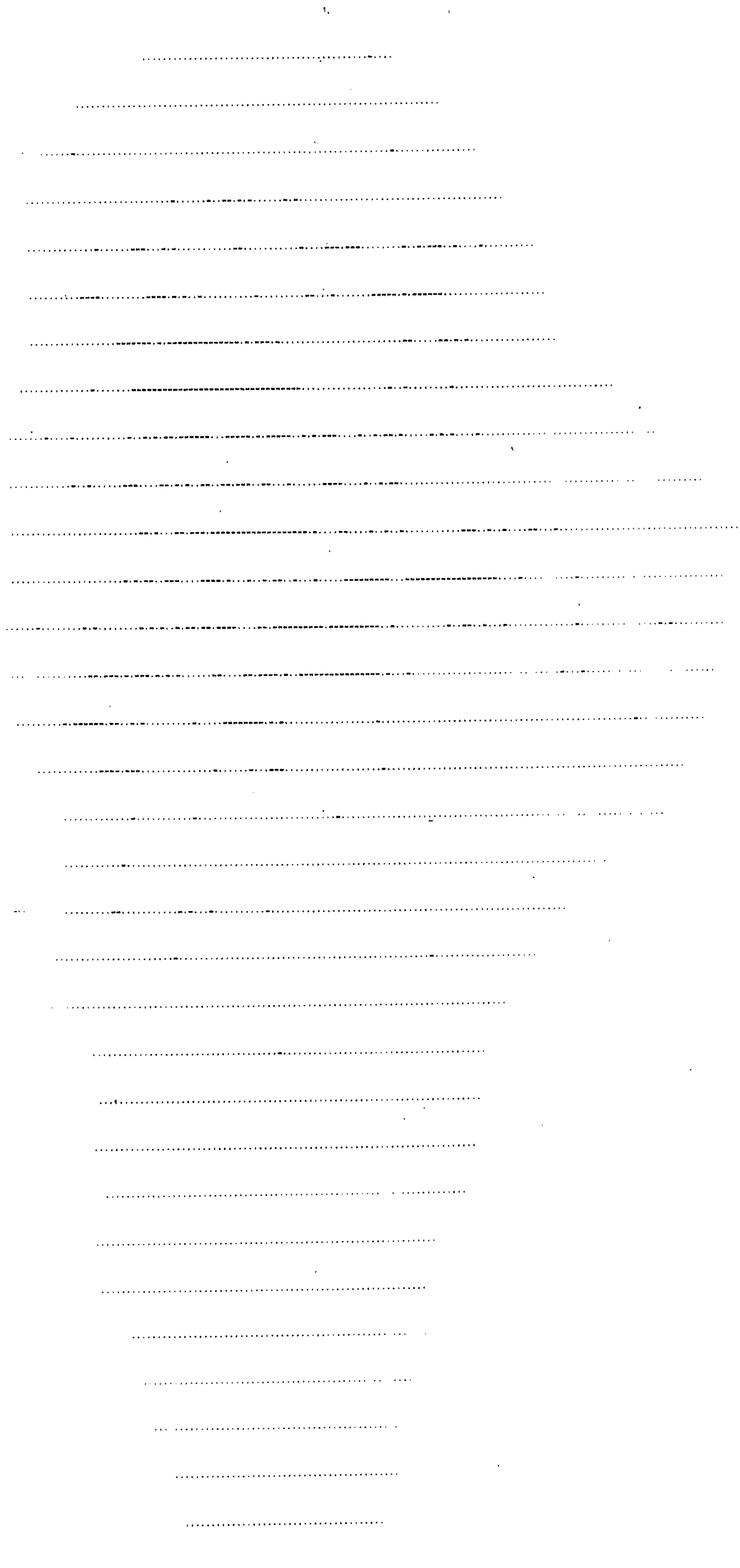


Figure 4.1. Pool 1, Vina Plains Preserve. *Chamaesyce hooveri* presence (bold marks in 420 of the 2997 quadrats shown), on 33 E-W transects, 10 meters apart N-S, covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

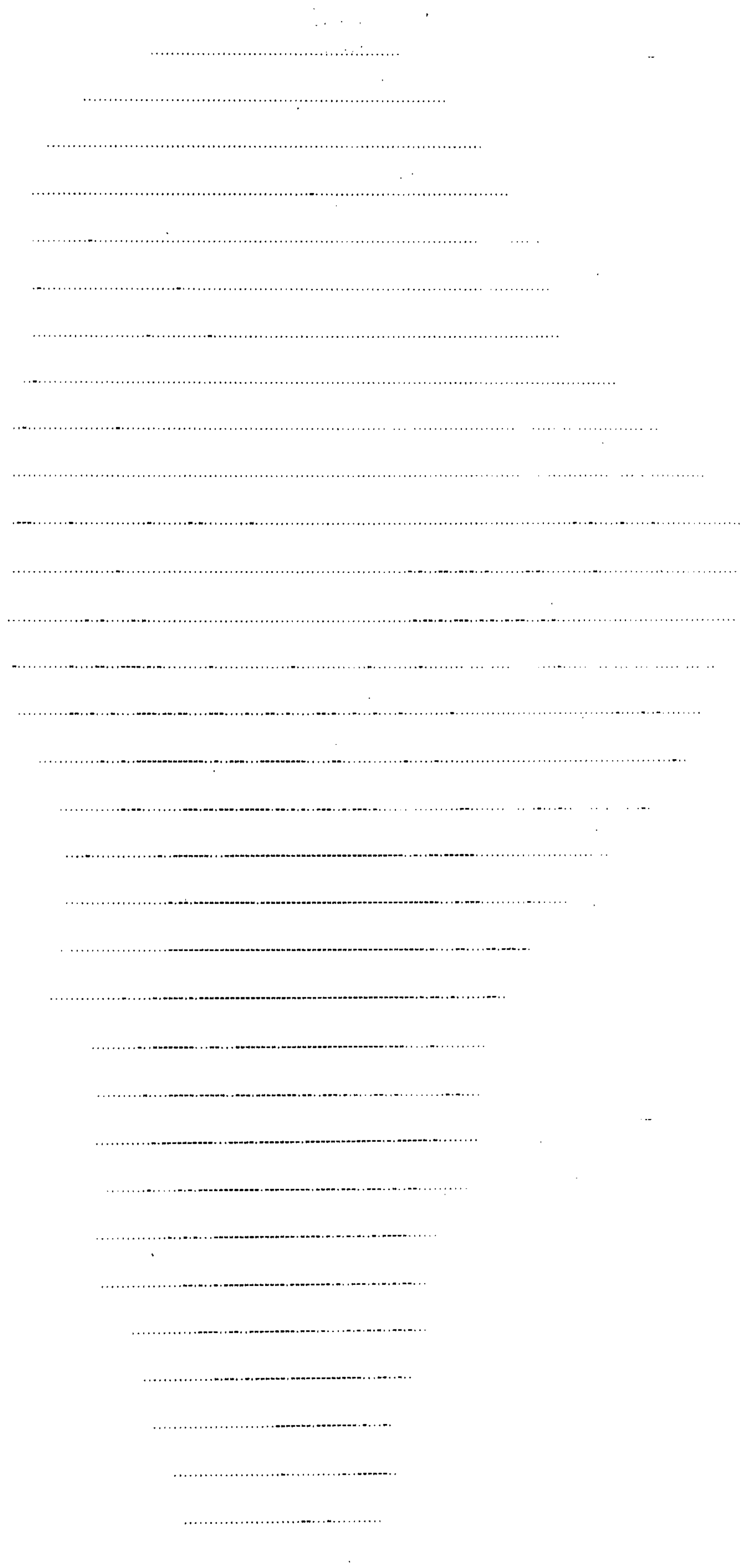


Figure 4.2. Pool 1, Vina Plains Preserve. *Orcuttia pilosa* presence (bold marks in 691 of the 2997 quadrats shown), on 33 E-W transects, 10 meters apart N-S, covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

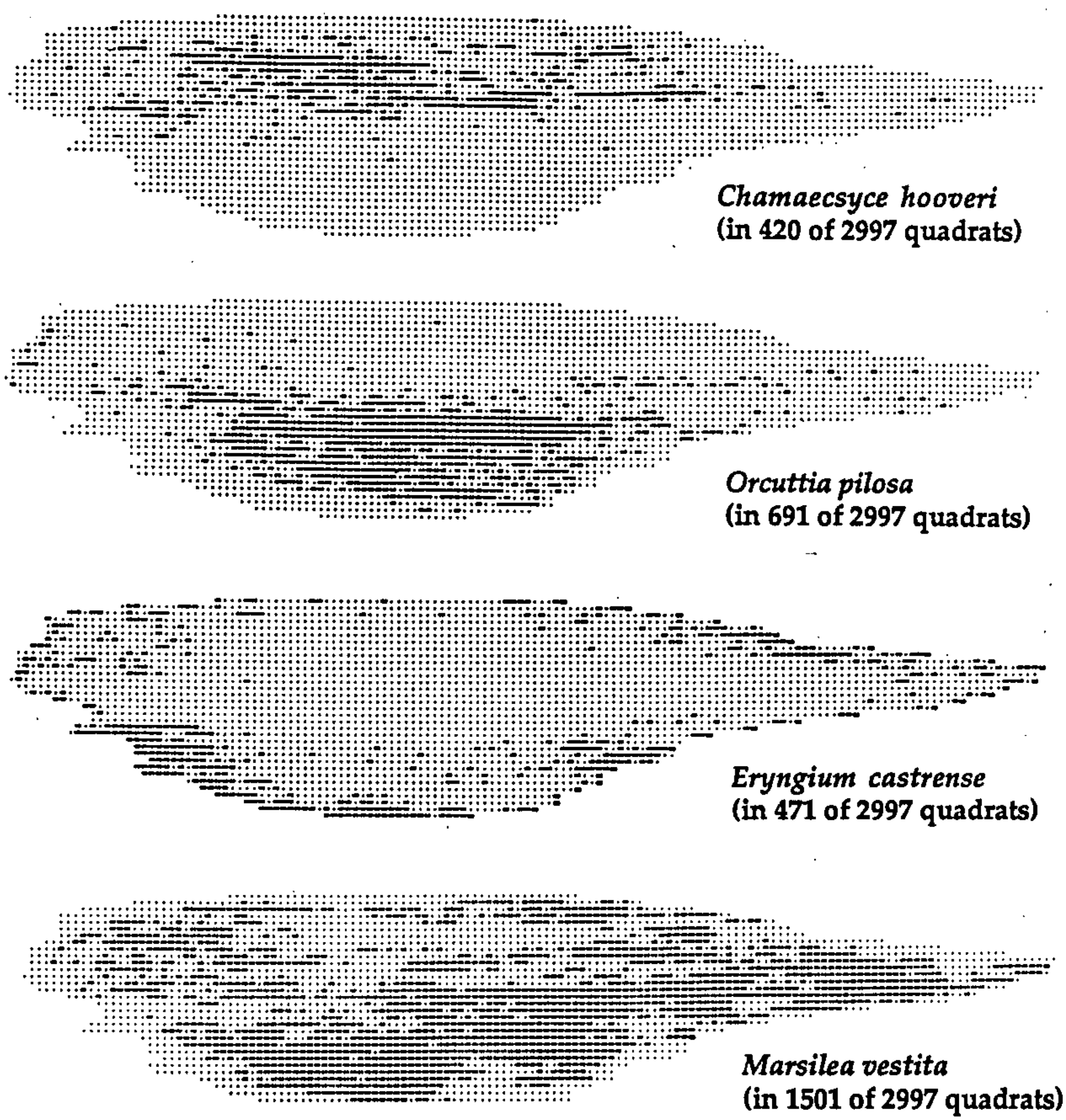


Figure 4.3. Pool 1, Vina Plains Preserve. Species presence (bold marks among the 2997 quadrats shown) on 33 E-W transects, in condensed views for the pool, showing transects only (with all 9-meter distances separating the transects from N-S omitted).

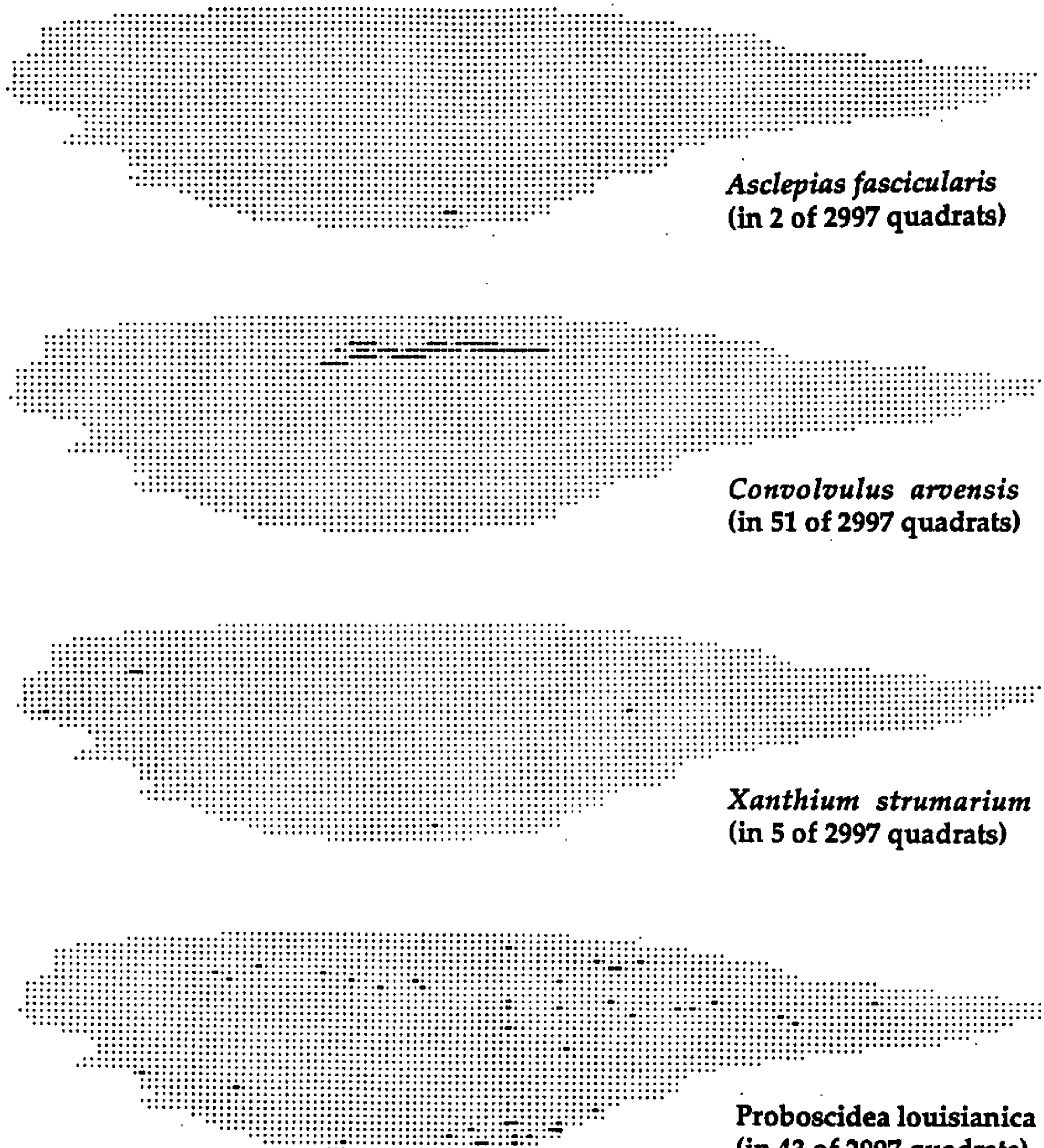


Figure 4.4. Pool 1, Vina Plains Preserve. Species presence (bold marks among the 2997 quadrats shown) on 33 E-W transects, in condensed views for the pool, showing transects only (with all 9-meter distances separating the transects from N-S omitted).

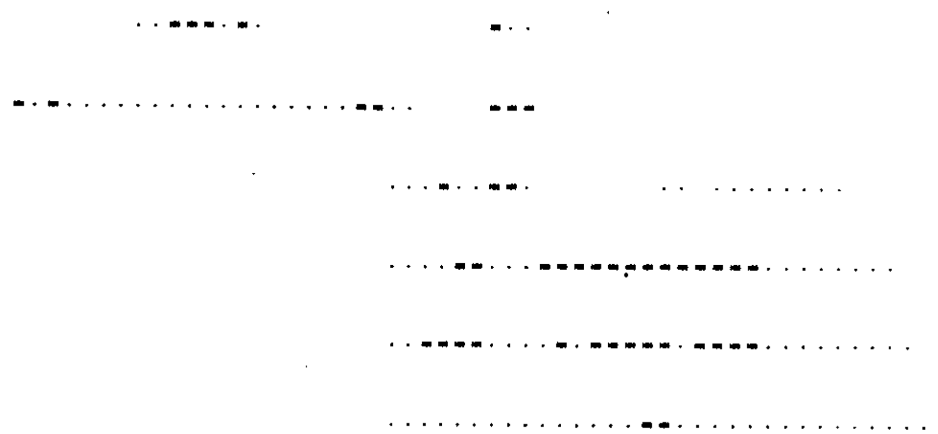
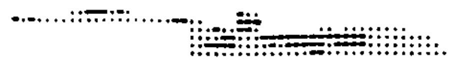
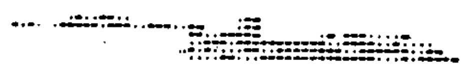


Figure 4.5. Region on the north side of Pool 14, Vina Plains Preserve, that contained *Tuctoria greenei* (bold marks in 46 of the 145 quadrats shown) on 6 E-W transects, 5 meters apart N-S. Although the area shown covered most of the population, about 20 individual plants were found scattered in other parts of the pool.

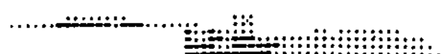
Tuctoria greenei
(in 46 of 145 quadrats)



Eryngium castrense
(in 95 of 145 quadrats)



Marsilea vestita
(in 39 of 145 quadrats)



Eremocarpus setigerus
(in 15 of 145 quadrats)

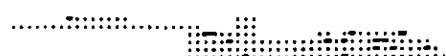


Figure 4.6. Region on the north side of Pool 14, Vina Plains Preserve. Species presence (bold marks among the 145 quadrats shown) on 6 E-W transects, in condensed views (in region of the pool that was sampled for *Tuctoria greenei*.), showing transects only (with all 4-meter distances separating the transects N-S omitted).

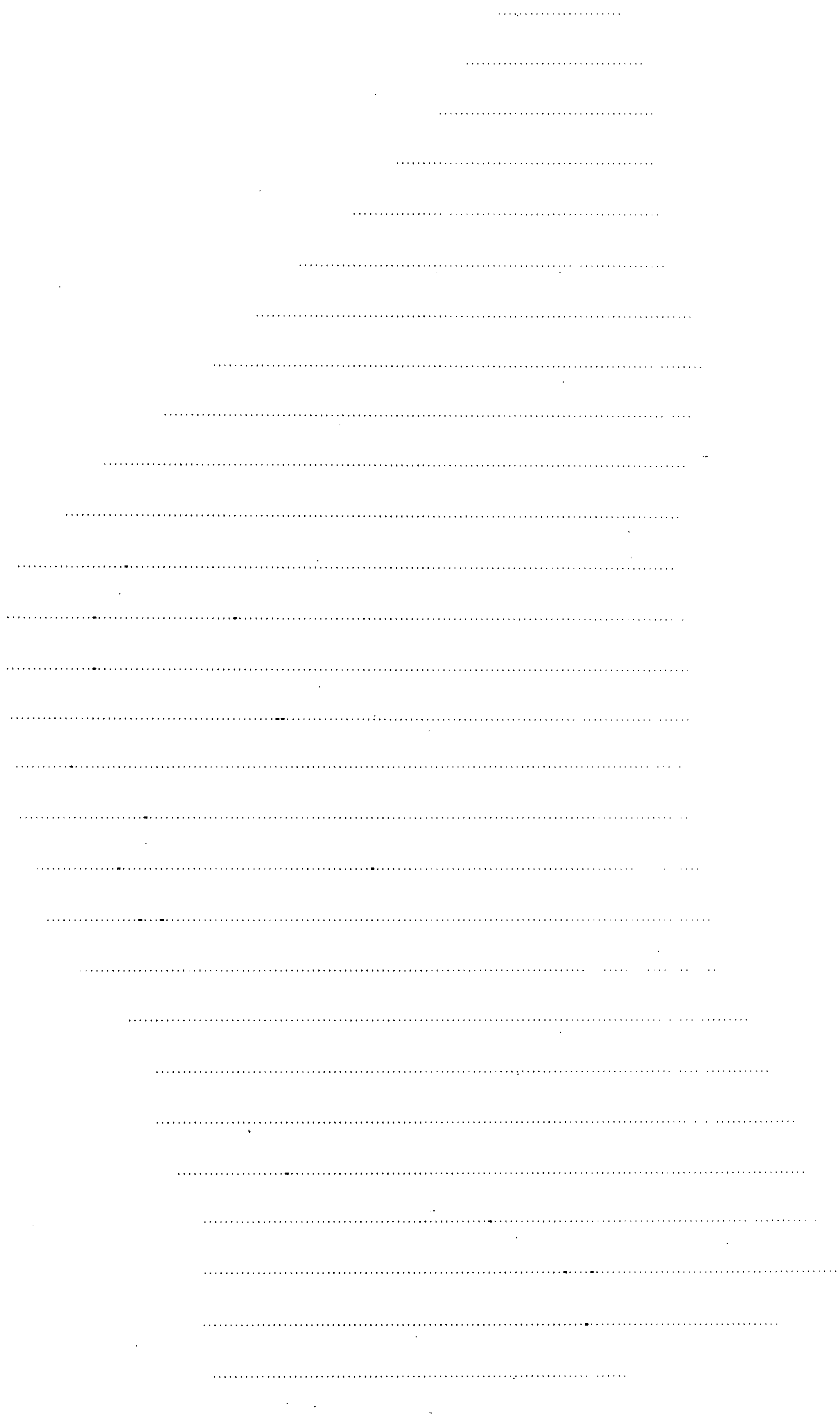


Figure 4.7. Pool 17, Vina Plains Preserve. *Chamaesyce hooveri* presence (bold marks in 17 of the 2824 quadrats shown), on 29 E-W transects, 10 meters apart N-S, covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

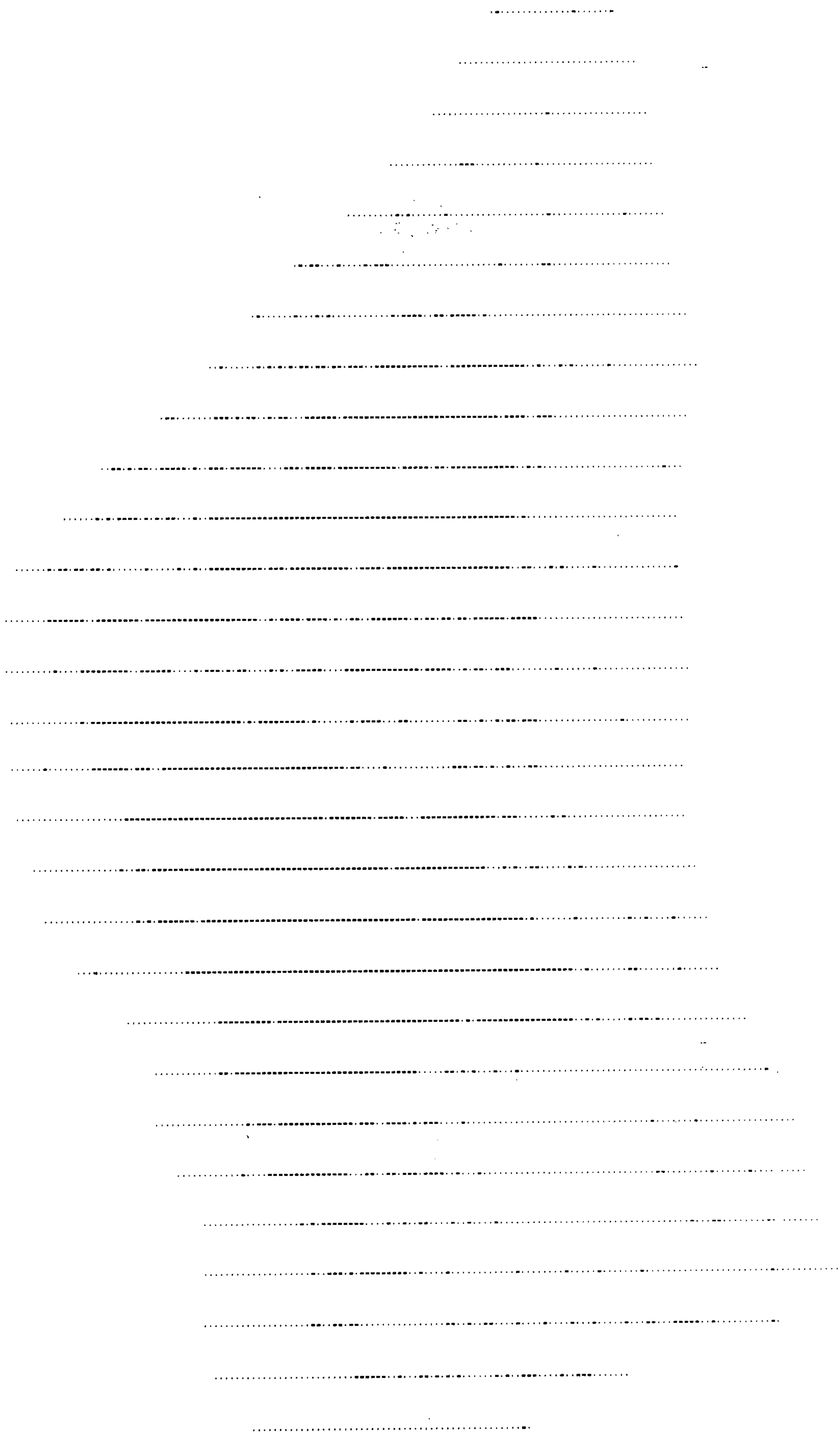


Figure 4.8. Pool 17, Vina Plains Preserve. *Orcuttia pilosa* presence (bold marks in 1135 of the 2824 quadrats shown), on 29 E-W transects, 10 meters apart N-S, covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

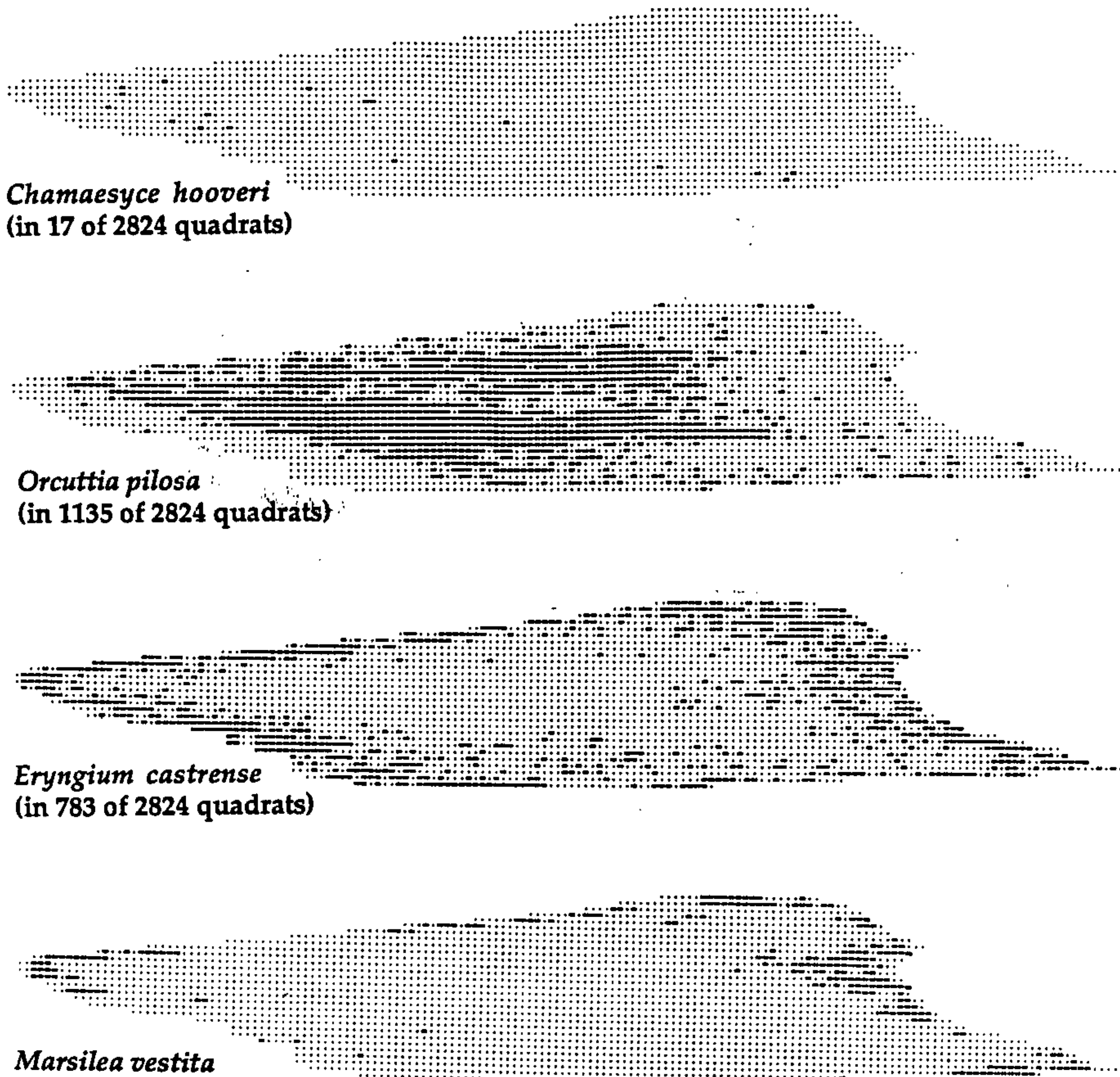
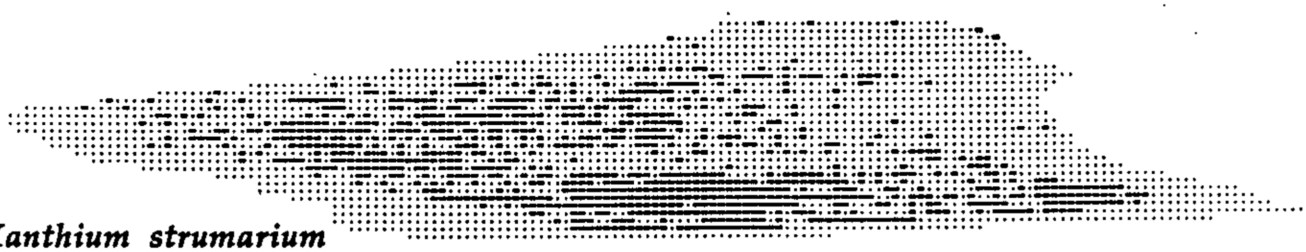


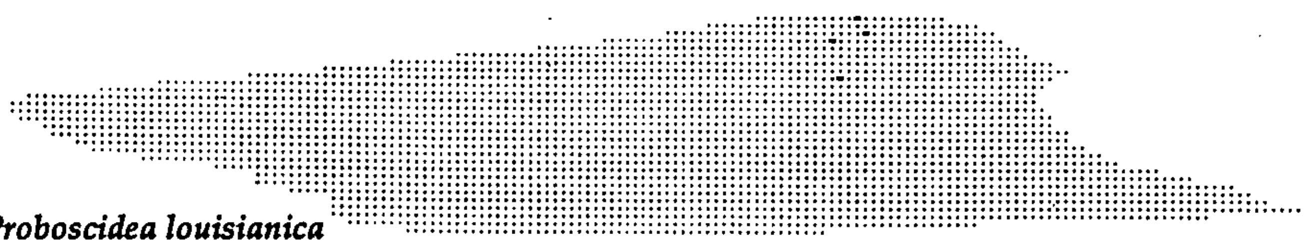
Figure 4.9. Pool 17, Vina Plains Preserve. Species presence (bold marks among the 2824 quadrats shown) on 29 E-W transects, in condensed views for the pool, showing transects only (with all 9-meter distances separating the transects N-S omitted).

Convolvulus arvensis
(in 1254 of 2824 quadrats)

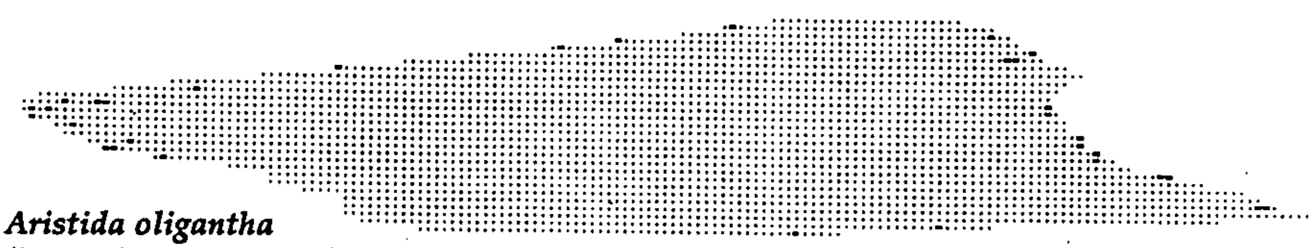


Xanthium strumarium
(in 838 of 2824 quadrats)

Asclepias fascicularis
(in 48 of 2824 quadrats)



Proboscidea louisianica
(in 4 of 2824 quadrats)



Aristida oligantha
(in 27 of 2824 quadrats)

Figure 4.10. Pool 17, Vina Plains Preserve. Species presence (bold marks among the 2824 quadrats shown) on 29 E-W transects, in condensed views for the pool, showing transects only (with all 9-meter distances separating the transects N-S omitted).

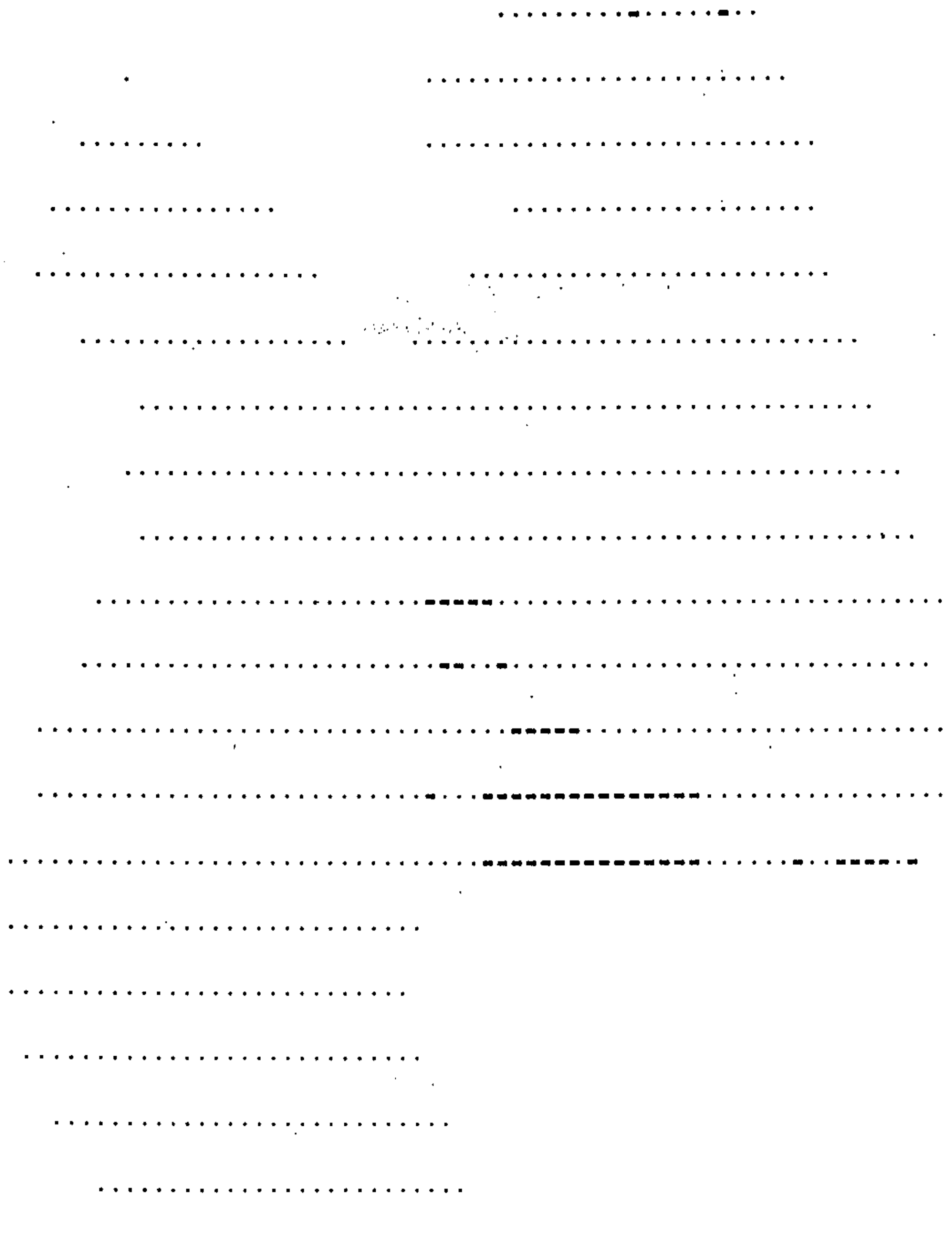
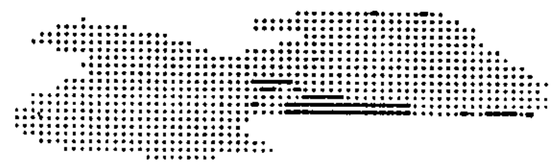
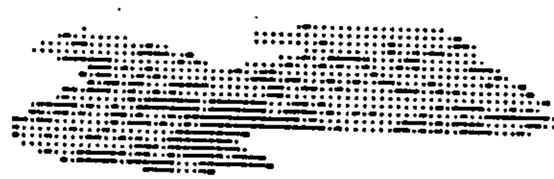


Figure 4.11. Pool 21, Vina Plains Preserve. *Tuctoria greenei* presence (bold marks in 52 of the 828 quadrats shown) on 20 E-W transects, 5 meters apart N-S, covering the entire pool. The symbols represent quadrants spaced 1 meter apart on a transect.

Tuctoria greenei
(in 52 of 828 quadrats)



Eryngium castrense
(in 321 of 838 quadrats)



Marsilea vestita
(in 331 of 828 quadrats)

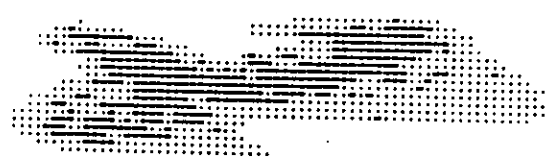


Figure 4.12. Pool 21, Vina Plains Preserve. Species presence (bold marks among the 828 quadrats shown) on 20 E-W transects, in condensed views for the pool, showing transects only (with all 4-meter distances separating the transects from N-S omitted).

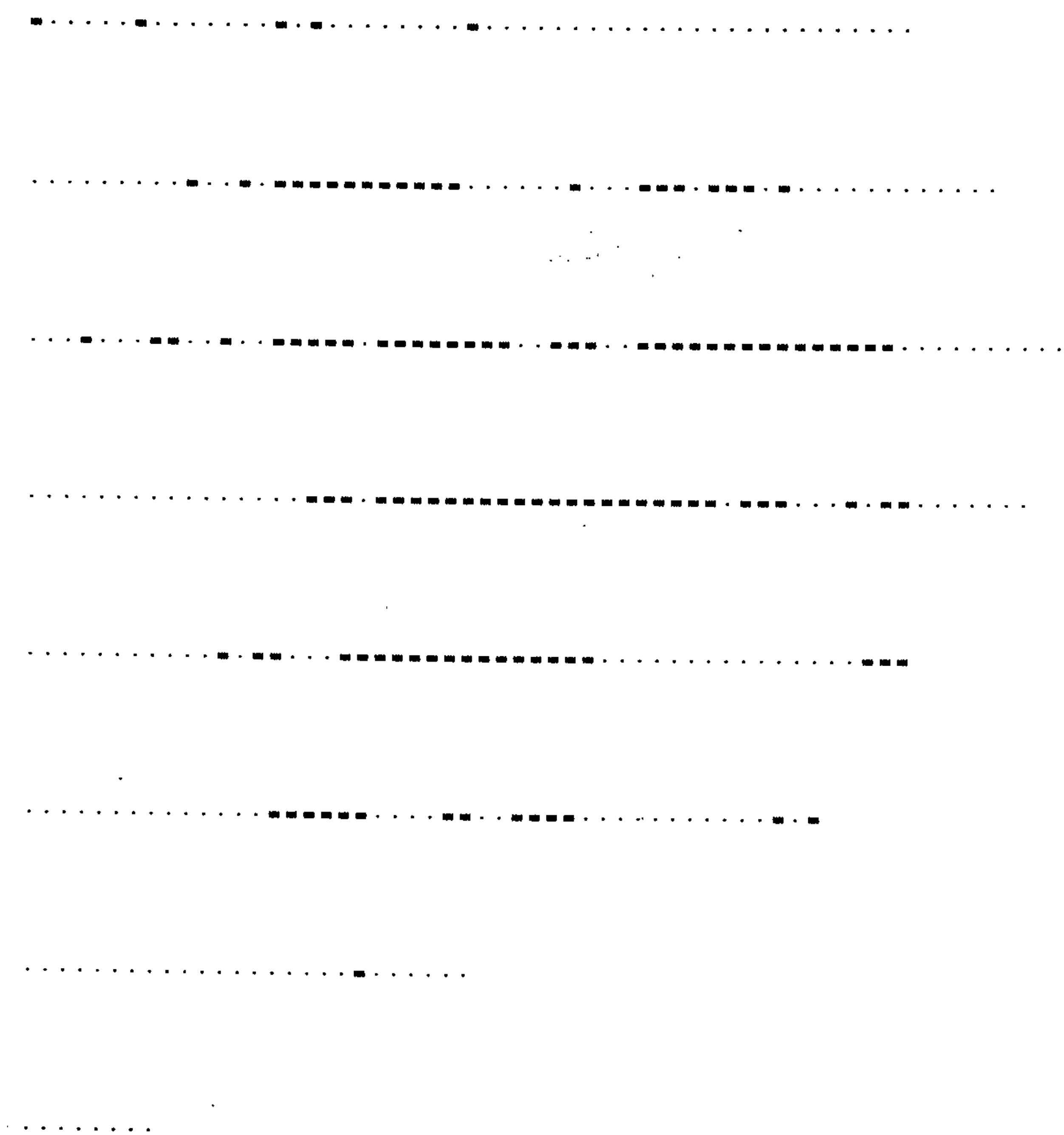


Figure 4.13. Region of Pool 22, Vina Plains Preserve that contained *Tuctoria greenei* (bold marks in 126 of the 352 quadrats shown), on 8 E-W transects, 10 meters apart N-S, covering the eastern half of the pool only. Symbols represent quadrats spaced 1 meter apart on a transect.

Tuctoria greenei
(in 126 of 356 quadrats)

Eryngium castrense
(in 317 of 356 quadrats)

Marsilea vestita
(in 52 of 356 quadrats)

Eremocarpus setigerus
(in 32 of 356 quadrats)

Figure 4.14. Region of Pool 22, Vina Plains Preserve. Species presence (bold marks among the 356 quadrats shown) on 8 E-W transects, in condensed views (for the eastern half of the pool that was sampled for *Tuctoria greenei*), showing transects only (with all 9-meter distances separating the transects N-S omitted).

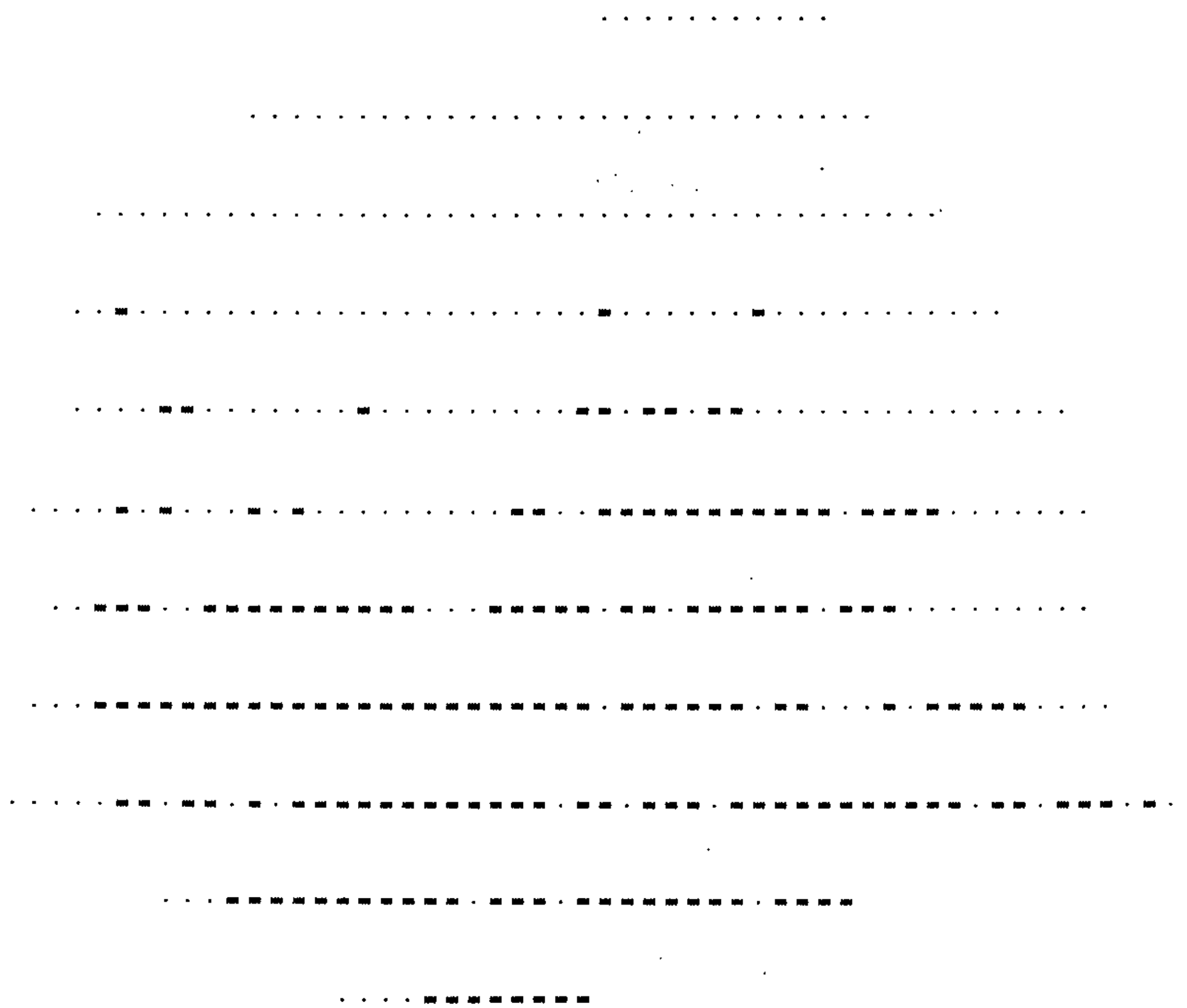
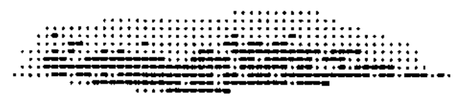
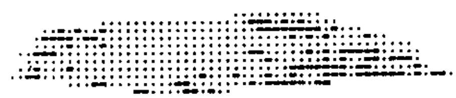


Figure 4.15. Pool 29, Vina Plains Preserve. *Orcuttia tenuis* presence (bold marks in 172 of the 414 quadrats shown), on 11 E-W transects, 5 meters apart N-S, covering the entire pool. The symbols represent quadrats spaced 1 meter apart on a transect.

Orcuttia tenuis
(in 172 of 414 quadrats)



Marsilea vestita
(in 96 of 414 quadrats)



Eryngium castrense
(in 2 of 414 quadrats)

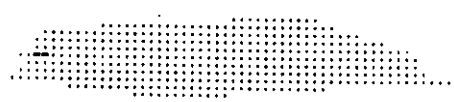


Figure 4.16. Pool 29, Vina Plains Preserve. Species presence (bold marks among the 414 quadrats shown), on 11 E-W transects, in condensed views for the pool, showing trnasects only (with all 4-meter distances separating the transects from N-S omitted).

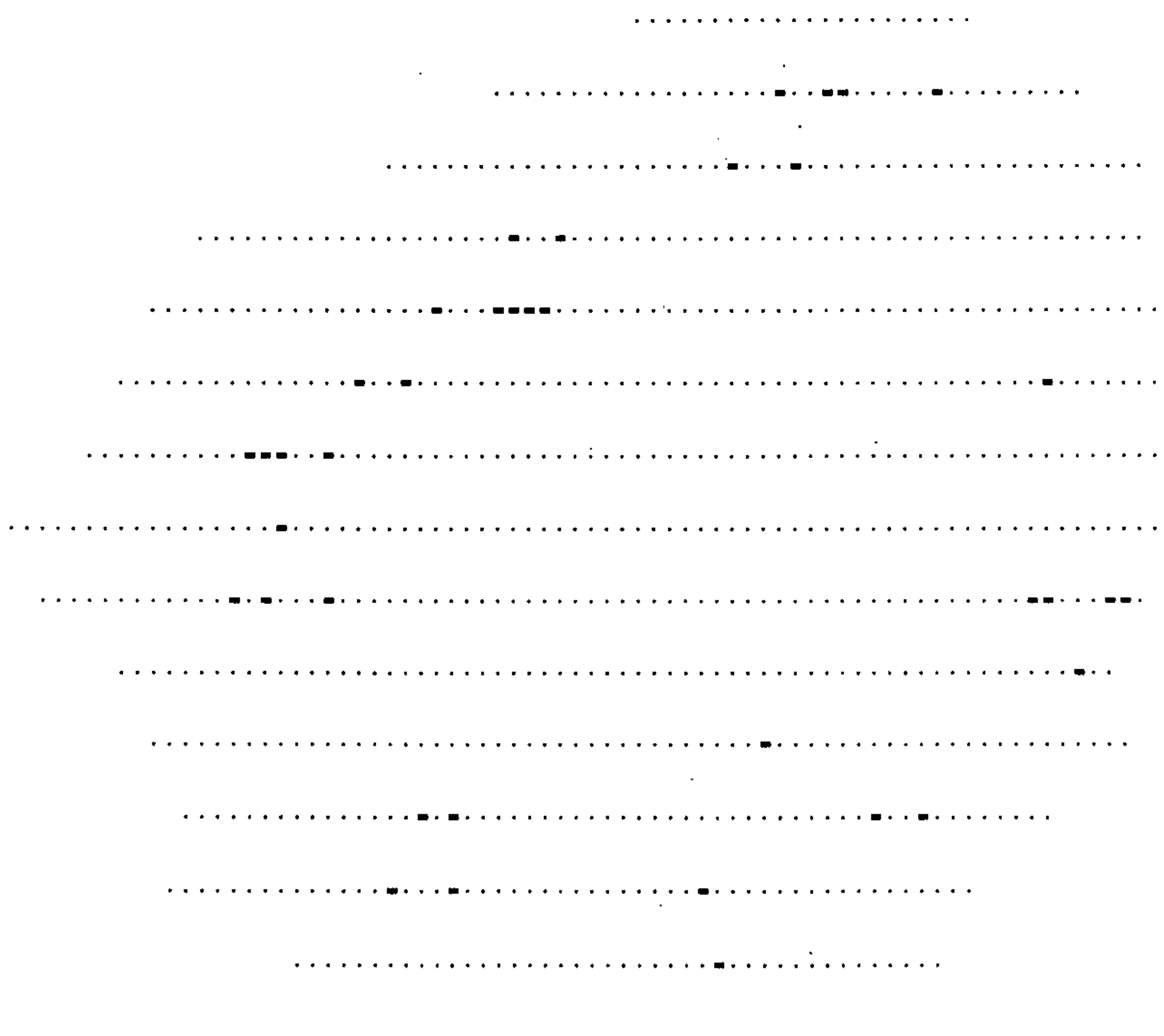


Figure 4.17. Pool 34, Vina Plains Preserve. *Chamaesyce hooveri* presence (bold marks in 38 of the 808 quadrats shown), on 15 E-W transects, 5 meters apart N-S, covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect

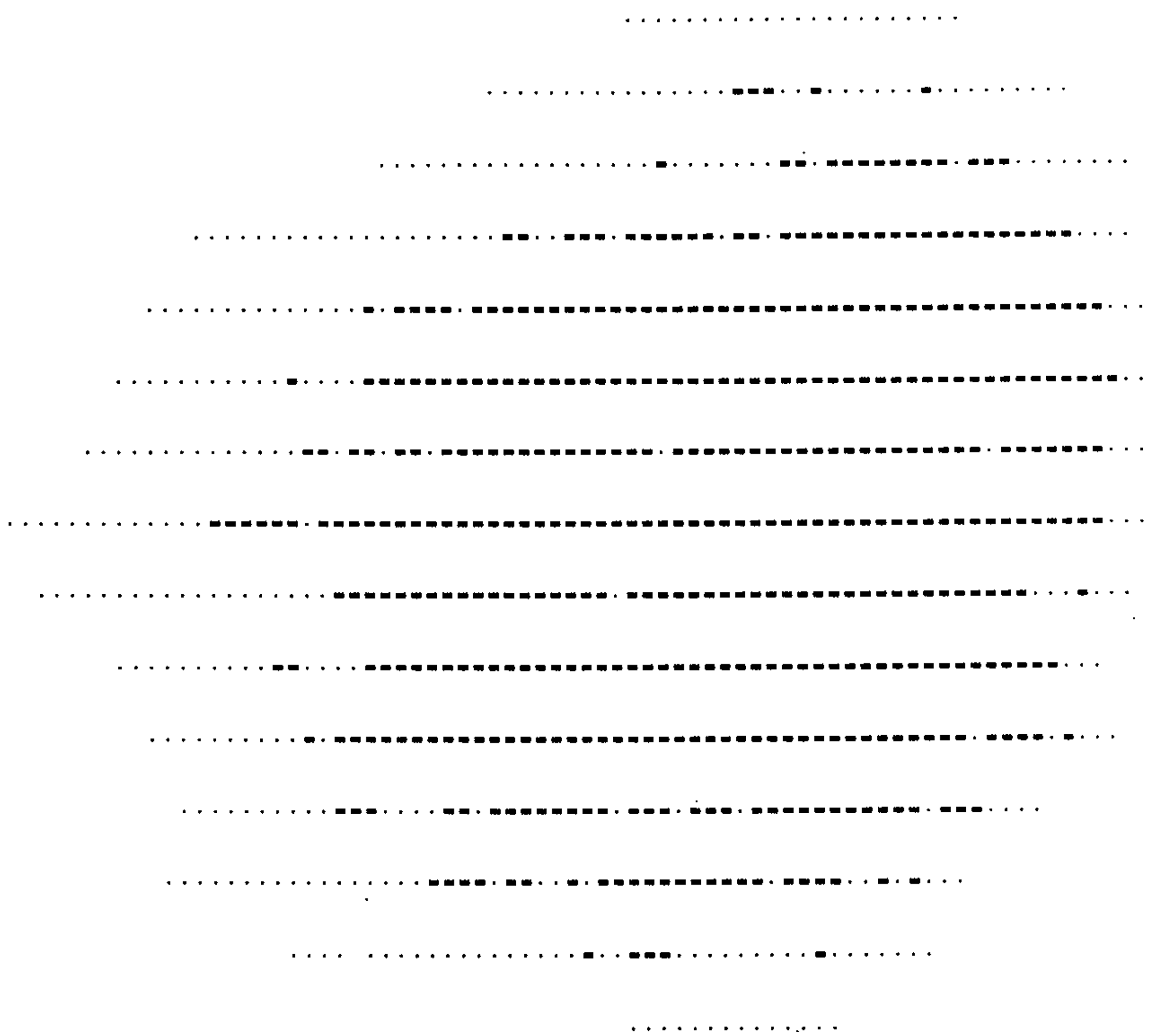


Figure 4.18. Pool 34, Vina Plains Preserve. *Orcuttia pilosa* presence (bold marks in 452 of the 808 quadrats shown), on 15 E-W transects, 5 meters apart N-S, covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

Chamaesyce hooveri
(in 38 of 808 quadrats)

Orcuttia pilosa
(in 452 of 808 quadrats)

Eryngium castrense
(in 252 of 808 quadrats)

Marsilea vestita
(in 26 of 808 quadrats)

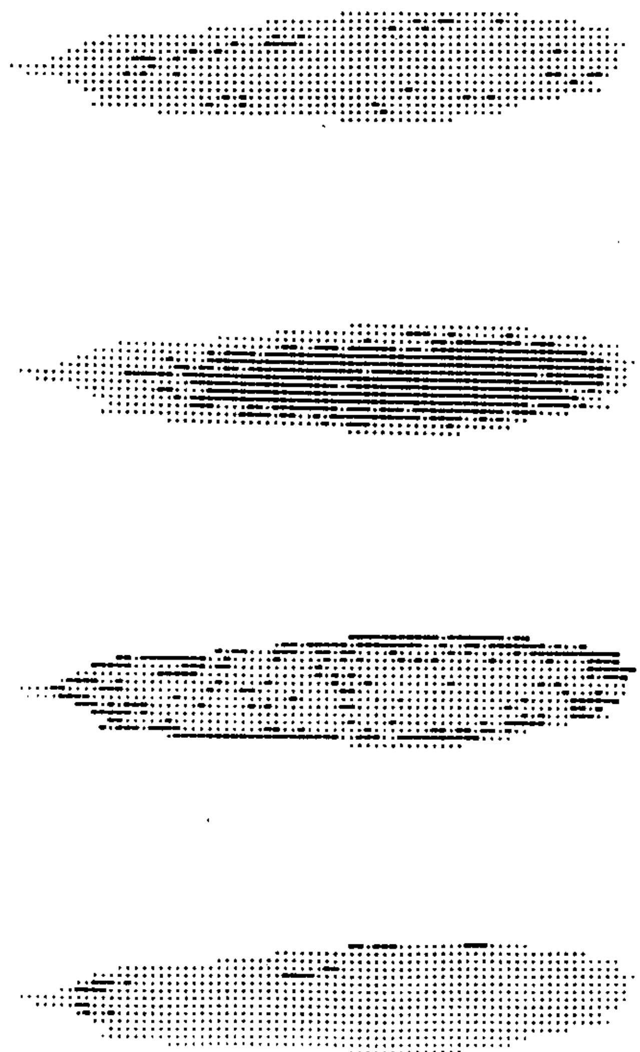
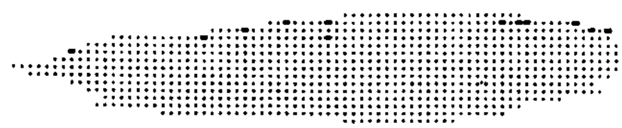
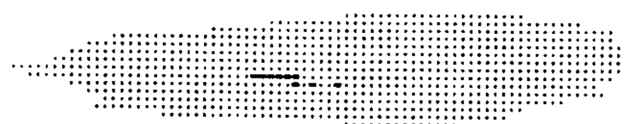


Figure 4.19. Pool 34, Vina Plains Preserve. Species presence (bold marks among the 808 quadrats shown) on 15 E-W transects, in condensed views for the pool, showing transects only (with all 4-meter distances separating the transects from N-S omitted).

Eremocarpus setigerus
(in 12 of 808 quadrats)



Convolvulus arvensis
(in 9 of 808 quadrats)



Amaranthus albus
(in 68 of 808 quadrats)

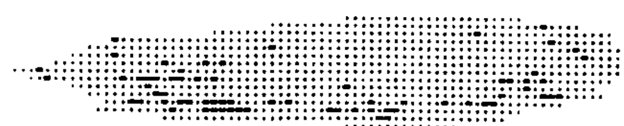


Figure 4.20. Pool 34, Vina Plains Preserve. Species presence (bold marks among the 808 quadrats shown) on 15 E-W transects, in condensed views for the pool, showing transects only (with all 4-meter distances separating the transects from N-S omitted).

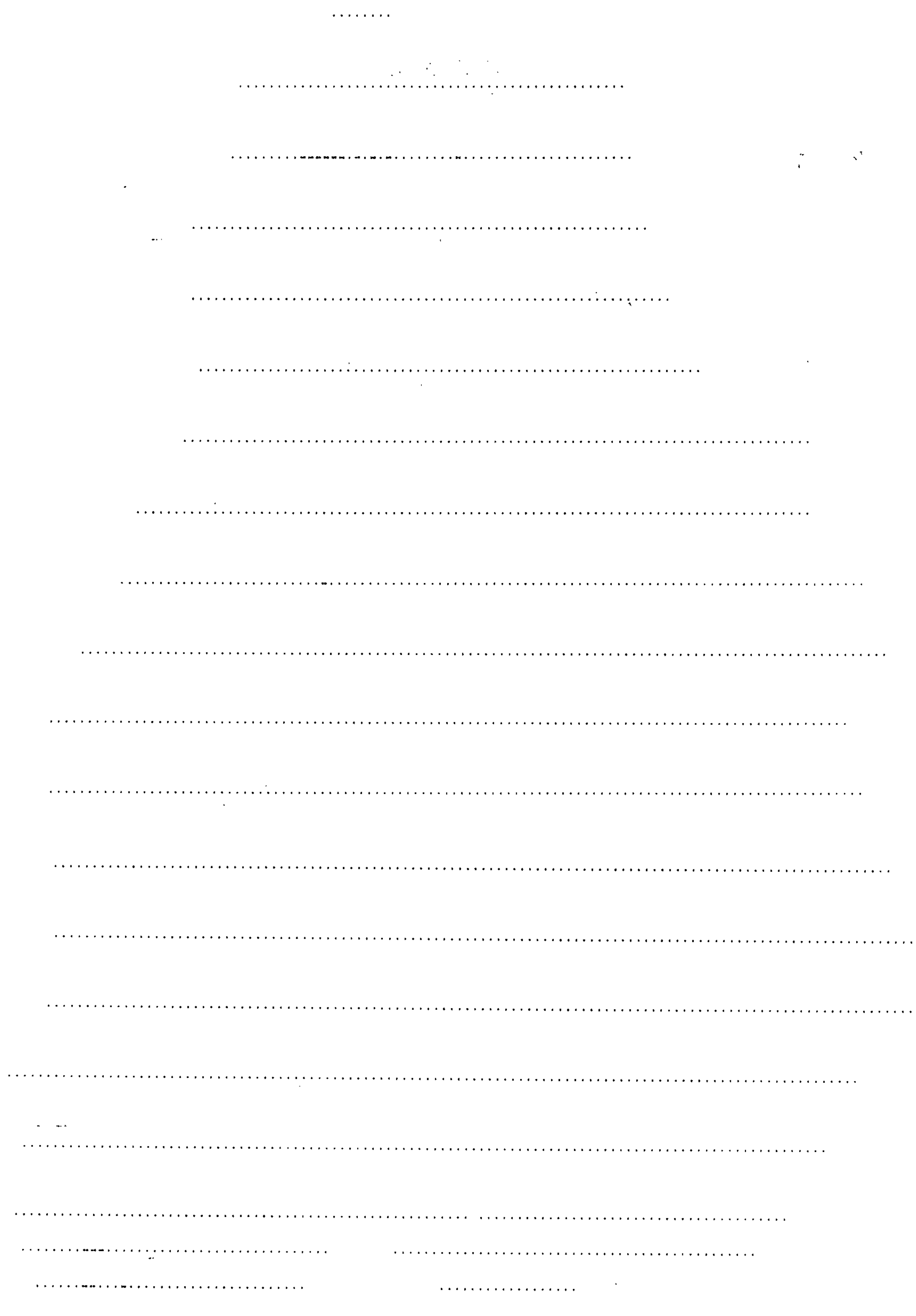


Figure 4.21. Pool 35, Vina Plains Preserve. *Chamaesyce hooveri* presence (bold marks in 17 of the 1684 quadrats shown), on 21 E-W transects, 10 meters apart N-S (except the last 4 transects only 5 m apart N-S), covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

Figure 4.22. Pool 35, Vina Plains Preserve. *Orcuttia pilosa* presence (bold marks in 923 of the 1684 quadrats shown), on 21 E-W transects, 10 meters apart N-S (except the last 4 transects only 5 m apart N-S), covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

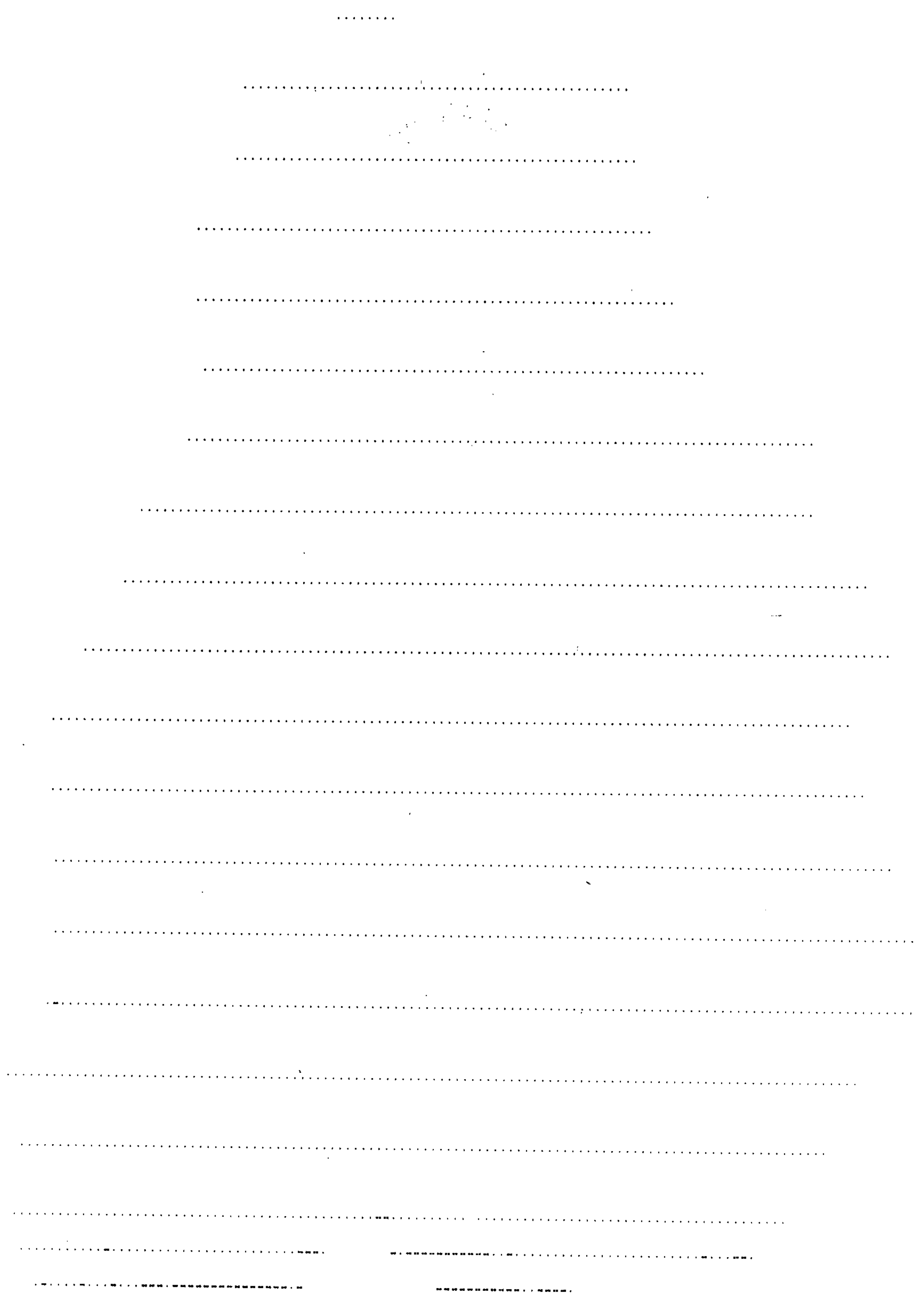
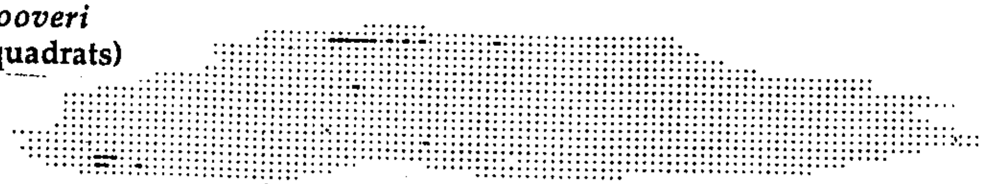
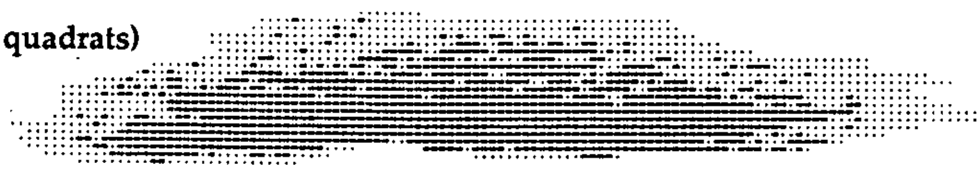


Figure 4.23. Pool 35, Vina Plains Preserve. *Tuctoria greenei* presence (bold marks in 80 of the 1684 quadrats shown), on 21 E-W transects, 10 meters apart N-S (except the last 4 transects only 5 m apart N-S), covering the entire pool. Symbols represent quadrats spaced 1 meter apart on a transect.

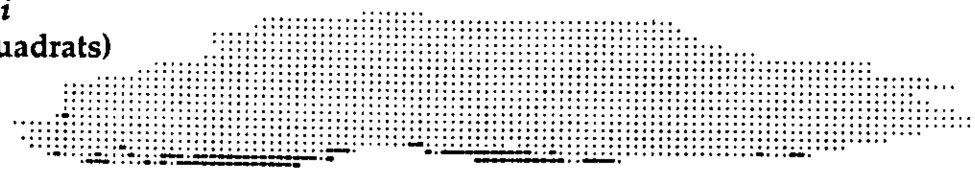
Chamaesyce hooveri
(in 17 of 1684 quadrats)



Orcuttia pilosa
(in 923 of 1684 quadrats)



Tuctoria greenei
(in 80 of 1684 quadrats)



Eryngium castrense
(in 336 of 1684 quadrats)

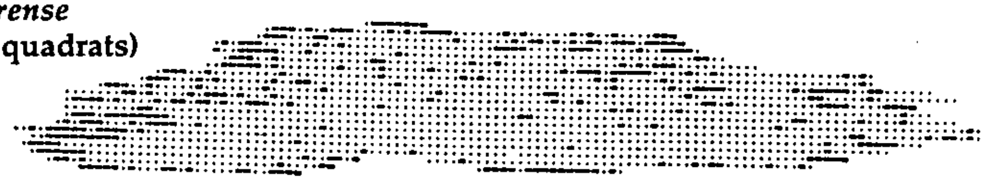


Figure 4.24. Pool 35, Vina Plains Preserve. Species presence (bold marks among the 1684 quadrats shown) on 21 E-W transects, in condensed views for the pool, showing transects only (with all distances separating the transects from N-S omitted).

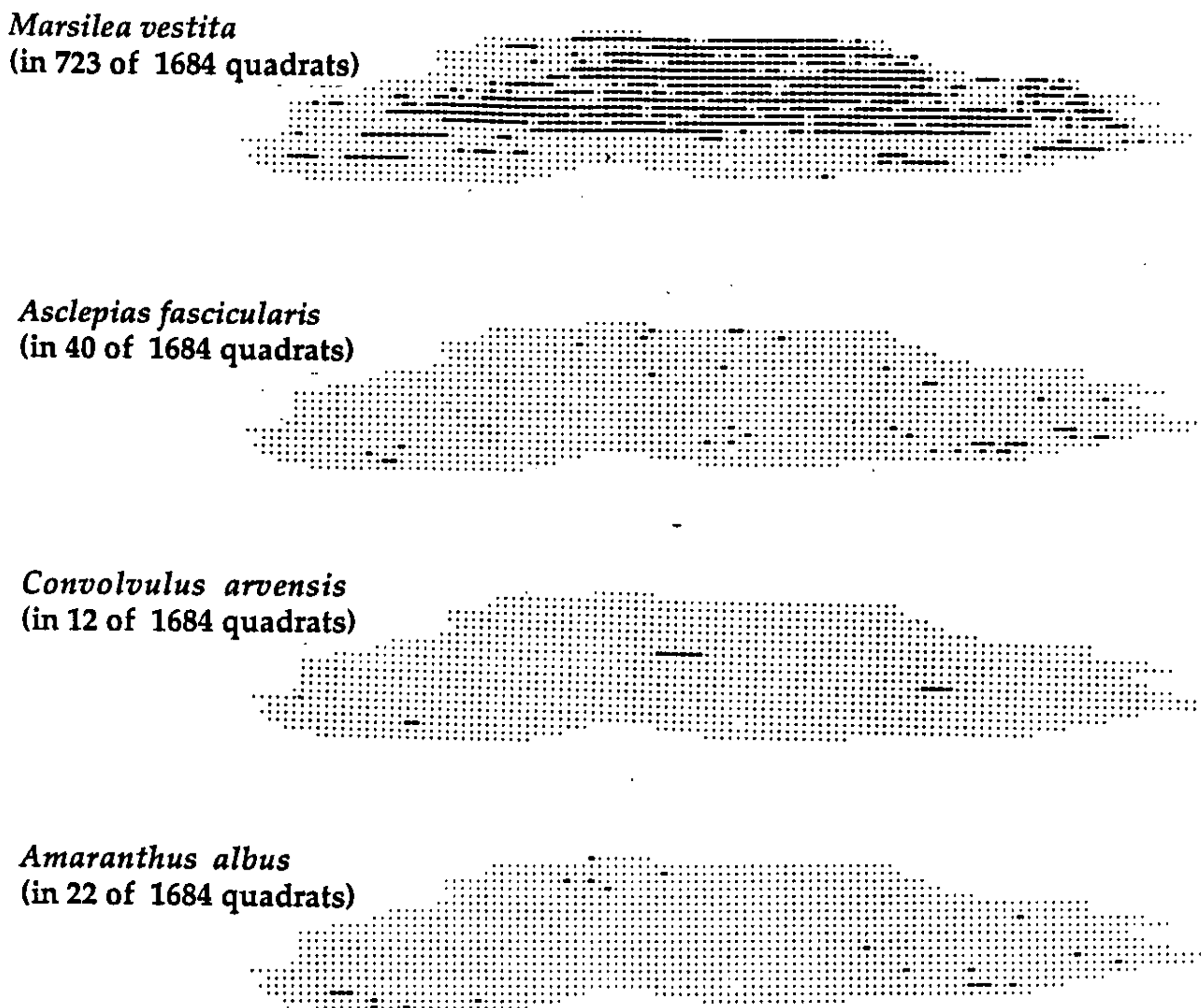


Figure 4.25. Pool 35, Vina Plains Preserve. Species presence (bold marks among the 1684 quadrats shown) on 21 E-W transects, in condensed views for the pool, showing transects only (with all distances separating the transects from N-S omitted).

-	-	-	-	-	-	-	-	-	-	5	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	4	-	-	-	-	-	-
-	-	-	-	1	7	7	-	-	-	-	-	-
-	-	-	-	6	2	6	1	1	-	-	1	-
-	-	-	-	-	-	2	9	-	18	14	-	-
-	-	-	-	-	-	-	1	-	-	7	5	20
-	-	1	-	3	-	-	-	-	6	3	4	2
1	2	1	1	-	-	-	-	-	-	-	1	7
4	10	9	2	3	-	-	-	-	-	-	-	9
57	47	20	18	7	6	3	4	2	-	1	-	5
33	38	84	75	21	18	15	10	-	-	1	-	-
4	16	29	88	94	76	59	13	-	13	6	3	-
3	7	10	14	16	40	94	17	2	-	-	-	-
1	12	11	14	6	7	5	6	2	-	-	-	-

Figure 4.26. Region of Pool 37, Vina Plains Preserve, that contained *Tuctoria greenei* plants (1319 total), in a 15 m X 13 m area on the west side of the pool. Each symbol represents one square meter.

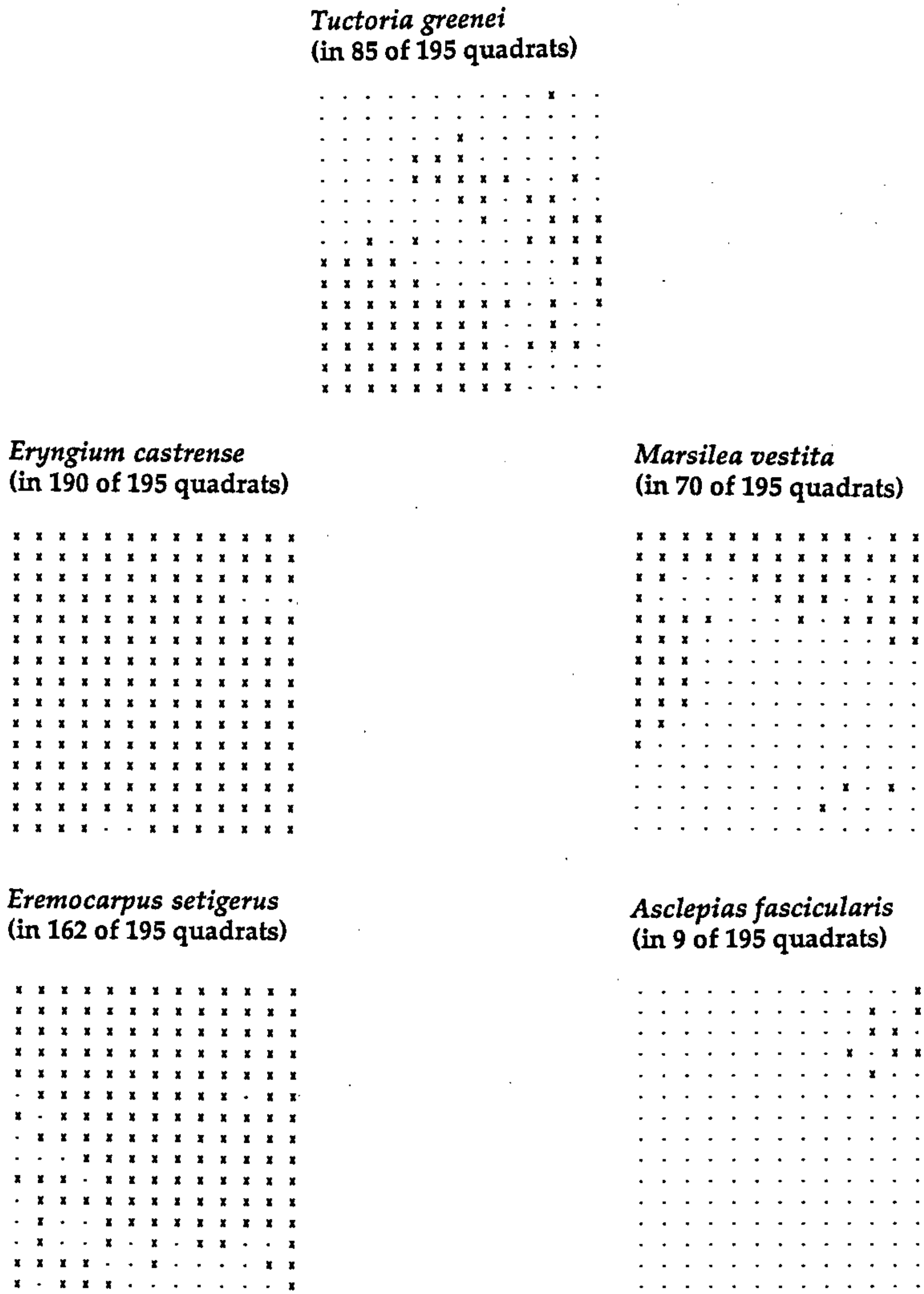


Figure 4.27. Region of Pool 37, Vina Plains Preserve. Species presence (indicated by X) in the 195 square meters sampled on the west side of the pool.

Orcuttia tenuis , in its only occurrence on the Preserve, was mainly in the southern (deeper) half of Pool 29 (Figure 4.15).

Tuctoria greenei had the most varied pattern of occurrence. It occurred abundantly throughout the eastern half only, in Pool 22 (Figure 4.13). In nearby Pool 37, it occurred in an elliptical area of about 195 m^2 (Figure 4.26). In its other three occurrences, *T. greenei* occurred in crescent-shaped areas, at the north side around incoming drainage (Pool 14, Figure 4.5), or at south sides where there are deep-cracking clay soils (Pool 21, Figure 4.11; Pool 35, Figure 4.23). The *Tuctoria greenei* crescent in the large Pool 35 overlapped with areas of both *Chamaesyce hooveri* and *Orcuttia pilosa*--the only sympatric occurrence of three rare plant species on the Preserve in 1995.

Frequency is illustrated for all four species throughout all the pools of occurrence in Figure 4.28. This figure illustrates differences in population patterns within and between pools. Pool 35 is the only pool that contains three of the summer rare species (*Chamaesyce hooveri, Tuctoria greenei, Orcuttia pilosa*), and pool 29 the only occurrence of *Orcuttia tenuis* .

Densities and estimated total population sizes for rare species

All rare plants that were mapped and sampled for density are summarized in Table 4.1. As indicated by the maps of the rare species, the plants never occurred uniformly throughout a pool. Hence, the density measurements are referred to as "crude," since they are based on averages that have included many zero measurements for broad regions where they were not in samples on the transects. Table 4.1 indicates, for several populations, where the crude density was calculated only for the transects in those portions or sides of a pool occupied by the plants (e.g.,*Tuctoria greenei* in Pool 35, Figure 4.23 and *Orcuttia tenuis* in Pool 29, Figure 4.15).

Table 4.1 also lists estimates of total population sizes for the rare species, and these population size estimates are shown graphically in Figure 4.29. Although variable from pool to pool, *Orcuttia pilosa* is clearly the most abundant rare plant on the Preserve.

Locations in pools, and frequencies, for associates of the rare species

The maps (Figures 4.1 to 4.27) and Tables 4.2 and 4.3 show that the summer-flowering rare plant populations had several native and several exotic associates growing with them in 1995. *Eryngium castrense* was the most consistent native associate with the rare species, but varied as to degree of overlap. For example, Pool 22 (Figure 4.14) and Pool 34 (Figure 4.19) show *E. castrense* sympatric with *Tuctoria greenei* or *Orcuttia pilosa* (both grow well in deep clayey soils), but Pools 1 (Figure 4.3) and 17 (Figure 4.9) both tend

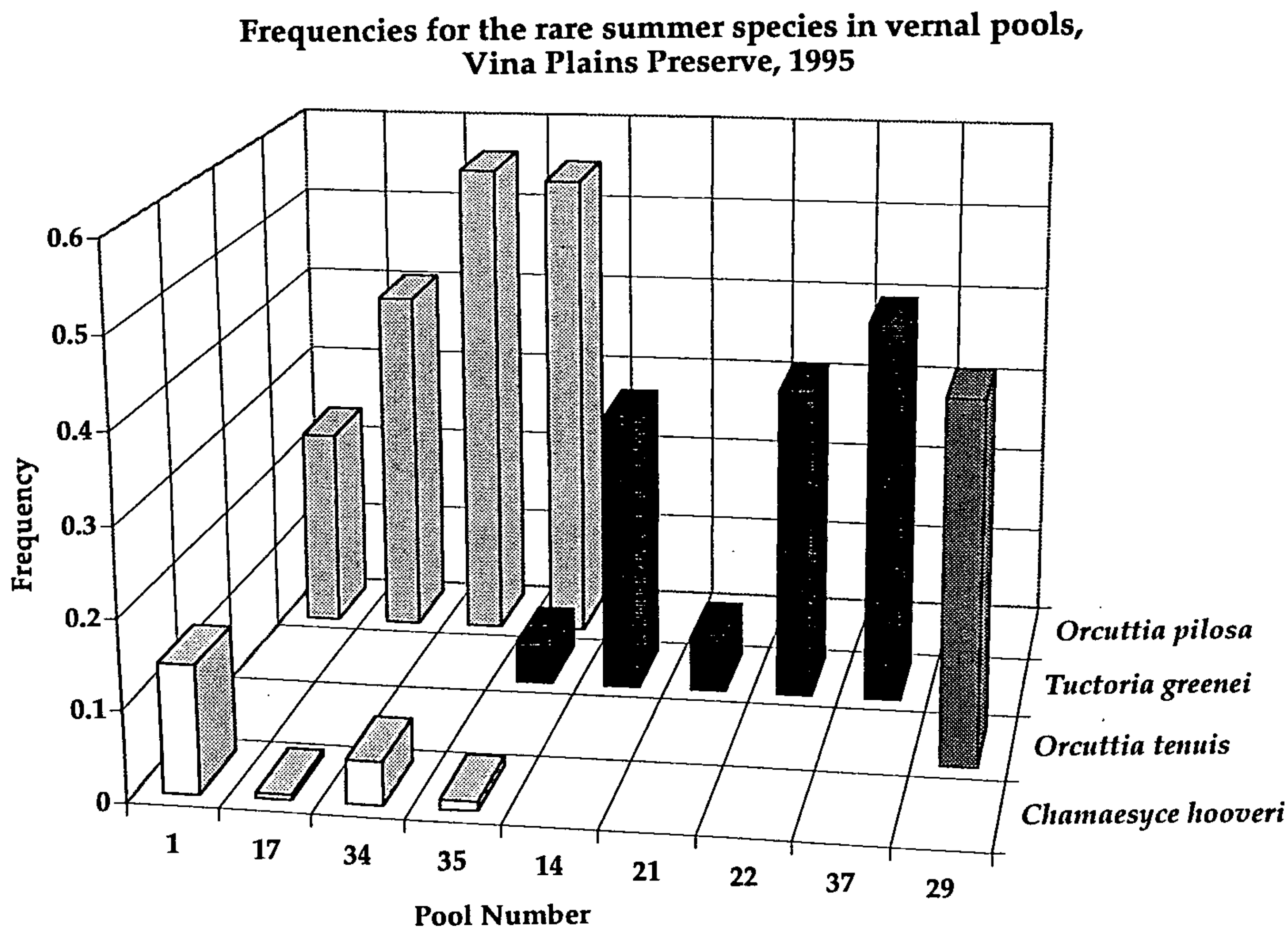


Figure 4.28. Frequencies for rare summer species observed on transects in nine pools, Vina Plains Preserve, 1995. Numbers of quadrats per pool are listed in Table 4.3.

Table 4.1. Mean crude density (and maximum density for any one meter sample) usually to the nearest 1 plant per square meter, and estimate of total population size to the nearest 100 plants, for the four rare plant species in the summer communities of vernal pools on the main unit of the Vina Plains Preserve, in 1995. Calculations refer to total pool density and total pool area unless listed otherwise in footnotes.

	Chamaesyce hooveri		*Orcuttia pilosa*		*Orcuttia tenuis*		*Tuctoria greenei*	
Pool	Density Mean (Max)	Pop Size Estimate	Density Mean (Max)	Pop Size Estimate	Density Mean (Max)	Pop Size Estimate	Density Mean (Max)	Pop Size Estimate
1 (n = 317)	6 (220)	183,400	45 (1,100)	1,355,800	0	0	0	0
14[a] (n = 31)	0	0	0	0	0	0	133 (1,240)	96,400
16[b]	0	0	—	3	0	0	0	0
17 (n =290)	0.1 (1)	3,900	142 (1,880)	3,987.900	0	0	0	0
18[c]	0	0	—	1	0	0	0	0
21 (n = 162)	0	0	0	0	0	0	26 (1300)	106,300
22[d] (n = 37)	0	0	0	0	0	0	49 (400)	173,200
29 (n = 118)	0	0	0	0	71 (840)	147,700	0	0

34 (n = 160)	1 (20)	5,600	474 (4,420)	1,913,400	0	0	0	0
35[e] (n = 157)	0.1 (1)	2,000	266 (3,780)	4,205,300	0	0	14 (640)	225,600
36[f]	—	1	0	0	0	0	0	0
37[h] (n = 195)	0	0	0	0	0	0	7 (94)	1,319

a Mean density of *Tuctoria greenei* in Pool 14 is based on only the portion of the pool sampled, rather than on the entire pool area (Fig. 4.5).

b Total population size was apparently 3. *Orcuttia pilosa* has not previously been recorded in Pool 16.

c Total population size was apparently 1. *Orcuttia pilosa* has not previously been recorded in Pool 18.

d Mean density of *Tuctoria greenei* in Pool 22 is based on only the half of the pool sampled, rather than on the entire pool area (Fig. 4.13).

e Mean density of Tuctoria greenei in Pool 35 is based on the total pool area, although it occured only in several transects at the south end of the pool (see discussion and Fig. 4.23).

f Total population size was apparently 1. Plants of *Chamaesyce hooveri* have been observed in Pool 36 in greater numbers in earlier years (Broyles, 1983; unpublished observations); the species was not found in this pool in 1994; Broyles (1983) also observed *Tuctoria greenei* in Pool 36 in 1982, but this species was not found here ineither 1994 or 1995.

g A total count, rather than a population estimate, is given for *Tuctoria greenei* in the occupied 15m X 13m portion of Pool 37.

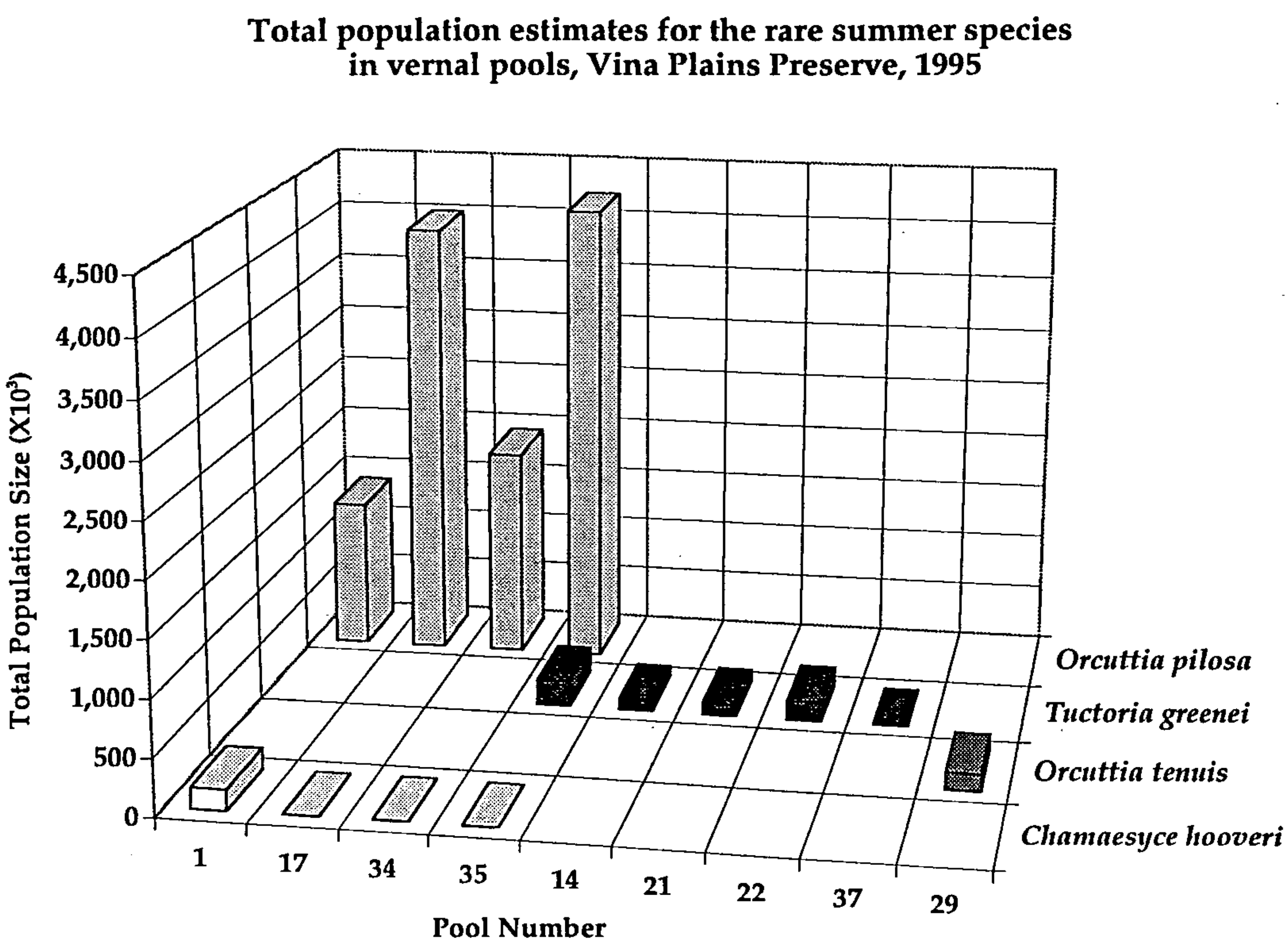


Figure 4.29. Total population estimates by pool, for the rare summer species observed on transects in nine pools, Vina Plains Preserve, 1995. Estimates are listed to the nearest 100 plants in Table 4.1, along with mean plants per square meter and number of samples made.

Table 4. 2. Species observed in summer plant communities in the nine vernal pools containing populations of the rare plants, Vina Plains Preserve, 1995. Several additional species, seen only 1 or 2 times in one or several pools, have not been included (e.g. *Rumex crispus, Mollugo verticillata, Heliotropium europaeum*). X indicates presence in a pool.

Species	Pool								
	1	14	17	21	22	29	34	35	37
Rare Plants									
Chamaesyce hooveri	X	-	X	-	-	-	X	X	-
Orcuttia pilosa	X	-	X	-	-	-	X	X	-
Orcuttia tenuis	-	-	-	-	-	X	-	-	-
Tuctoria greenei	-	X		X	X	-	-	X	X
Other Native plants									
Aristida oligantha	X	X	X	X	-	-	X	X	X
Asclepias fascicularis	X	-	X	-	-	-	X	X	X
Chamaesyce ocellata	X	-	X	X	-	X	X	X	X
Eremocarpus setigerus	X	X	X	X	X	X	X	X	X
Eryngium castrense	X	X	X	X	X	X	X	X	X
Hemizonia fitchii	X	X	X	X	-	X	X	-	-
Marsilea vestita	X	X	X	X	X	X	X	X	X
Exotic Plants									
Amaranthus albus	X	-	X	-	X	X	X	X	X
Convolvulus arvensis	X	X	X	-	-	-	X	X	-
Crypsis schoneoides	-	X	X	X	-	X	-	X	-
Proboscidea louisianica	X	-	X	-		-	X	X	-
Xanthium strumarium	X	-	X	X	X	-	-	-	-

Table 4.3. Frequencies for major plants of the summer communities in the nine vernal pools containing populations of rare plant species, Vina Plains Preserve, in 1995. Number of samples taken on transects are indicated for each pool; Pres = number of samples with the species present; Freq = frequency for the species (proportion of the total samples occupied by the species, to the nearest 0.001). For pools 14, 22, and 37 presence and frequency are shown for only portions of the pool.

Pool No., (and number samples made in pool)	*Amaranthus albus*		*Asclepias fascicularis*		*Chamaesyce hooveri*		*Convolvulus arvensis*		*Eremocarpus setigerus*		*Eryngium castrense*	
	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.
Pool 1 (2997 samples)	2	.001	2	.001	420	0.141	51	.017	6	.002	471	.157
Pool 14[a] (145 samples)	0	0	0	0	0	0	0	0	15	.103	95	.655
Pool 17 (2824 samples)	2	.001	48	.016	17	0.006	1254	.444	2	.001	783	.277
Pool 21 (828 samples)	0	0	0	0	0	0	0	0	11	.013	321	.388
Pool 22[b] (356 samples)	1	.003	0	0	0	0	0	0	32	.090	317	.890
Pool 29 (425 samples)	0	0	0	0	0	0	0	0	1	.002	2	.005
Pool 34 (808 samples)	68	.084	0	0	38	.047	9	.011	7	.009	252	.312
Pool 35 (1684 samples)	22	.013	40	.024	17	.010	12	.007	4	.002	336	.200
Pool 37[c] (195 samples)	0	0	9	.046	0	0	0	0	162	.831	190	.974

Pool No., (and number samples made in pool)	*Marsilea vestita*		*Orcuttia pilosa*		*Orcuttia tenuis*		*Proboscidia louisianica*		*Tuctoria greenei*		*Xanthium strumarium*	
	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.	Pres.	Freq.
Pool 1 (2997 samples)	1501	.501	691	.231	0	0	43	.014	0	0	5	.002
Pool 14[a] (145 samples)	39	.269	0	0	0	0	0	0	46	.317	0	0
Pool 17 (2824 samples)	228	.081	1135	.402	0	0	4	.001	0	0	838	.297
Pool 21 (828 samples)	331	.400	0	0	0	0	0	0	52	.063	0	0
Pool 22[b] (356 samples)	52	.146	0	0	0	0	0	0	126	.354	1	.003
Pool 29 (425 samples)	96	.226	0	0	172	.405	0	0	0	0	0	0
Pool 34 (808 samples)	26	.032	452	.559	0	0	1	.001	0	0	0	0
Pool 35 (1684 samples)	723	.429	923	.548	0	0	0	0	80	.048	0	0
Pool 37[c] (195 samples)	70	.359	0	0	0	0	0	0	85	.436	0	0

a Pool 14 had only the northern portion (where *Tuctoria greenei* occurred), sampled for plants in 1995.

b Pool 22 had only the eastern half (where *Tuctoria greenei* occurred) sampled for plants in 1995.

c Pool 37 had the entire population of *Tuctoria greenei* counted in the 15m X 13m grid encompassing it (195 samples); the other species also were sampled only in this portion of the pool.

to show the *Eryngium* mainly peripheral in the pool, and with less overlap with the rare species.

The *Eryngium* and other summer associates sampled with the rare species help illustrate how biologically unique the different pools are here (see Tables 4.2 and 4.3, as well as the maps cited below). The native perennial *Asclepias fascicularis* was found in both deeper (Pool 17, Figure 4.10) and shallower (Pool 37, Figure 4.27) pools. The native grassland annual, *Eremocarpus setigerus* (Euphorbiaceae) had a only few individuals recorded in most pools sampled, but the shallow Pool 37 had this species in 162 of the 195 quadrats sampled for *Tuctoria*. (Figure 4.27).

The maps (Figures 4.1 to 4.27) and Tables 4.2 and 4.3 show interesting and non-conforming patterns from pool to pool, when the non-native species occurring with the rare plants here are examined. Several of the pools showed a low frequency of occurrence for the perennial, *Convolvulus arvensis*: (i.e., in 51 of 2997 quadrats, for a frequency of .02 in Pool 1; Figure 4.4; and in 9 of 808 quadrats, for a frequency of .01 in Pool 34; Figure 4.20). But in Pool 17, the deepest pool on the preseve, and one that harbors *Chamaesyce* and *Orcuttia pilosa*, the *Convolvulus* occupied 1254 of the 2824 quadrats, for a frequency of .44 (Figure 4.10). Similarly, few plants of the (presumed) non-native annual, *Xanthium strumarium*, occurred in Pool 1 (Figure 4.4) and in Pool 34 (no figure), but in the deep Pool 17 this plant was well dispersed, and occurred in 833 of 2824 quadrats, for a higher frequency of .30 (Figure 4.10). Additional non-native annuals, *Amaranthus albus* (Pool 34, Figure 4.20) and *Proboscidia louisianica* (Pool 34, no figure and Pool 1, Figure 4.4), occurred in low frequencies. Other species not mapped that occurred incidentally or in only several quadrats in one or more pools are listed in Tables 4.2 and 4.3.

Spring Plant Communities in Pools of the Vina Plains Preserve, based on single-transect analysis in 1995

A single, more or less centrally located transect was studied intensively to characterize each of 18 pools, in terms of their spring vegetation. Species found within quadrats on these transects are shown in Table 4.4; Table 4.5 also shows these species from the transects, but also lists other species observed in the pool off the transects.

There were several problems in indentification of taxa for these tables, the most complicated of which involved *Downingia* species. Three species, as indicated in both Table 4.4 and 4.5, were found in the pools as a group. But many of the transects included *Downingia* plants past flower, and in a few cases included plants still in unopened bud, and since these could not be determined to species with certainty, they had to be grouped as "*Downingia* species" for analysis of the spring transect data and for presentation in graphs. Similarly, "*Epilobium* spp." is used because barely-flowering or pre-flowering

Table 4.4. Species names, and the total numbers of vascular plants found in the spring transects for 18 pools, Vina Plains Preserve, 1995. Numbers of quadrats in the transect for each pool are: Pool 1, 159; Pool 4, 22; Pool 14, 109; Pool 15. 94; Pool 17, 120; Pool 18, 16; Pool 21, 59; Pool 21a, 31; Pool 22, 99: Pool 29, 26; Pool 30, 33; Pool 31, 18; Pool 34, 74; Pool 35, 104; Pool 36, 111; Pool 37, 89; Pool 38, 43; Pool 39, 35. Species names are abbreviated, with the first four letters of the generic name followed by the first four letters of the specific epithet. Complete names are listed at the end of Table 4.5. The three species of *Downingia* are listed together as "*Downingia* spp." in this table since all individuals could not be distinguished during the sampling, and they are counted only as one taxon for the totals. The downingias are listed again below the species total for each pool, to indicate which species were sometimes identifiable in each of the pool transects.

	Pool Number																		Total pools per species
Species	1	4	14	15	17	18	21	21a	22	29	30	31	34	35	36	37	38	39	
AchyMoll	-	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
AlopSacc	-	X	X	X	-	-	-	X	-	-	-	X	-	-	-	X	-	X	7
AsclFasc	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
BlenNanu	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	2
BrodLevs	X	-	X	-	-	-	X	X	-	X	X	X	-	X	X	-	X	-	10
BromHord	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	-	-	-	3
CallMarg	-	-	-	X	X	X	-	-	-	X	X	X	-	-	X	X	X	-	9
ChamHoov	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	2
ConvArve	-	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	2
CrasAqua	-	X	-	X	-	X	X	-	-	X	X	X	X	-	X	X	X	X	12
CrypSpp.	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	2
CuscHowe	-	X	X	X	-	X	-	X	-	X	-	X	X	-	-	X	X	X	11
DescDant	-	X	-	-	-	X	X	X	-	X	-	X	X	X	X	X	X	-	11
DownSpp.	X	X	X	X	-	X	X	X	X	X	X	X	X	-	X	X	X	X	16
EleoMinu	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1
EleoMach	-	-	X	-	X	-	-	-	-	-	-	-	-	X	-	X	-	-	4
EpilSpp.	X	X	X	X	X	-	X	X	X	-	-	X	X	X	X	X	X	X	15
EremSeti	-	-	X	-	-	-	X	-	X	-	-	-	-	-	X	X	X	-	6
ErynCast	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	17
GratHete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	1
HypoGlab	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	-	-	3
IsoeOrcu	-	-	X	X	X	X	X	X	-	X	X	X	-	X	X	X	X	X	14
JuncBufo	-	-	-	-	X	-	X	-	-	-	-	X	-	X	X	-	X	-	6
JuncUncl	-	X	-	X	-	X	-	X	-	X	X	X	-	-	-	X	X	X	10

LastFrem	-	X	X	X	-	X	X	X	-	X	X	X	-	-	X	X	X	X	13
LastGlab	-	-	X	-	-	-	X	X	X	-	-	-	-	-	X	X	X	X	8
LayiFrem	-	-	X	-	-	-	X	-	-	-	-	X	-	-	X	X	-	-	5
LimnDoug	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	2
LoliMult	-	X	-	-	-	X	X	-	-	X	-	X	-	-	X	X	-	-	7
MarsVest	X	-	X	X	-	-	X	X	X	-	-	-	-	X	X	X	-	-	9
MimuTric	-	X	-	-	-	-	-	-	-	-	-	X	-	-	X	-	-	-	3
MyosMini	-	-	-	X	-	X	-	-	-	X	-	X	-	-	-	X	-	-	5
NavaLeuc	X	X	X	X	-	X	X	X	-	X	X	X	X	X	X	X	X	X	16
OrcuPilo	X	-	-	-	X	-	-	-	-	-	-	-	X	X	-	-	-	-	4
PiluAmer	-	-	X	X	-	-	-	X	-	-	-	-	-	-	X	-	-	X	5
PlagStMi	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	18
PogoZiph	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1
PsilBrev	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	18
PsilOreg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	1
SidaHirs	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	2
TaenCapu	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TrifDepa	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	X	-	-	3
TrifWild	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	1
VeroPere	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	3
XantStru	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total/Trans	12	18	18	17	16	16	19	17	8	16	11	20	10	13	25	27	17	14	
DownBlco	-	-	X	-	-	-	X	X	-	-	X	-	X	-	X	X	X	X	9
DownCusp	-	-	X	X	-	X	X	X	-	X	X	X	-	-	X	X	X	-	11
DownOrna	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

Table 4.5. Species names, and the total numbers of vascular plant species found in the 18 pools studied, Vina Plains Preserve, 1995. This list includes all of the species found on the spring and summer transects, as well as other species seen elsewhere, in the pools. Species names are abbreviated, with the first four letters of the generic name followed by the first four letters of the specific epithet. Complete names are listed at the end of the table.

	Pool Number																		Total Pools
Species	1	4	14	15	17	18	21	21a	22	29	30	31	34	35	36	37	38	39	for species
AchyMol	-	X	-	X		-	-	-	-	-	-	X	-	-	-	-	-	-	3
AlliAmpl	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1
AlopSacc	-	X	X	X	-	-	-	X	-	-	-	X	X	X	X	X	X	X	11
AmarAlba	X	-	-	X	-	-	-	-	X	X	-	-	X	X	-	X	X	-	8
ArisOlig	X	-	X	-	X	-	X	-	-	-	-	-	X	X	-	X	-	-	7
AsclFasc	X	X	-	-	X	-	-	-	-	-	-	-	X	X	-	X	-	-	6
BlenNanu	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	2
BrodLevs	X	-	X	-	-	X	X	X	-	X	X	X	X	X	X	-	X	-	12
BromHord	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	-	-	-	3
CallMarg	-	-	-	X	X	X	-	-	-	X	X	X	-	-	X	X	X	-	9
CentMini	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	1
ChamHoov	X	-	-	-	X	-	-	-	-	-	-	-	X	X	X	-	-	-	5
ChamOcel	-	-	-	X	X	X	X	-	-	X	-	-	X	X	-	X	X	-	9
ConvArve	X	-	X	-	X	-	-	-	-	-	-	-	X	X	X	-	-	-	6
CrasAqua	-	X	X	X	-	X	X	-	-	X	X	X	X	-	X	X	X	X	13
CrypSpp.	-	X	X	-	X	-	X	-	-	X	-	-	-	X	X	-	-	-	7
CypeSpe.	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CuscHowe	-	X	X	X	-	X	-	X	-	X	-	X	-	-	-	X	X	X	10
DescDant	-	X	-	X	-	X	X	X	-	X	-	X	X	X	X	X	X	-	12
DownBico	X	-	X	X	-	-	X	X	X	X	X	-	X	-	X	X	X	X	13
DownCusp	-	-	X	X	-	X	X	X	X	X	X	X	-	-	X	X	X	-	12
DownOrna	-	X	-	X	X	-	-	X	-	-	-	-	-	-	-	X	X	X	7
EleoMinu	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1
EleoMach	X	X	X	-	X	-	X	-	X	-	-	-	X	X	-	X	-	-	9
EpilClei	X	X	X	X	X	-	X	X	X	-	-	X	X	X	X	X	X	X	15

EpilPygm	-	-	X	-	-	-	X	-	X	-	-	-	X	-	X	X	X	-	7
EremSeti	X	-	X	X	X	-	X	-	X	X	-	-	X	X	X	X	X	-	12
ErynCast	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	17
GratEbra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	1
GratHete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	1
HeliEuro	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	2
HemiFitc	X	-	X	-	X	X	X	-	-	X	-	-	X	-	-	-	X	-	8
HypoGlab	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X	X	-	-	3
IsoeHowe	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	X	-	2
IsoeOrcu	-	-	X	X	X	X	X	X	-	X	X	X	-	X	X	X	X	X	14
JuncBufo	X	-	-	-	X	X	X	-	-	-	-	X	-	X	X	X	X	-	9
JuncUnci	-	X	-	X	-	X	-	X	-	X	X	X	-	-	-	X	X	X	10
LastFrem	X	X	X	X	X	X	X	X	X	X	X	X	X	-	X	X	X	X	17
LastGlab	-	-	X	-	-	-	X	X	X	-	-	-	-	-	X	X	X	X	8
LayiFrem	-	-	X	-	-	-	X	-	X	-	-	X	-	-	X	X	-	-	6
LimnDoug	-	X	-	X	-	-	-	X	-	X	-	X	-	-	-	X	-	X	7
LimnFloc	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
LoliMult	-	X	-	X	-	X	X	X	-	X	-	X	-	-	X	X	-	-	9
MarsVest	X	-	X	X	X	-	X	X	X	X	-	-	X	X	X	X	-	-	12
MimuGutt	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	1
MimuTric	-	X	X	-	-	X	-	-	X	X	-	X	-	-	X	-	-	-	7
Mollvert	-	-	X	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	3
MontFont	-	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	2
MyosMini	-	-	-	X	-	X	-	-	-	X	-	X	-	-	-	X	-	-	5
NavaLeuc	-	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	16
OrcuPilo	X	-	-	-	X	X	-	-	-	-	-	-	X	X	-	-	-	-	5
OrcuTenu	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	1
PaniSpe.	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	1
PiluAmer	-	-	X	X	-	-	-	X	-	-	-	X	X	-	X	-	-	X	7

PlagStip	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	18
PlagStSt	-	-	X	X	X	-	-	X	-	-	-	-	-	-	X	X	-	-	6
PogoZiph	-	X	-	X	-	X	X	-	-	X	-	X	-	-	-	-	-	X	7
ProbLoui	X	-	-	-	X	-	-	-	-	-	-	-	X	X	-	-	-	-	4
PsilBrev	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	17
PsilOreg	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	2
RumexCr	X	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	3
SidaHirs	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	2
TaenCapu	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	1
TrifDepa	-	-	-	-	X	X	-	-	-	X	-	-	-	-	-	X	-	-	4
TrifWild	-	-	-	-	-	-	-	-	-	X	-	-	-	-	X	-	-	-	2
TuctGree	-	-	X	-	-	-	X	-	X	-	-	-	-	X	-	X	-	-	5
VeroPere	-	X	X	X	-	-	-	-	-	X	-	-	-	-	X	X	-	-	6
XantStru	X	-	-	-	X	-	X	-	X	-	-	-	-	-	-	X	-	-	5
Total/Pool	23	21	30	28	29	23	29	21	18	35	12	25	26	25	33	38	26	17	

AchyMoll = *Achyrachaena mollis*, AlliAmpl = *Alliuim amplectens*, AlopSacc = *Alopecurus saccatus*, AmarAlbu = *Amaranthus albus*, ArisOlig = *Aristida oligantha*, AsclFasc =*Asclepias fascicularis*, BlenNanu =*Blennospermum nanum*, BrodLevs = *Brodiaea* leaves, BromHord = *Bromus hordeaceus*, CallMarg = *Callitriche marginata*, CentMini = *Centunculus minimus*, ChamHoov = *Chamaesyce hooveri*, ChamOcel = *Chamaesyce ocellata* ssp. *ocellata*, ConvArve = *Convolvulus arvensis*, CrasAqua = *Crassula aquatica*, CrypSpp. = *Crypsis schoenoides* and C. *vaginiflora*, CuscHowe = *Cuscuta howelliana*, CypSpe. = an unidentified species of *Cyperus*, DescDant = *Deschampsia danthonioides*, DownBico = *Downingia bicornuta*, DownCusp = Downingia cuspidata, DownOrna = *Downingia oranatissima*, DownSpp. = *Downingia species*, EleoMinu = a minute-bodied, unidentified species of *Eleocharis*, EleoMach = *Eleocharis machrostachya*, EpilClei = *Epilobium cleistoganum* EpilPygm = *Epilobium pygmaeum*, EremSeti = *Eremocarpus setigerus*, ErynCast = *Eryngium castrense*, GratEbra = *Gratiola ebracteata*, GratHete = *Gratiola heterosepala*, HeliEuro = *Heliotropium europaeum*, HemiFitc =*Hemizonia fitchii*, HypoGlab = *Hyperchoeris glabra*, IsoeHowe = *Isoetes howellii*, IsoeOrcu =*Isoetes orcuttii*, JuncBufo = *Juncus bufonius*, JuncUnci = *Juncus uncialis*, LastFrem = *Lasthenia fremontii*, LastGlab = *Lasthenia glaberrima*, LayiFrem = *Layia fremontii*, LimnDoug = *Limnanthes douglasii* ssp. *rosea*, LimnFloc = *Limnanthes floccosa* ssp. *floccosa*, LoliMult = *Lolium multiflorum*, MarsVest = *Marsilea vestita*, MimuGutt = *Mimulus guttatus*, MimuTric = *Mimulus tricolor*, MollVert = *Mollugo verticillata*, MontFont = *Montia fontana*, MyosMini = *Myosurus minimus*, NavaLeuc = *Navarretia leucocephala* ssp. *leucocephala*, OrcuPilo = *Orcuttia pilosa*, OrcuTenu = *Orcuttia tenuis*, PaniSpe. = an unidentified species of *Panicum*, PiluAmer = *Pilularia americana*, PlagStMI = *Plagiobothrys stipitatus* var. *micranthus*, PlagStSt = *Plagiobothrys stipitatus* var. *stipitatus*, PogoZiph = *Pogogyne zizyphoroides*, ProbLoui = Proboscidea *louisianica*, PsilBrev = *Psilocarphus brevissimus*, PsilOreg = *Psilocarphus oregonus*, RumeCris = *Rumex crispus*, SidaHirs = *Sidalcea hirsuta*, TaenCapu = *Taeniatherum caput-medusae*, TrifDepa = *Trifolium depauperatum*, TrifWild = *Trifolium wildenovii*, TuctGree = *Tuctoria greenei*, VeroPere = *Veronica peregrina* ssp. *xalapensis*, XantStru = *Xanthium strumarium*

Epilobium plants could not always be placed in *E. cleistoganum*, due to the uncommon occurrence of the similar-appearing *E. pygmaeum* in the pools. "*Crypsis* spp." had to be used as well, because there are apparently two introduced species of this grass both known now in vernal pools; however, very few *Crypsis* plants occurred in quadrats. Finally, small individuals of *Pilularia* and *Isoetes* could easily be confused.

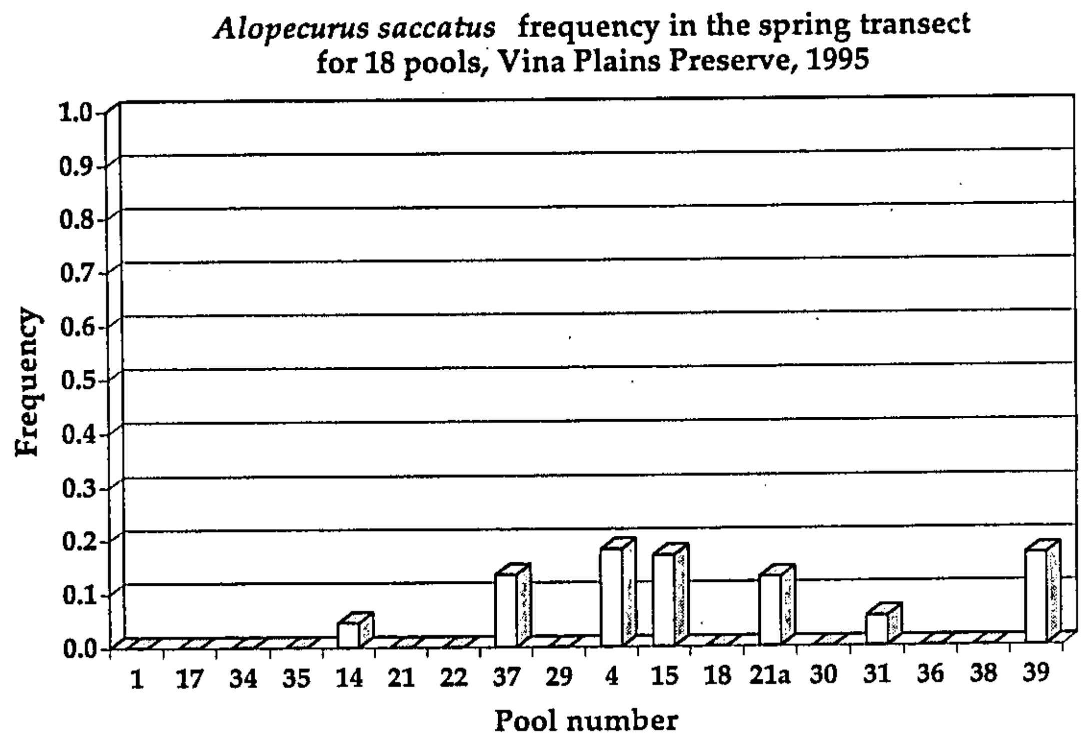
Frequency and density, when it could be determined for a species, are summarized for species encountered on all spring transects in Appendix 3. The common spring vascular plants in these pools at the Vina Plains Preserve can easily be identified in this appendix, and 15 of the most common of these are illustrated by graphs of frequency and/or density for all 18 pools studied (Figures 4.30 to 4.44). These figures clearly document that this set of 18 pools studied in the spring of 1995 can be sorted into different kinds of pools in terms of their main vascular plants--even though they are often closely adjacent to each other (for pool numbers and locations, see map in Figure 2.6).

During spring transect sampling on 9 May, a rare species formerly unknown on the Preserve was discovered in Pool 37. *Gratiola heterosepala* (Bogg's Lake hedge- hyssop), was recorded in 12 of the 89 quadrats (within a length of 14 m on the transect), for a frequency of 0.13 and a mean density of $67.4/m^2$. No additional observations were made for this species.

The most obvious repeated pattern documented with spring transect data in Figures 4.30 to 4.44 is that Pools 1, 17, 34 and 35--the large pools that contain *Chamaesyce hooveri* and *Orcuttia pilosa* in the summer (and that are shown on the left in all these figures)--had few, if any, plants of the most common spring vernal pool species for the Preserve.

The next largest and/or deepest pools (Pools 14 to 29) are grouped next in Figures 4.30 to 4.44 since they (along with Pool 35 already mentioned) contained populations of the early summer-flowering *Tuctoria greenei*. These pools tended to contain the spring transect species to varying degrees. For example, Pools 14 and 37 had high frequencies and densities of many of the spring species, although Pool 22, similarly containing *Tuctoria greenei*, had suprisingly few of the spring transect plants. Pool 29, placed next in Figures 4.30 to 4.44, contained the earliest flowering (late spring) rare species, *Orcuttia tenuis*, as well as an assortment of the spring species.

The other nine pools (numbers 4 through 39) tend to be the smallest and/or shallowest, and hence earliest-drying of the study pools, and these are the ones that contained most of the common spring vernal pools species (but see Pools 30 and 31 as unusual, even among these).



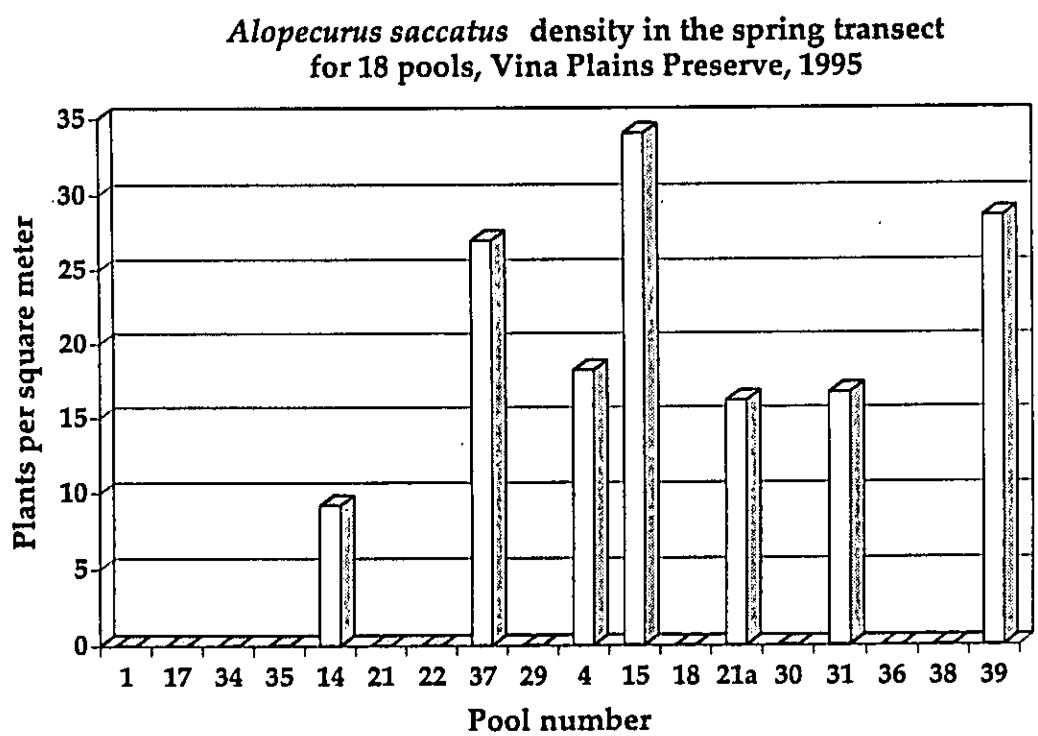
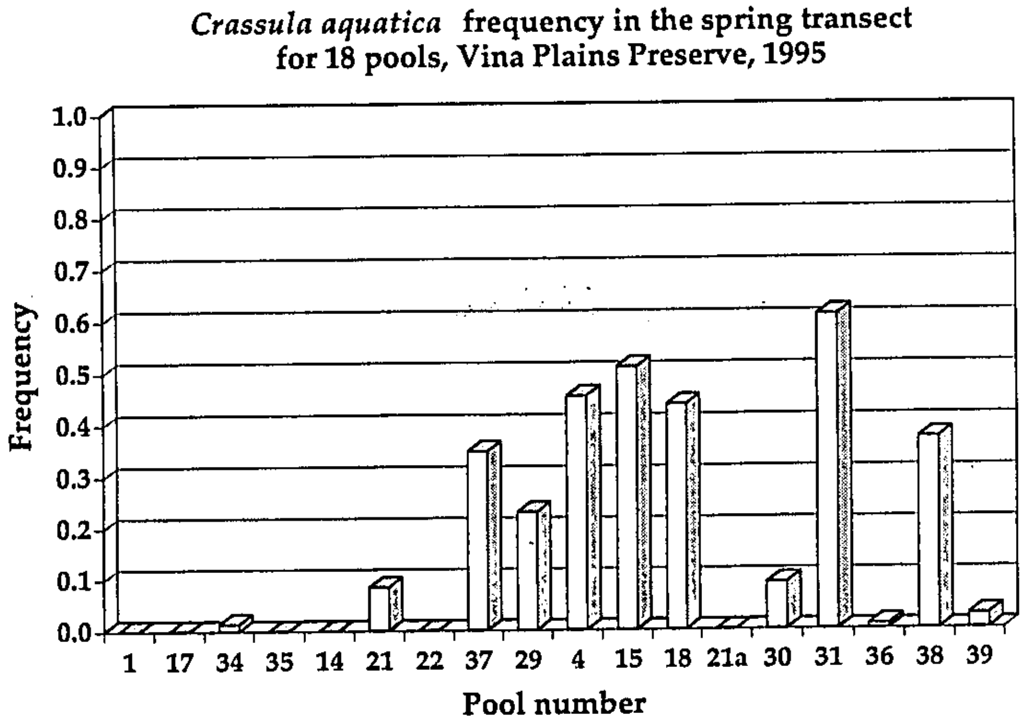


Figure 4.30. *Alopecurus saccatus* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



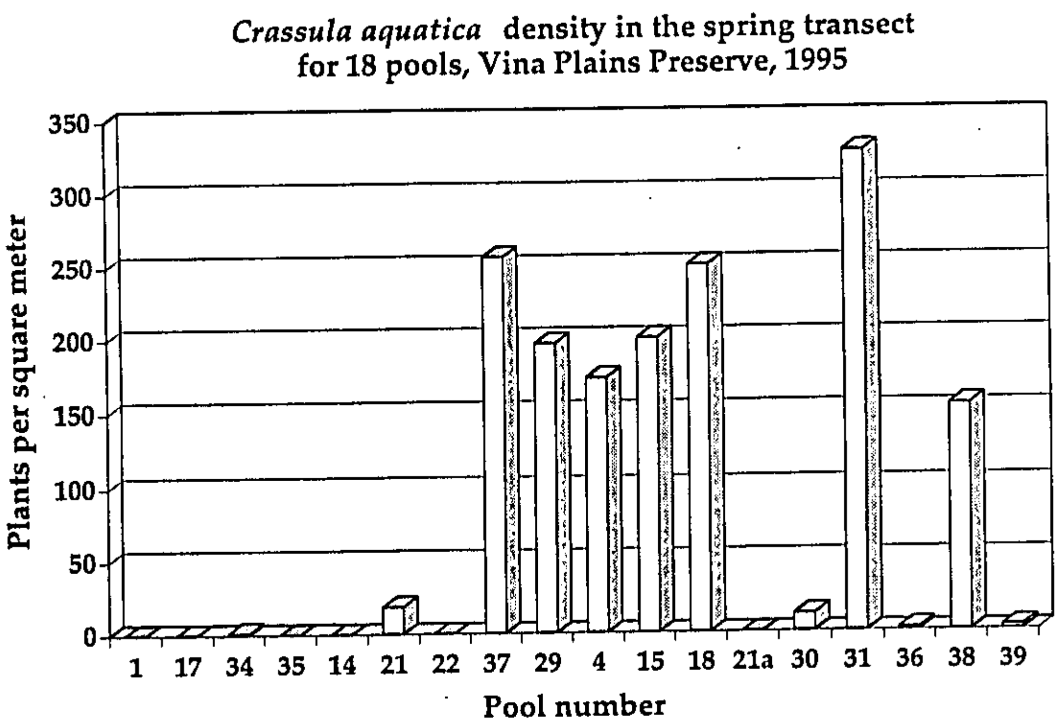
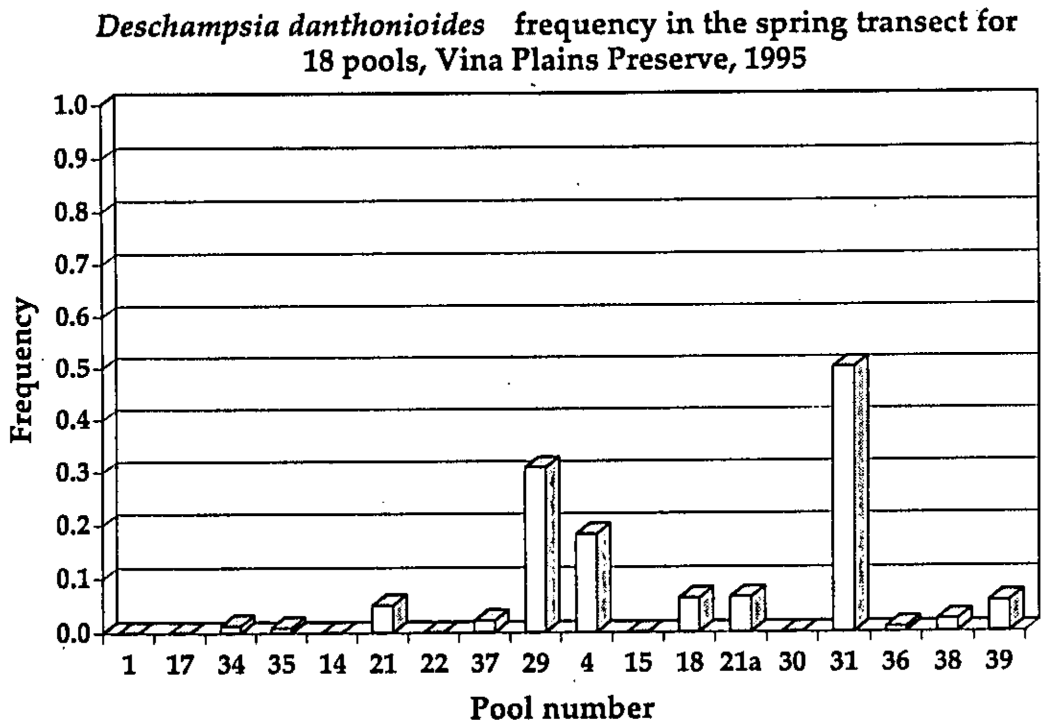


Figure 4.31. *Crassula aquatica* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



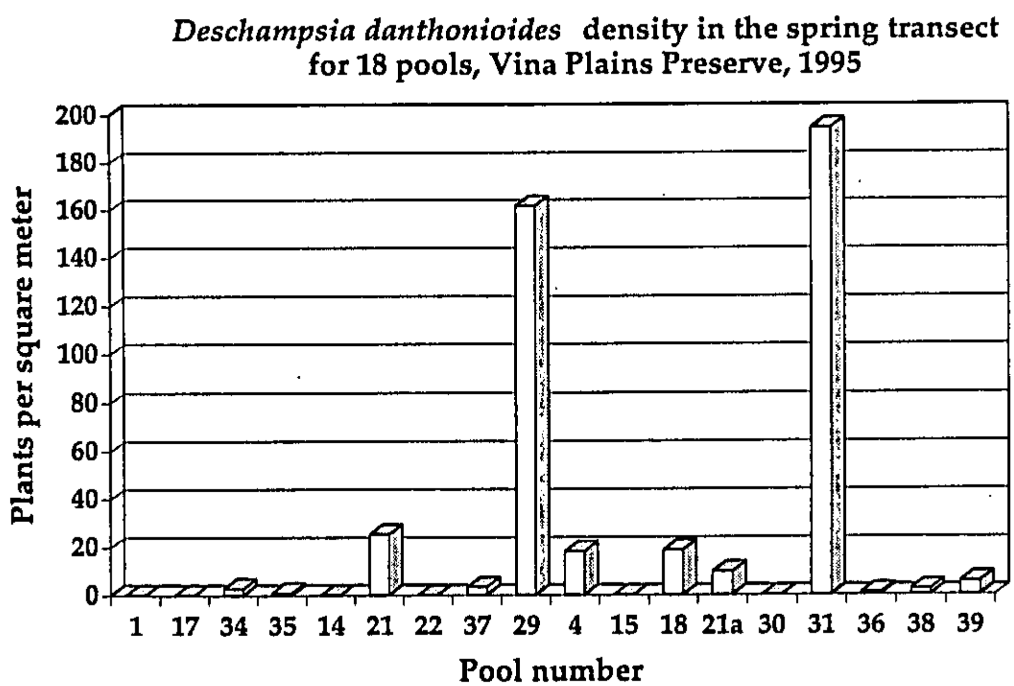
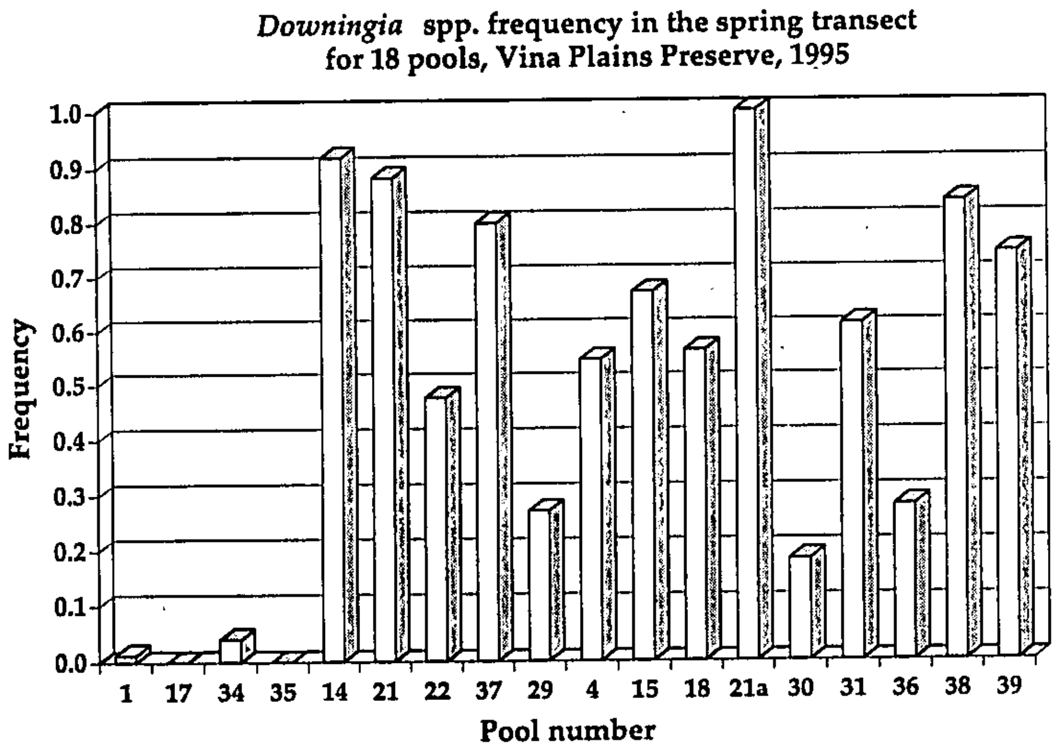


Figure 4.32. *Deschampsia danthonioides* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



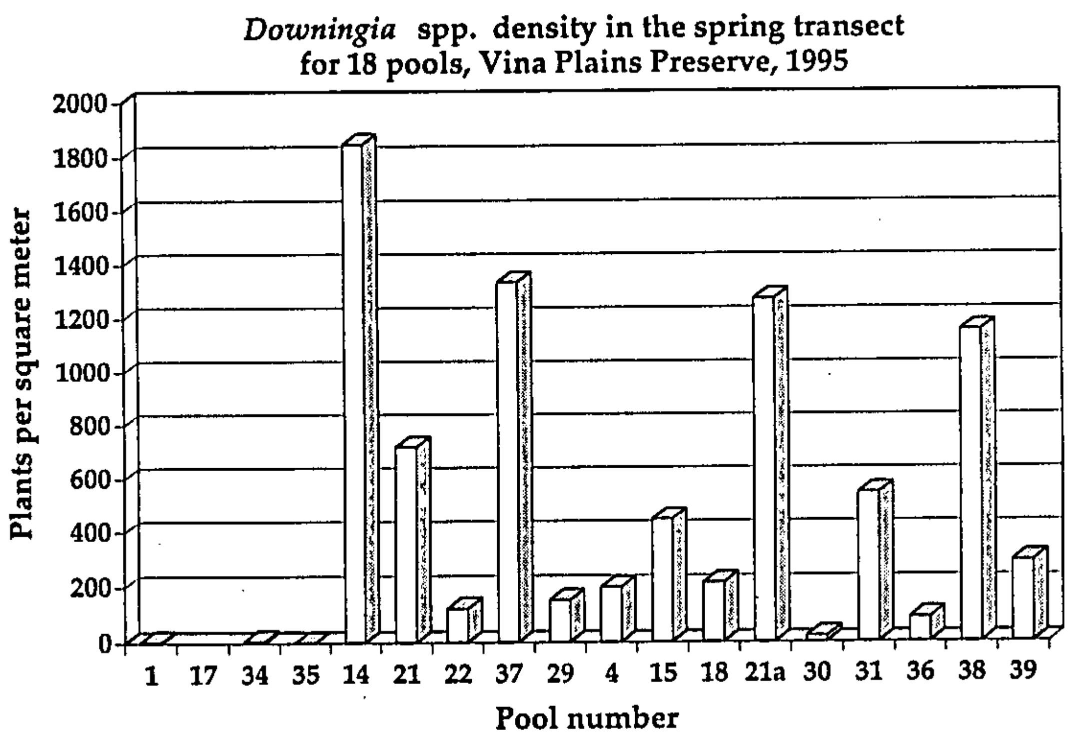
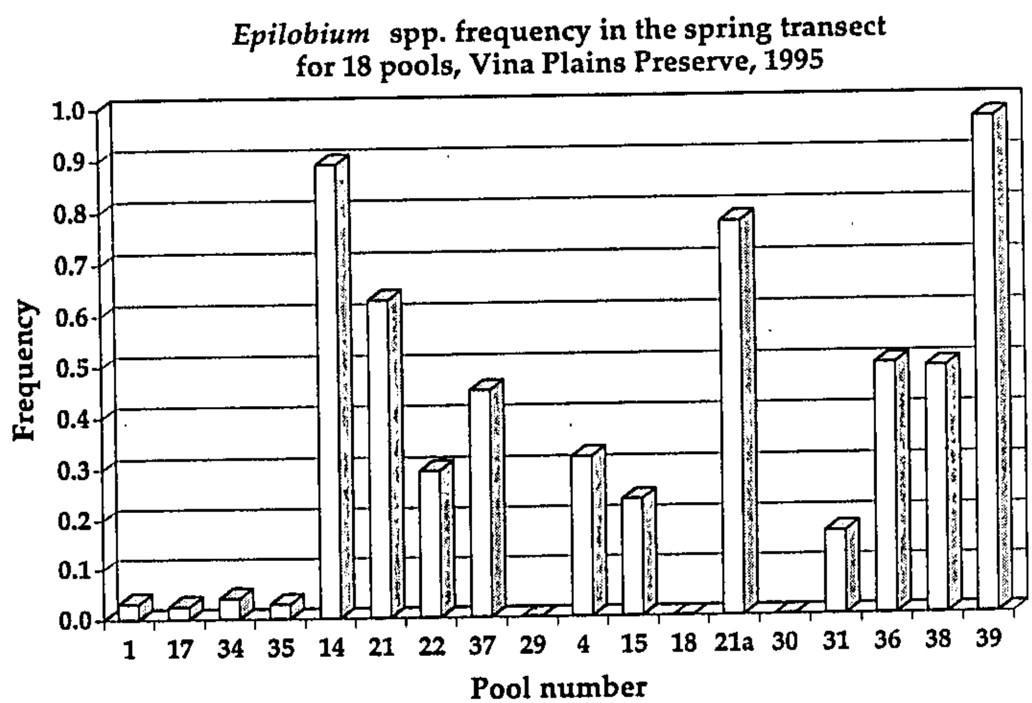


Figure 4.33. *Downingia* spp. frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995. *D. bicornuta* and *D. cuspidata* are the two main species represented by the data.



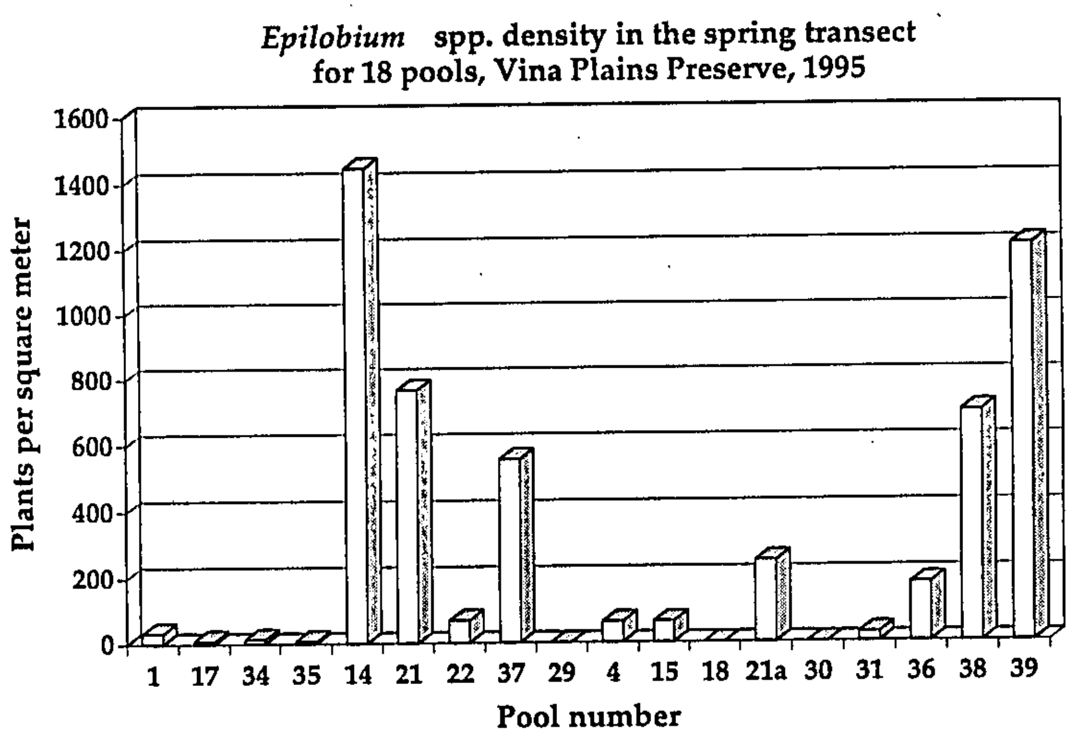
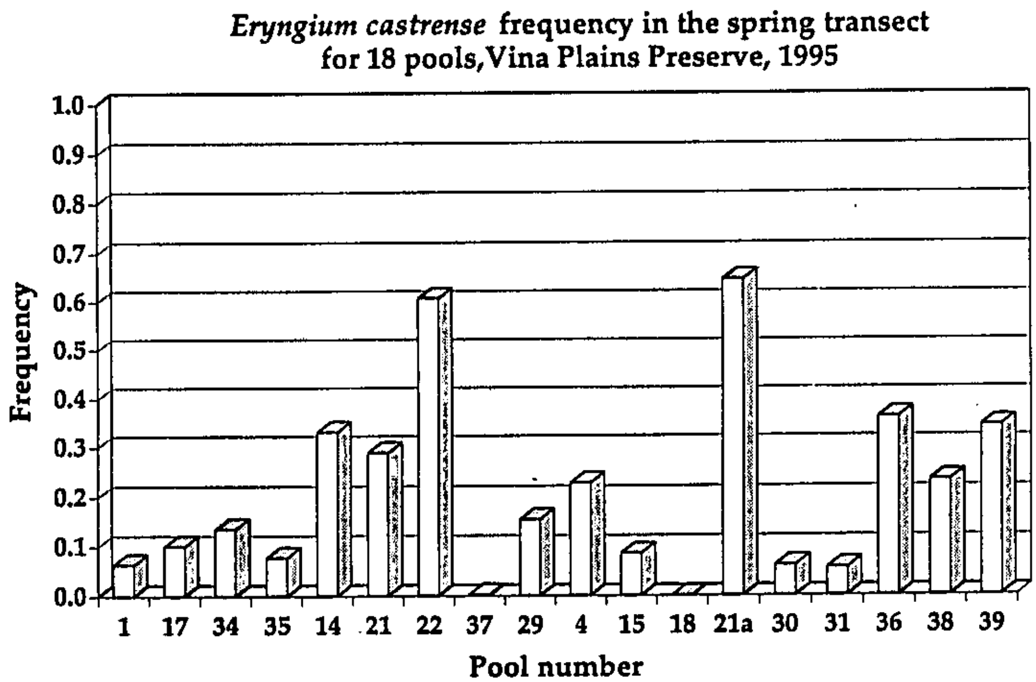


Figure 4.34. *Epilobium* spp. frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995. The main species represented by the data is *E. cleistogonum*, although a few plants of the later-flowering *E. pygmaeum* may be included.



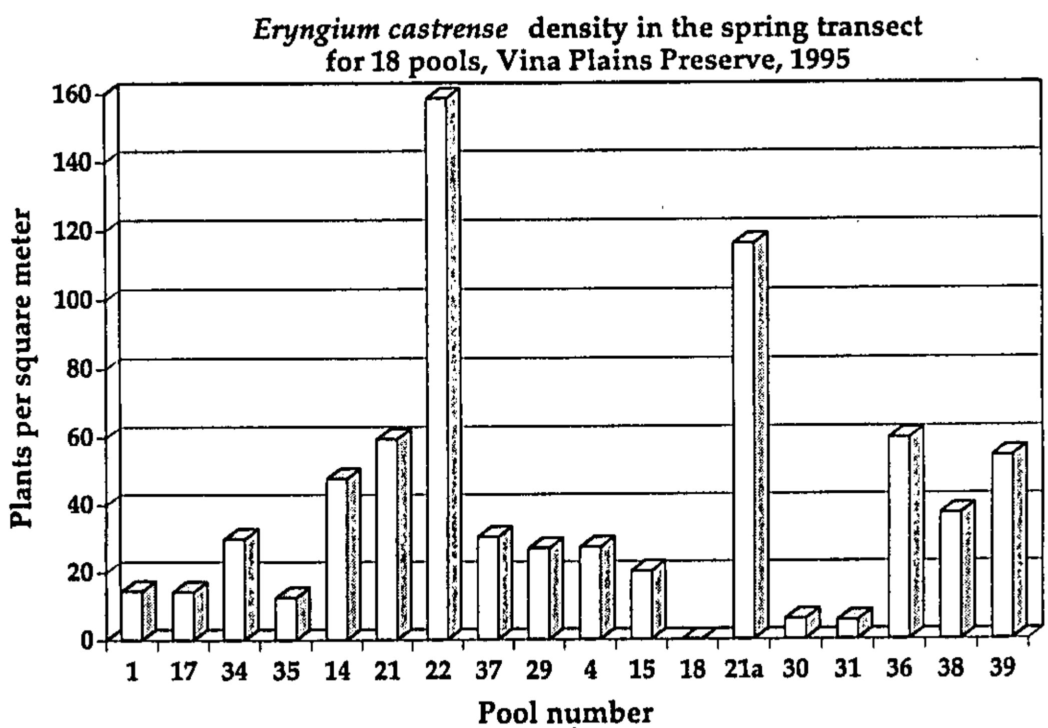


Figure 4.35. *Eryngium castrense* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.

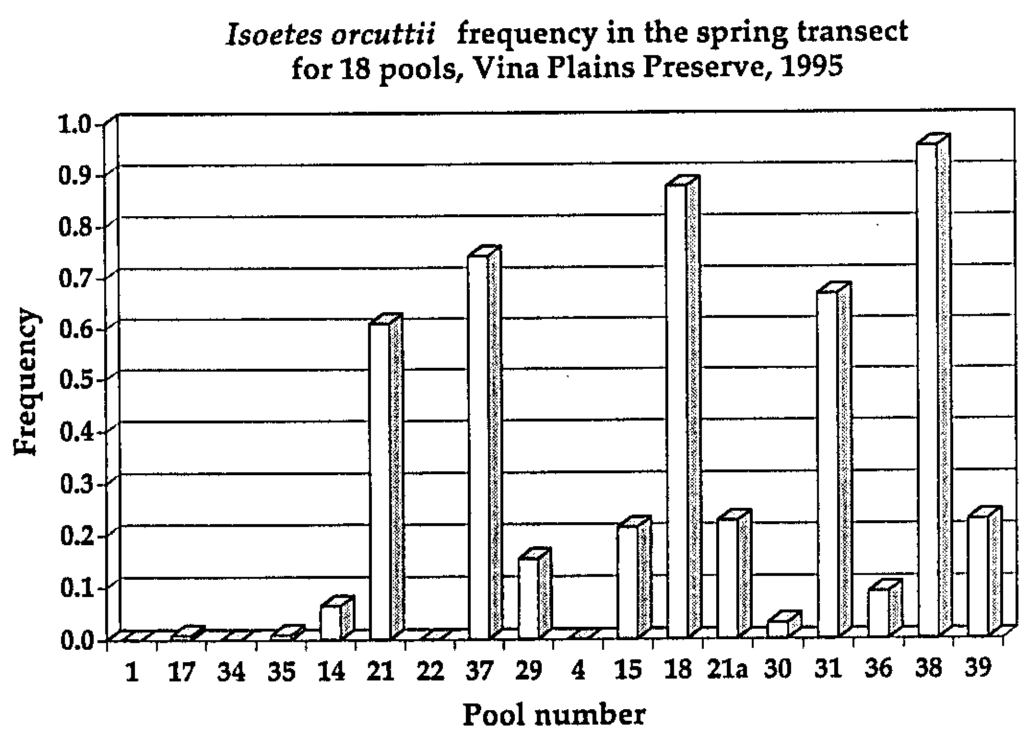
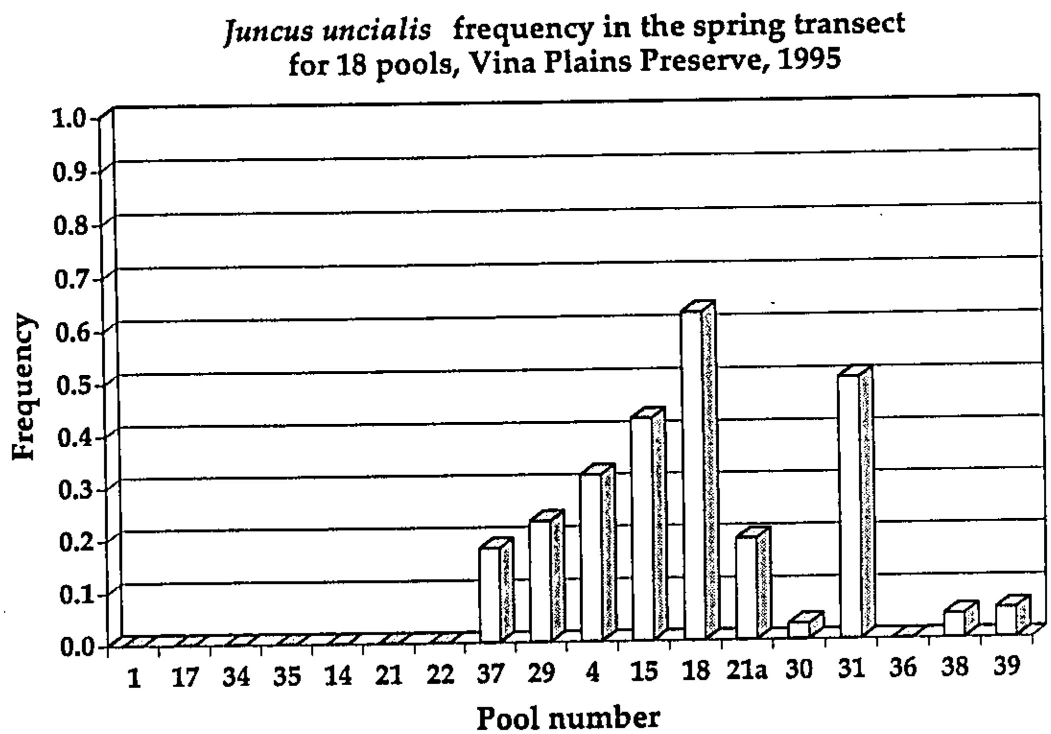


Figure 4.36. *Isoetes orcuttii* frequency based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



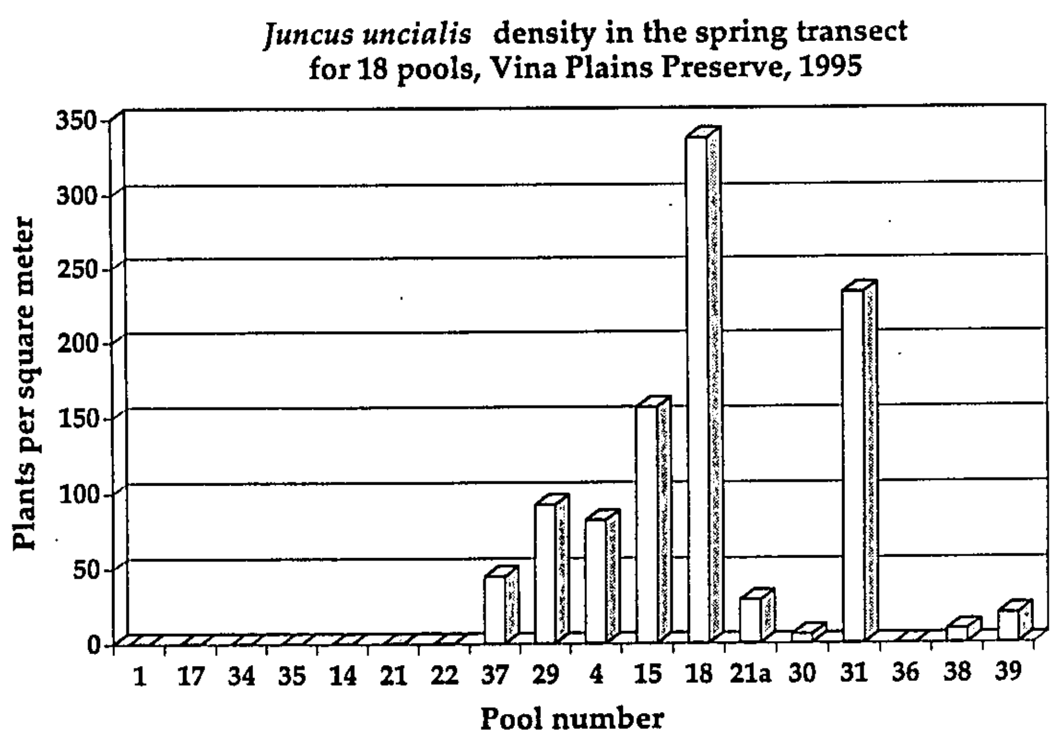
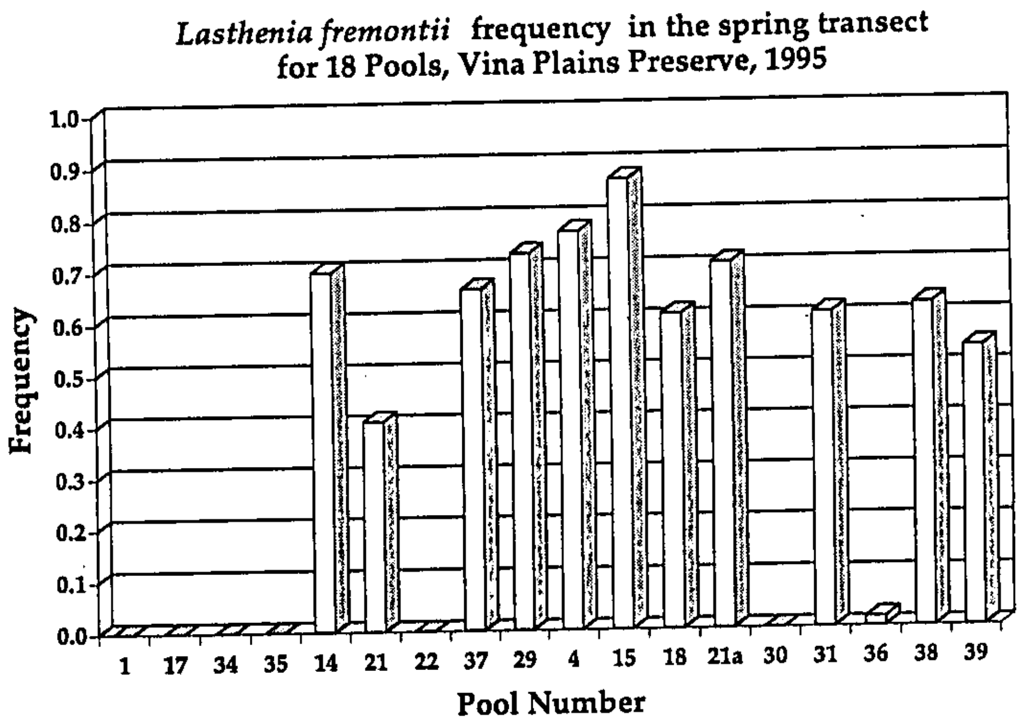


Figure 4.37 *Juncus uncialis* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



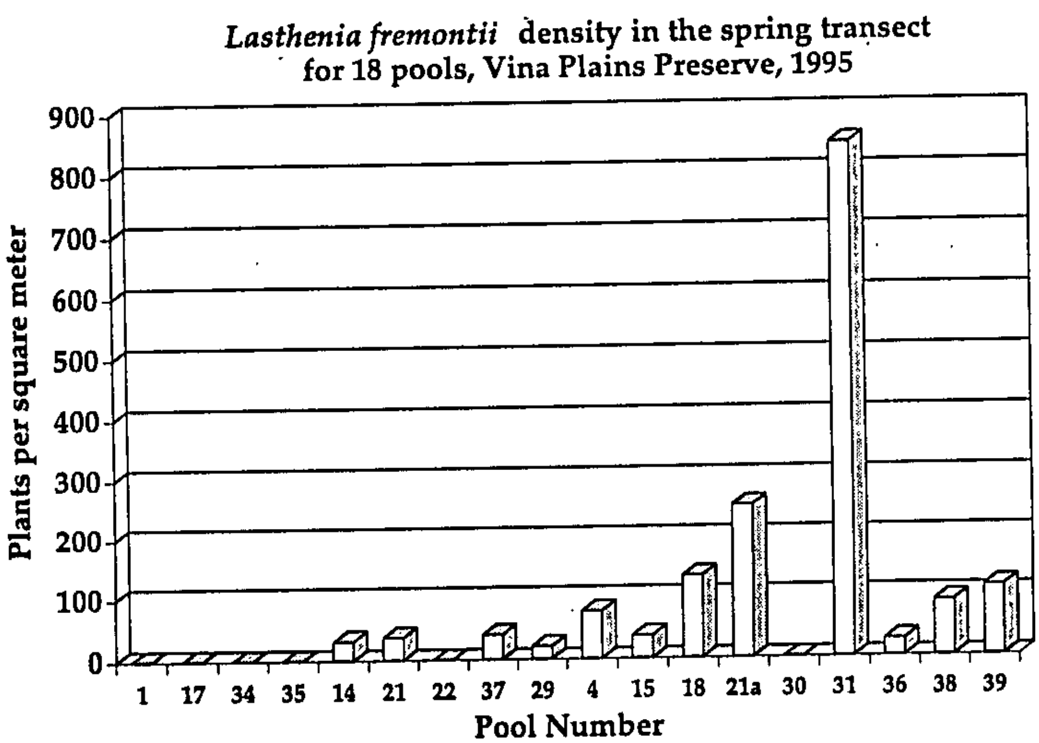
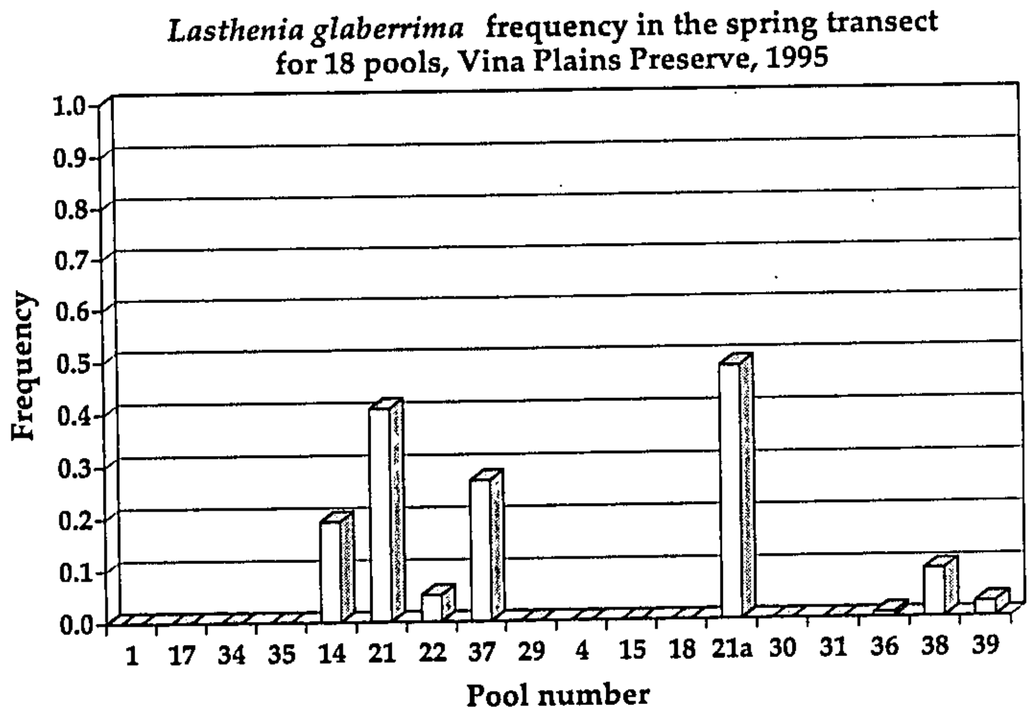


Figure 4.38. *Lasthenia fremontii* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



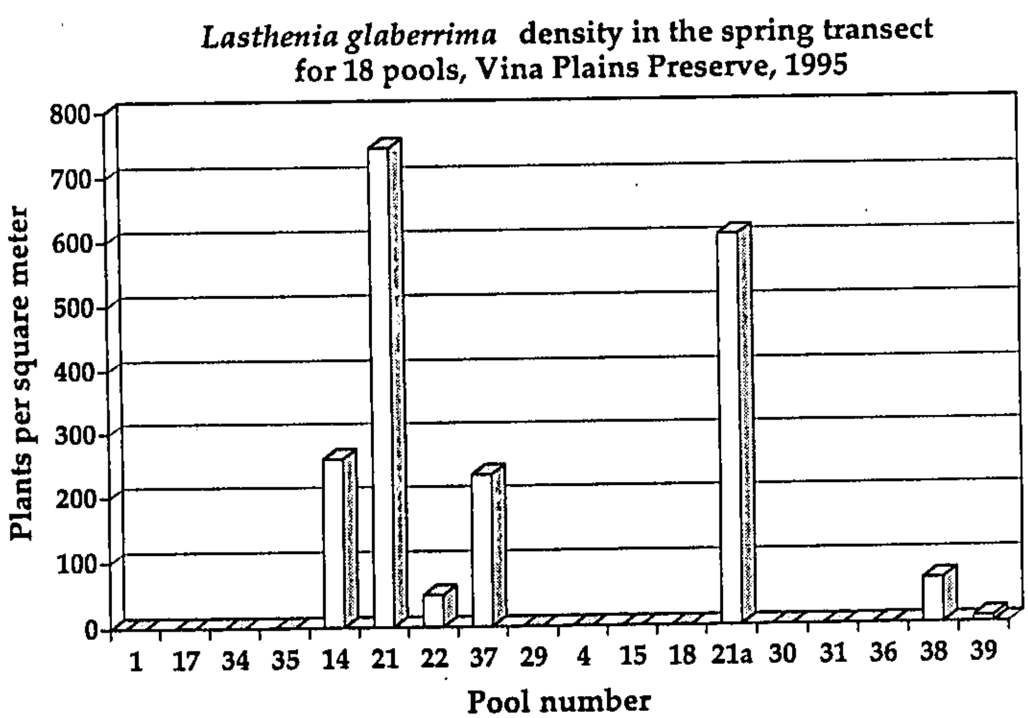


Figure 4.39. *Lasthenia glaberrima* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.

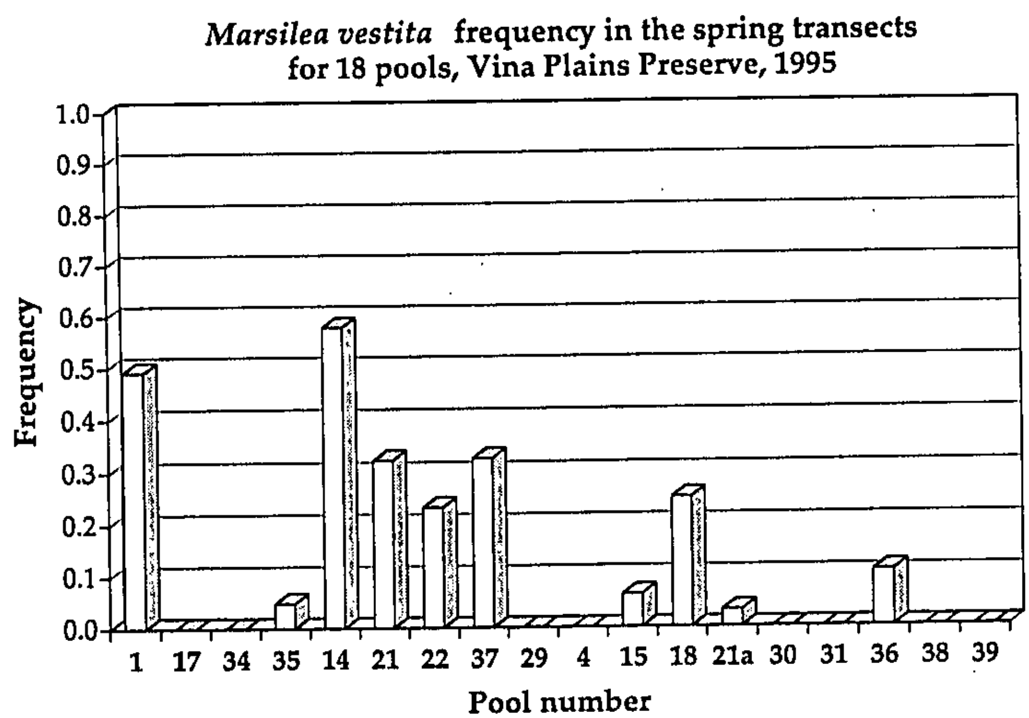
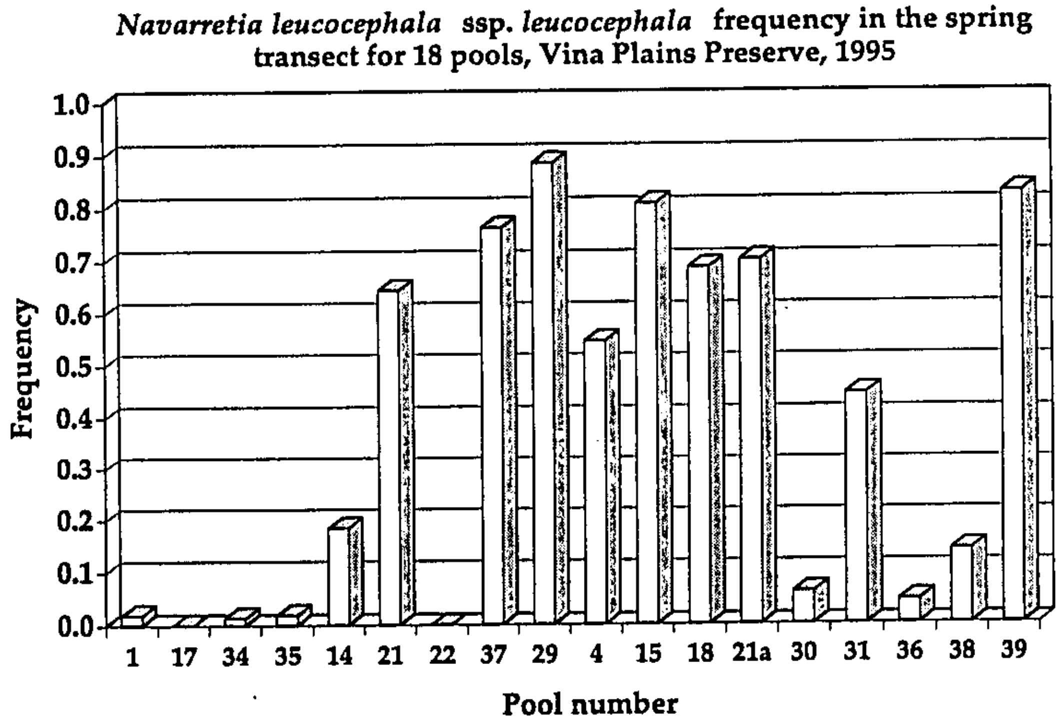


Figure 4.40. *Marsilea vestita* frequency based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



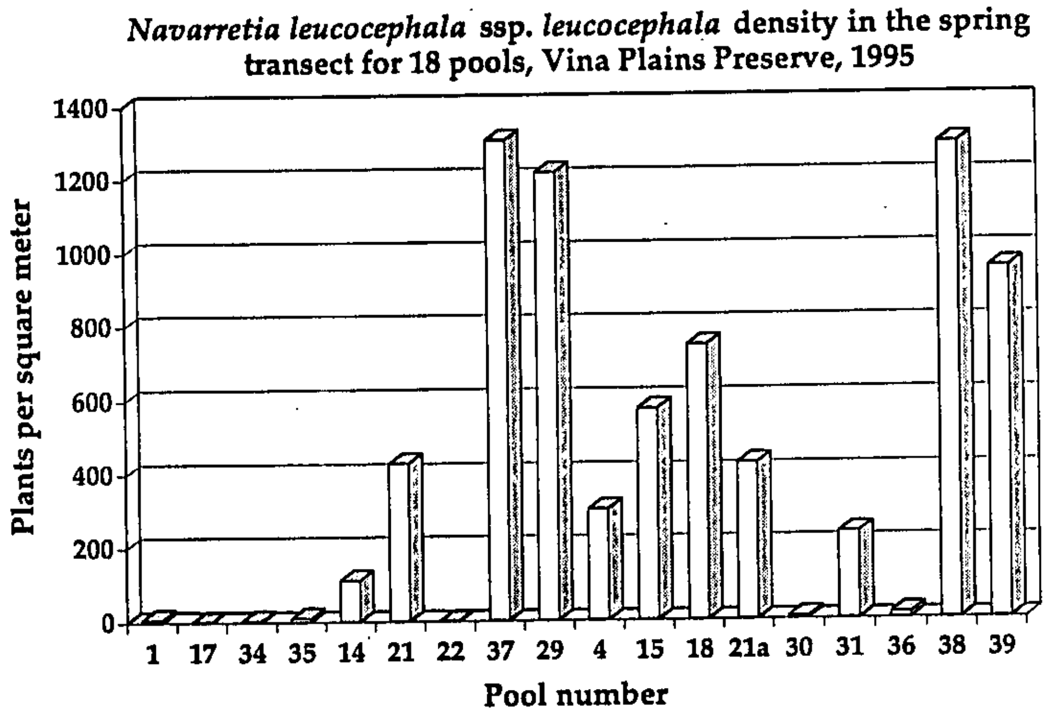


Figure 4.41. *Navarretia leucocephala* ssp. *leucocephala* frequency (top) and density (bottom based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.

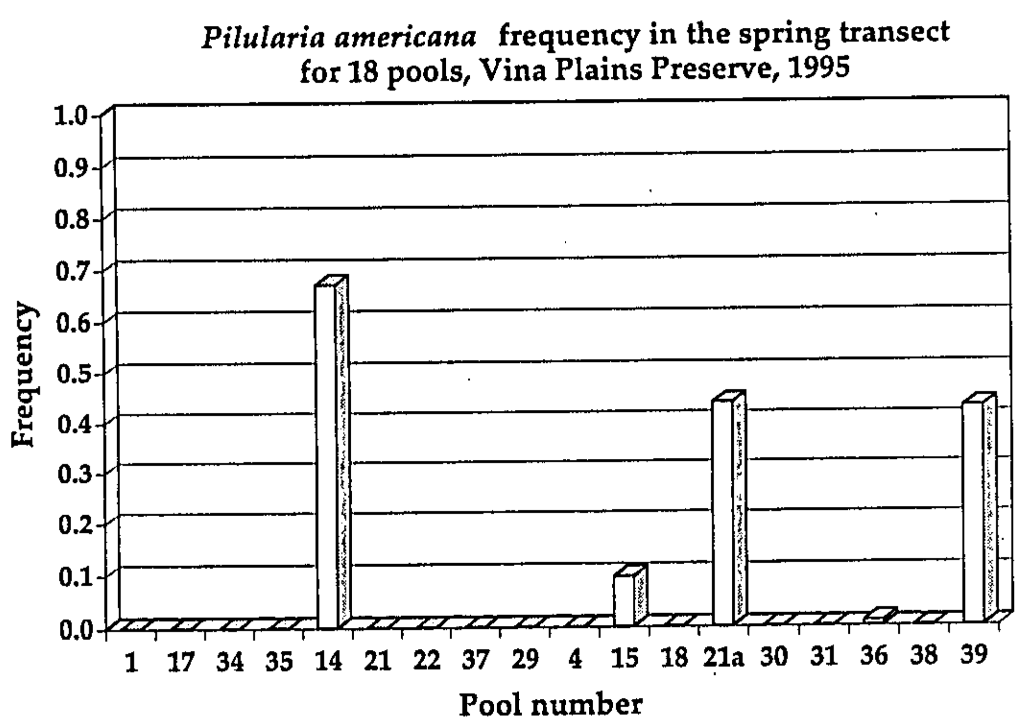
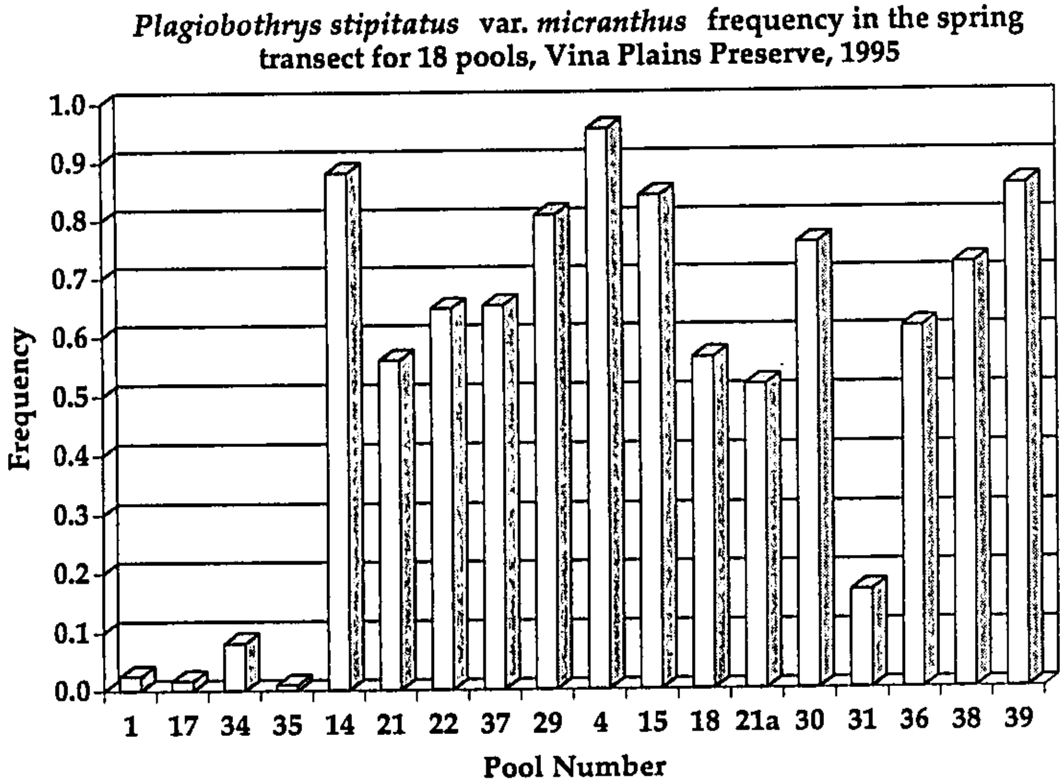


Figure 4.42. *Pilularia americana* frequency based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



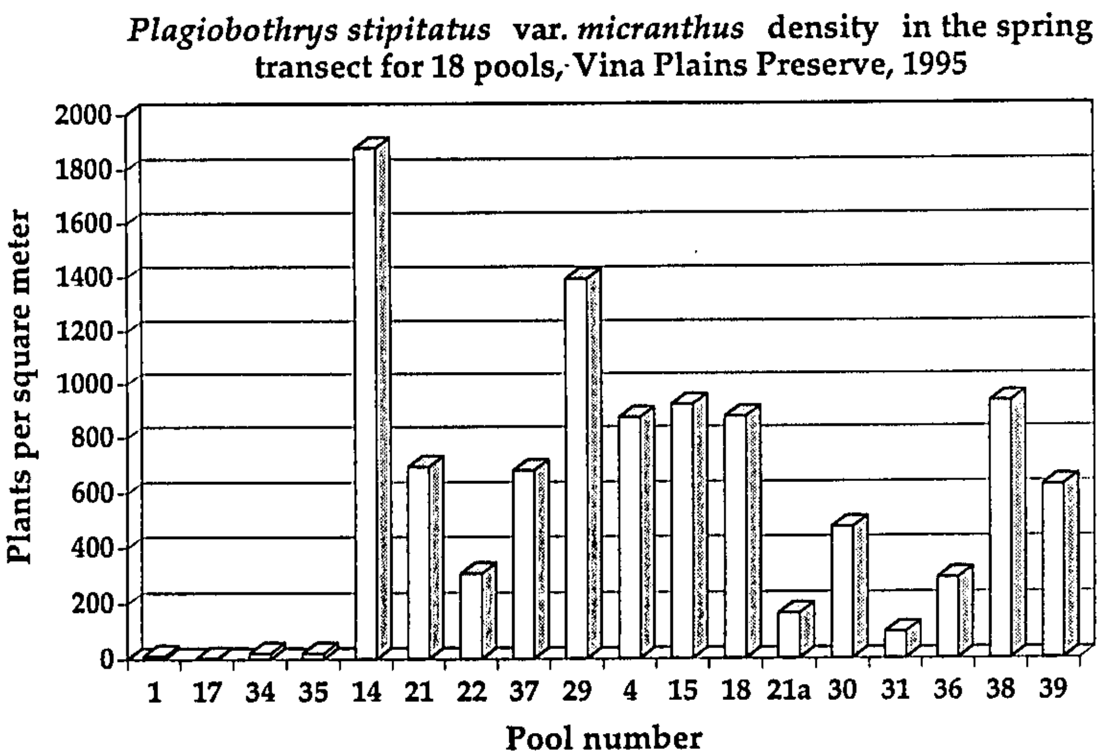
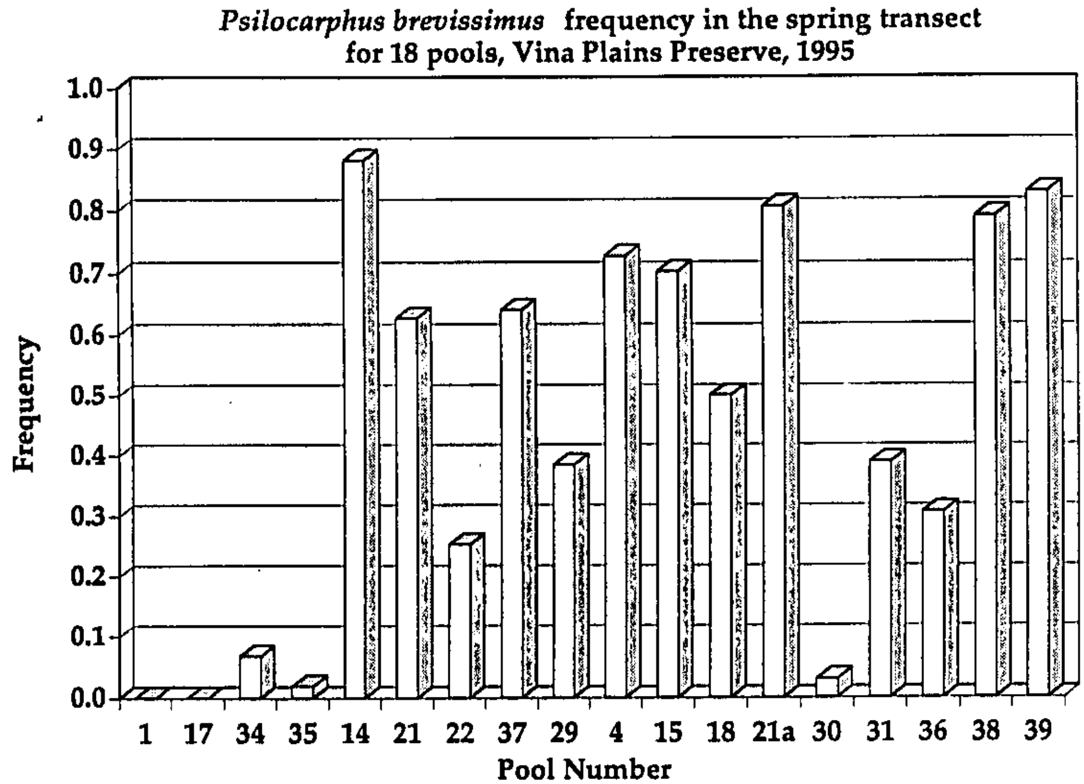


Figure 4.43. *Plagiobothrys stipitatus* var. *micranthus* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.



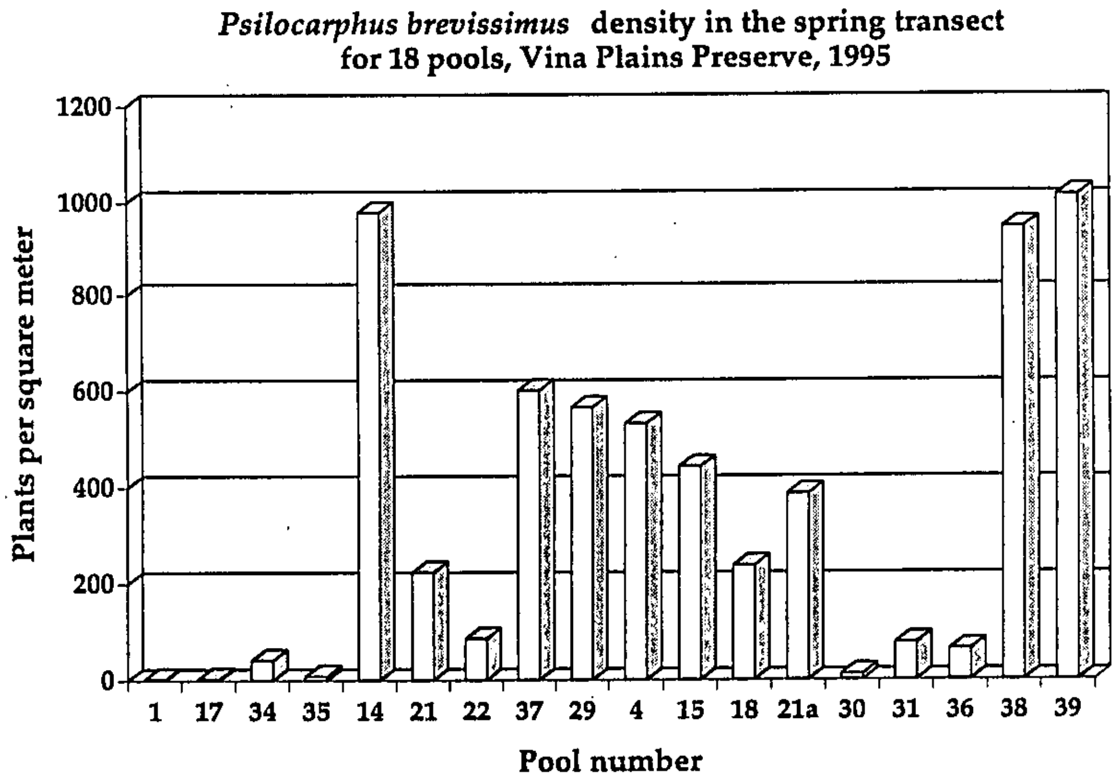


Figure 4.44. *Psilocarphus brevissimus* frequency (top) and density (bottom) based on a spring transect for 18 pools at the Vina Plains Preserve, 1995.

In summary, the deepest pools, with standing water of longest duration, ultimately had the poorest display of "spring vernal pool species,"– even after these pools had dried down. This is in terms of frequency (much of the spring transect was still under standing water when other pools were completely dried down) and also in terms of densities (few individuals of the spring plants occurred in sparse or narrow rings around the deeper standing water in the spring).

DISCUSSION

Characteristics of plant communities or of ecosystem functioning in vernal pools are sometimes assumed, or are treated as self-evident. The data presented from this community study of plants in pools on the Vina Plains Preserve help quantitatively document several phenomena. The 1995 spring and summer numerical data on plants, along with additional field observations and published information, illustrate and support several ideas relevant to pool preservation and management. These ideas on community and ecosystem function will be discussed under "patterns in time" and "patterns in space" below. However, discussion will focus on 1) differences among pools in the Vina Plains landscape, and 2) the necessity of studying/understanding pools during the entire year, not just from time of standing water through drydown and flowering.

Patterns in time

Vernal pool vascular plants show a series of growth strategies

The vernal pool vascular plants display different life history patterns that can generally be placed into three strategies: 1. The "grow-all-winter" strategy characterizes plants with fall/winter resumption of growth (e.g., *Isoetes, Marsilea, Pilularia*) and with germination under standing water. 2. Plants that germinate as pool waters are warming and evaporating represent the second strategy. 3. The third strategy is represented by plants that germinate and grow rapidly after all standing water has evaporated.

Plants that display the first strategy can potentially occur in fall or early winter, providing a long period for production of root systems and rosettes of leaves. Such plant groups include *Orcuttia* (Griggs, 1980), *Downingia, Marsilea, Plagiobothrys, Pilularia, Isoetes*, etc. (Keeley, 1990), and *Sidalcea* (Schlising, 1989). Years with early pool filling, permitting or promoting this early growth, may favor these particular species over others as the pool community develops in the spring. Photosynthesis in these green plants may actively influence the free carbon dioxide and the oxygen available in pool waters (Keeley, 1990), and potentially influence other organisms in the winter vernal pool ecosystem. A potential disadvantage of this strategy results from mortality when large numbers of green seedlings are uprooted, possibly due to waterfowl activity.

The plants that have seed germination as pool waters are warming and evaporating (e.g., *Tuctoria*, as indicated by Griggs, 1980) are potentially competing with the plants that germinate earlier. These plants may have less time for growth before dessication, but are found in deeper clays that probably represent the last sediments to dry.

In the final strategy, seed germination is followed by very rapid growth only after all standing water has evaporated. This is illustrated by *Chamaesyce hooveri* and by *Xanthium strumarium*. (e.g., in Pools 1, 17, 34 and 35).

These three strategies form distinctive patterns, with the last two only found in select intra-pool habitats. Some pools at the Vina Plains Preserve may have all vascular plants showing the same grow-all-winter strategy (e.g., Pools 4, 15, 18, 21a, 30, 31, 38 and 39). Other pools may have all three strategies (growth chronologies) represented (e.g., Pools 34 and 35).

Plant reproduction can continue long into summer in some years

The four rare plant species, illustrating all three of the strategies described above, have the ability to continue producing seeds in summers when moisture remains available in pool basins. Griggs (1980) has described species of *Orcuttia* and *Tuctoria* as unusual grasses in that their spikelets can show indeterminate growth, and can continue to elongate and to add florets if soil water is available. Likewise, *Chamaesyce hooveri* can take advantage of even late summer soil moisture (e.g., from thundershowers or from the occasional fall rainstorms). Green, growing, flowering and seeding *Chamaesyce* plants can be seen some years (e.g., in Pools 1, 17 and 35) well into September or early October (Schlising, unpublished information; see also Stone et al., 1988). Favorable conditions thus may permit these plants to obtain large size and produce larger numbers of propagules. This "plastic" growth ability, well known for annuals of upland sites, could potentially be of importance in managing vernal pool landscapes where these four rare annuals occur in pool basins.

Another example of rare plants' summer reproduction was recorded by Broyles (1983). *Orcuttia tenuis* in Pool 29 produced a second crop of plants in 1982, following a summer rainstorm. No date or further details on the storm or on the growth or sizes of the plants are available.

Different pool plant combinations support different consumer combinations

Plants of *Downingia* and *Lasthenia*, shown to be frequent and/or dense in the spring communities of several of the smaller pools at the Vina Plains Preserve (Figures 4.33 and 4.38), are known to support the brood-rearing activies of specialist pollen-collecting native bees (Thorp 1990). Pairs of adjacent pools may differ in their community plant--bee relationships! Pool 31 and Pool 37 could support the *Lasthenia* bees with frequently occurring *Lasthenia* resources, but Pool 30 and Pool 22, closely adjacent to Pool 31 and Pool 37, respectively, had no *Lasthenia* (on transect samples) to offer these herbivores. Plants of *Downingia* tended to be found in more of the 18 pools studied in 1995, but the fact remains that differing sets of plants in spring pools serve differently to consumers like the specialist bees.

Sidalcea hirsuta, seen in transects in Pools 1 and 17 (Table 4.4)--in the only two pools where it is known on the Preserve--has another set of several different insects using its pollen and nectar (Schlising, unpublished information). These insects include a specialist bee that collects pollen from plants of the mallow family only (R. Thorp, personal communication). These bees may also be foraging in the adjacent pool landscape as well as in the Preserve pools.

The summer flowering of *Chamaesyce hooveri* and *Asclepias fascicularis* in a number of mainly larger pools (e.g., Pools 1, 17, 34, 35 and 37) attracts large guilds of pollen- or nectar-eating insects. These are almost entirely different species feeding on and "servicing" these summer plants, from those observed on spring plants, and these too may be flying among pools on the Preserve and off the Preserve in their foraging activities. Insects making up the summer communities with these plants include especially Hymenoptera, Lepidoptera, Diptera and Coleoptera. In addition, the milkweeds have been found with specialist herbivores on their vegetative parts--despite their being in disjunct locations within the landscape. Homoptera, Hemiptera, Coleoptera and Lepidoptera are all represented as *Asclepias* specialists in some of the pools on the Preserve. Most of the insects observed do not have food resources in the adjacent dry grasslands.

Pool plants vary through the years

Detailed numerical data are on hand for 1995 only, and the following comments support the need for continual monitoring of plant communities in pools at the Vina Plains Preserve. It was considered a "good year" for vernal pools in 1995. That is, rainfall was well-spaced during the winter and spring, with large amounts in January and March, and with a number of late rains which kept many pools wet long into the spring (Figure 2.3). The spring conditions also provided good soil moisture across the extent of the pool basins, even up to the time at which high air temperatures finally caused drydown. But we do not know how typical the spring transect data are, or how similar plant frequency and density would be in other years. The same pertains in the response to residual moisture in the pool soils by the summer communities containing the rare plants.

A photograph taken in May 1983 by Schlising, shows the large and deep Pool 17 with a broad, bright yellow margin produced by *Lasthenia fremontii*. In 1995 the spring transect did not have any *L. fremontii* on it, although some plants of this species were found elsewhere in the pool. In fact, few spring species showed up on the spring transect (Figures 4.30 to 4.44). It appears that if the large pools dry down early (or fill early) in some years, they may "act" more like the smaller pools in terms of their spring plant communities. It would be interesting to determine if they have a longterm seed bank of spring species propagules. It has been shown that the spring population of *Sidalcea hirstua* varies statistically in the size of total flowering population from year to year (1983 to 1986) in this pool (Schlising 1989). Viewing a pool in one year may not show the species or the community of plants that the pool could potentially produce.

Concerning the summer communities with their rare plant species, it can at least now be said that there are good, detailed baseline data for one year that can be compared with other years (Tables 4.1 to 4.3).

There are some data on hand from earlier years for the rare species (Broyles 1983, California Department of Fish and Game 1995) since their rarity did invoke interest in monitoring populations. However, it is not clear how much, if any, formal sampling was done to obtain estimates of population size. Earlier information, if it could be attributed to a numbered pool to compare with the 1995 data, is shown in Table 4.6. An excellent source on rare plant population size for the Vina Plains area, including the Vina Plains Preserve, is provided by Stone et al. (1988), but their size estimates can not be referred to specific pools. In another source, some data exist on densities of *Chamaesyce hooveri* and *Orcuttia pilosa*, but found within different regions of Pools 17 and 35 for 1983 and 1984 (California Nature Conservancy 1986). These are not directly comparable with our 1995 data, but suggest considerably higher densities for *C. hooveri* than we obtained. No total population size estimates are given.

The same TNC data set (obtained with sampling methods roughly comparable to those used in this study for 1995) provides data on associates of the summer rare plants in Pools 17 and 35 (California Nature Conservancy 1986). The exotic perennial bindweed, *Convovulus arvensis*, had a frequency of .03 [sic] in 1984 and .32 in 1985 within Pool 17 (compared with .44 in 1995). It had a frequency of 0 in Pool 35 in 1984 (compared with .007 in 1995). Table 4.2 indicates that five of the nine pools studied in the summer had *Convolvulus* present in 1995.

Table 4.6. Historical estimates of total population size, and year, if identifiable to specific vernal pool, for four rare plant species at the Vina Plains Preserve, compared with 1995 estimates based on systematic/random samples (Table 4.1).

Pool	Source of information	*Chamaesyce hooveri*	*Orcuttia pilosa*	*Orcuttia tenuis*	*Tuctoria greenei*
1	California Dept & Game (1995)	--	300 in 1980	--	--
	Broyles (1983)	2,000 to 3,000, plus 1 in tiny pool east of Pool 1 in 1983	10,00 in 1983	--	--
	California Dept & Game (1995)	about 3,000 in 1986	< 500 in 1980	--	--
	THIS STUDY	183,400 in 1995	1,355,800 in 1995	--	--
14	Broyles (1983)	--	2 in 1983	--	95 in 1983
	THIS STUDY	--	--	--	96,400 in 1995
17	Broyles (1983)	2,000 to 3,000 in 1983	< 10,000 in 1983	--	--
	THIS STUDY	3,900 in 1995	3,987,900 in 1995	--	--
21	Broyles (1983)	--	--	--	< 30,000 in 1983
	California Dept & Game (1995)	--	--	--	2,000 in 1988
	THIS STUDY	--	--	--	106,300 in 1995
22	Broyles (1983)	6 in 1983	<100 in 1983	--	300 in 1983
	THIS STUDY	--	--	--	173,200 in 1995

29	Broyles (1983)	--	--	5,000 to 10,000, + 1,000 after a sum-mer rain in 1983	--
	California Dept & Game (1995)	--	--	4,000 in 1988	--
	THIS STUDY	--	--	147,7000 in 1995	--
34	Broyles (1983)	1,500 +/- 100 in 1983	3,000 in 1983	--	--
	Alexander (class data)	2,312 in 1990	--	--	--
	Alexander (class data)	16 in 1992	--	--	--
	THIS STUDY	5,600 in 1995	-1,913,400 in 1995	--	--
35	Broyles (1983)	2,000 to 3,000 in 1983	5,000 to 10,000	--	a few hundred in 1983
	THIS STUDY	2,000 in 1995	4,205,300 in 1995	--	225,600
36	Broyles (1983)	25 in 1983	--	--	present in 1983
	THIS STUDY	1 in 1994	--	--	--
		1 in 1995	--	--	--
37	Broyles (1983)	--	--	--	present in 1983
	THIS STUDY	--	--	--	1,319 in 1995

The exotic annual *Xanthium strumarium* had a frequency of .41 in 1984 and .31 in 1985 within Pool 17 (compared with .297 in 1995). It had a frequency of .046 in 1985 within Pool 35 (compared with 0 in 1995). The *Xanthium*, due to hand-pulling of plants over several seasons, was not present in Pool 35 in 1995.

These data on plant changes through time may have implications for vernal pool management at the Vina Plains Preserve. Exotics are occupying increasing parts of the pool floors, and may well be displacing the rare plant species (e.g., Stone et al. 1988). Furthermore, these plants may well be impacting the dynamics of the ecosystem at other times (for example, by producing a different quantity or quality of plant biomass for detrital consumers).

Patterns in space

The plant patterns in time just discussed, of course, interface with plant patterns in space within and among the vernal pools. But a major set of patterns in space involves views of one species occurring within differing regions of the pools in a complex of pools (Figures 4.1 to 4.27). Patterns shown by *Chamaesyce hooveri* in 1995, for example, include occurrence in the north half of Pool 1 (Figures 4.1 and 4.3), in a "wavy ring" in Pool 34 (Figures 4.17 and 4.19), and sparsely located "here and there" in Pool 17 (Figures 4.7 and 4.9) and Pool 35 (Figures 4.21 and 4.25). It appears that populations of this species could be overlooked in some cases, without a thorough search throughout an entire pool. There is no documentation for which environmental factors influence/cause these patterns in one year, nor is it known how to predict patterns of the same species in the same pools in following years. Photographs taken by Schlising in Pools 17 and 35 in the early and mid 1980s indicate a pattern of wide *Chamaesyce* dispersion in both pools, as well as higher densities, but these densities were not measured.

Edaphic conditions of soil basins, as well as the duration of standing water, correlate with patterns shown by vernal pool plants (Holland and Dains 1990, Zedler 1987). Some species, such as*Tuctoria greenei* (Figures 4.5, 4.11, 4.13, 4.23 and 4.26) and perhaps *Orcuttia tenuis* (Figure 4.15) appear to be restricted to a specific soil type. A less-varying pattern occurred in 1995 for *Orcuttia pilosa*. Its populations occurred broadly throughout central portions of four pools (Figures 4.2, 4.8, 4.18 and 4.22). The pattern in Pool 1 (Figure 4.2), however, tends to be in the southern half, a region which corresponds to Anita clay soil type, as opposed to the Tuscan loam soil type underlying the northern half of the pool with the more frequent *Chamaesyce* (U. S. Department of Agriculture 1967). Recognizing these patterns here reiterates that each pool is different in exact combination of rare plants and their associates, soils, depths and duration of water.

Observations on another type of pattern in 1995 (and earlier) imply that pools in a complex, as at the Vina Plains, may influence each other and may need to be taken into consideration for preservation or management actions. From time to time the presence of one or a few plants of a rare species can be found in a pool not known to support a reproducing population. Table 4.6 indicates that Broyles (1983) saw a few individuals of several rare species disjunct from the larger populations (e.g., two *Orcuttia pilosa* in Pool 14 and six *Chamaesyce hooveri* in Pool 22 in 1983). In 1995 such patterns in space were documented again: Pool 18 had one plant of *O. pilosa* and Pool 16 (not otherwise studied for plants) had three plants of *O. pilosa*. Pool 16 is connected to Pool 17 by water from time to time during some winters. Pool 18 is not connected to other pools. Similarly, Pool 36 had one plant of *Chamaesyce* in 1994, one in 1995, and according to Broyles (1983; Table 4.6) had 25 plants in 1983. This implies that pools in a complex may "feed" each other, at least in terms of the rare plants here with propagules being dispersed from pools with major populations. This could be a useful idea in terms of viewing whole complexes of vernal pools.

Stone et al. (1988) suggest that the spatial patterns (and the numbers of individuals in a population) may well depend on features of management. *Chamaesyce* populations, they suggest, may show a more widespread or dense pattern if grazing removes the weedy species growing with it (*Convolvulus* and *Xanthium*), leaving open area for growth of the native plants. Their suggestion may pertain to this rare plant in Pools 1 and 17 for example; however, cattle traditionally are removed from the dried grassland/vernal pool landscapes before these large pools dry down and these particular weeds begin germination of seeds in the mud or begin regrowth from extensive rhizomes in the pool soils.

These comments on plant patterns in space (and in time) identify a need to monitor or to examine a pool or a pool complex through a series of years. Three summary points are: 1. There may be no such thing as an "average" pool in a pool landscape. This is not only in terms of abiotic features like landforms, types of soils, and duration of standing water, but also particularly in terms of the plants (and animals) present in the communities within the pools. Even in terms of the plant communities alone, dissimilarity appears to be the "norm." 2. It is essential, for preserving and for manageing vernal pools in a complex, to be familiar with the organisms--their population dynamics, and with their life history chronologies throughout the entire year (or years), and not just at times of standing water and pool drydown. 3. Conservation of vernal pools should strive to find, preserve and manage a complex or a landscape that includes a real array of pool sizes, depths and living communities. It seems that only then will species richness and ecosystem interactions within and among the pools continue to reflect nature.

Chapter 5
MANAGEMENT RECOMMENDATIONS DEVELOPED FROM KEY IDEAS ABOUT VERNAL POOLS

The following key ideas are derived from the information presented in this report, combined with observations we have made over many years on vernal pools. We have divided this presentation into eight key ideas about vernal pools. The **key ideas** start with comments on the physical environment and are followed by population characteristics and end with ecosystem comments. Each key idea is followed by some associated **management recommendations** and these are followed by a **discussion**.

The information in this Chapter is expanded beyond Vina Plains Preserve and Tehama County to include other parts of California's Central Valley. Vina Plains Preserve represents an important vernal pool complex on an arc of pools extending from Redding to Sacramento between the Sacramento River floodplain and the foothills. The eight ideas presented below may need to be modified when considering some vernal pools between Oregon and Baja California due to major climatic differences. The strength of this presentation is derived by combining animal and plant observations into an ecosystem perspective.

1. Vernal pools form hydrologically independent ecosystems consisting of single pools or groups of connected pools. These pools are found in relatively level landscapes that include many kinds of pools varying in basin size, depth to impermeable layer, amount of clay, and types of organisms.

Management recommendation

Whole landscapes must be preserved, with consideration given to the integrity of individual pool drainage basins. Some mega-preserves (e.g., Vina Plains region) must be established. Management of large vernal pool landscapes is more effective than managing the equivalent area of small isolated preserves; however, small preserves potentially act as stepping stone corridors between mega-preserves (see below).

Preservation must include diverse pool systems, especially in regions where pool systems have been lost. Management of California's Central Valley vernal pools must include a regional coordination.

Discussion

Different times of pool flooding and dry down, for pools in the same landscape unit during any one year, reflect both basin differences and hydrological independence of pool ecosystems. The Vina pools with large basins flood early in contrast to some of the larger pools that have proportionally smaller basins. These differences are modified by soil depth in pool floors and the irregular units of adjacent clay soils. The clay soils beside pools give and remove water from the pools at different seasons. Changes in pool hydroperiod are also influenced by the height of sills on drainage channels. These differences are not static, and some basins that are hydrologically independent during dry years are connected in wet years.

Building a drainage ditch through a vernal pool landscape or draining additional water into pool basins compromises the integrity of the pool basins as much as land fill or sediment removal. Although groups of pools are components of ecosystems defined by hydrology, the same systems are interconnected by biotic transfer (see below). Furthermore, these hydrologically independent ecosystems have the potential of accumulating pollutants carried by air or water or from solid waste deposited at any point in the drainage basin.

Vernal pool topography on the edge of the valley is naturally divided by incised rivers, and not all parts of individual preserves can be contiguous.

The punching impact of cattle that modifies the water exchanges in both the clay soils and the upland soils (very shallow loam at Vina) impacts pool hydrodynamics. This impact is difficult to document because of major differences in climatic patterns from year to year (see below). Some stock ponds constructed out of vernal pools still have marginal areas that contain vernal pool characteristics.

In summary, our vernal pools owe their integrity to hydrologically well-bounded units.

2. The Mediterranean climate has a seasonal sequence that includes a winter wet period and a summer dry period. Although the initiation, intensity and duration of these seasons cannot be predicted, large pools typically hold water for several months. Year to year differences in the Mediterranean climate can change vernal pool ecosystems at the same location.

Management recommendation

Management must use information generated during years that are extremely dry or wet before decisions are made. Therefore decisions must include information generated over many years. Because this information will take decades to obtain, the establishment of vernal pool preserves should have high priority.

Management must be aware of the variability in the sequence of events such as pool flooding and pool dry down. Management calendars must be flexible because specific events (e.g., flooding and dry down) are variable from year to year.

Discussion

The aquatic phase of our vernal pools is variable and the specific time when rains start can change considerably from year to year. Wide fluctuations in fall air temperatures between night and day result in atmospheric water input and sediment modification before the initiation of rains. Limited basin size controls maximum pool size and, once full, additional surface water flows from the pools. However, the time between storms can be so long that considerable water is lost by evaporation before the next rain. The unpredictable nature of rain and the length of interstorm periods (as well as the intensity of winds) also changes the rate of water gain and loss from year to year. This combination of unpredictable water gain and loss results in pools that are astatic some years and relatively constant other years.

Late spring rains potentially refill some pools after the basins are dry. Animal communities (including mosquitoes) potentially use these pools. In contrast to these aquatic differences, the late rains can potentially increase plant biomass and seed production of vascular plants.

In summary, different climatic sequences modify ecosystem characteristics from one year to the next.

3. Populations reproducing in California vernal pool ecosystems are especially adapted to year-to-year differences. These specialized populations grow and reproduce at different and distinctive times through the year. California vernal pool organisms (as diverse as macroinvertebrates and vascular plants) have common life history strategies that include survival during unfavorable times (cysts and

seeds), synchronized start of growth (hatching, germination), rapid development and reproduction.

Management recommendation

Management must consider survival of, and human impact on, all stages of vernal pool organisms throughout the year. This must include conditions that control a) propagule survival (cysts in summer, seeds in winter), b) hatch (in the aquatic phase) and germination (underwater in winter or in summer), c) growth, and d) reproduction. As a result, management strategies must combine, at the same location, concern for aquatic animals that are adult in the winter pools and concern for the plants found reproducing in the spring and summer basins.

Management must recognize the need for taxonomic descriptions of many aquatic invertebrates and the necessity for ecological and genetic information not yet documented for important vernal pool species.

Management should recognize that although vernal pool populations are locally abundant they are dependent upon a narrow set of conditions found only in vernal pool habitats.

Discussion

The plasticity of life history dynamics from year to year and place to place requires a commitment to a long term study of the ecology and genetics comparing these species in space and time. The level of taxonomic knowledge of the invertebrates is both incomplete and complicated by the need to involve specialists to determine the identification of specific taxa.

Collecting aquatic invertebrates will potentially impact the underwater germination of the vernal flora and summer floristic surveys and will potentially impact the survival of cysts in the dry sediments. Although the physical evidence of disturbance is very evident in the wet basins during flooding and dry down, the summer dry pool basins (that are potentially attractive to human off road vehicle use) must also be protected. Although the cysts and seeds are resistant, activity that repositions these propagules in the sediment horizons will undoubtedly have an impact on survival and hatching or germination.

Years that are favorable for some organisms are less favorable for others. In many vernal pool complexes there are species found only in the larger pools and other species found in the small pools. In the Vina Plains region there is a difference with Anostraca with the most viable populations *of Branchinecta conservatio.* found in the larger pools, *Linderella occidentalis* found in intermediate size pools and *Branchinecta lynchi* found in the smaller pools. However, this relationship is not static as the pool types change from heavy rainfall to low rainfall years.

In summary, we observe most vernal pool populations adapted to a pulse perturbation with an important life history stage that bridges unfavorable times and a finely tuned break in dormancy allowing annual initiation of growth at appropriate times. There also appears to be a selective advantage in remaining inactive during some unfavorable years (especially in the species that require a longer hydroperiod).

4. California vernal pool organisms have highly variable densities from year to year and pool to pool, with low to no individuals in some years and extremely high densities of reproductive individuals in other years. Resistant propagules (cysts, seeds), represent many overlapping generations that ensure population viability countering years of low density.

Management recommendation

The small size of vernal pool populations during some years requires extremely careful management. This low population size can potentially be countered by management that preserves resistant propagules.

Management must not be satisfied with only a few large pools with high propagule density (or plant and animal population density). Management must preserve a variety of pools in the landscape and maintain conditions that support dispersal among pools (see below) to insure higher propagule diversity as well.

Discussion

Vernal pool organisms are potentially found in very high densities. Although the filter feeding animals that have numerous free living developmental stages generally have decreasing densities with growth, the number of adults is often very high. Although plants also have changing densities, plasticity in plant body size is large and, as a result, seed production can be very different from year to year.

The maintenance of vernal pool populations depends upon the quantity and diversity of the propagule bank. The environments that favor the development of large numbers of individuals will also have the largest propagule bank. The ability of species to remain viable for several years contributes to the genetic diversity of populations that develop any one year. The propagule diversity will also be greatly increased by dispersal between pool types. In some pools, reproduction varies from year to year with high propagule production some years and a loss of individuals before significant reproduction other years.

Although the climatic pattern results in pools most years, the aquatic populations with adaptations that allow resistant stages to remain for more than one year will have a selective advantage during the very dry years when some pools have a reduced hydroperiod. The years with reduced soil water accumulation may have reduced vascular plant density and seed production.

In summary, many vernal pool species are dependent upon a resistant stage that has the potential of remaining dormant through several years (these can be favorable as well as unfavorable times). The presence of these developmental stages allows annual species to have overlapping generations, linking chronologically displaced populations (gene pools) of the same species. The presence of developmental stages does not indicate that the pools support reproduction (because of dispersal).

5. California vernal pool populations are part of metapopulations displaced in time and space. Individual pool populations are linked by animal, water or wind dispersal of whole organisms, propagules or pollen. Vernal pool Landscape diversity is higher than individual pool diversity. Specific species and numerous species interactions shift through the landscape during years with different rainfall patterns.

Management recommendation

Management must recognize that the exchange of individuals and propagules between different vernal pool populations (dispersal) is necessary for the maintenance of metapopulations and a level of genetic diversity that supports long term survival. The diversity of vernal pool ecosystems can only be maintained and determined from a landscape perspective.

Management recommendation concluded

The linkage of vernal pool populations by dispersal agents (e.g. waterfowl) requires the coordination of all valley environments with the management of vernal pool preserves. Management should recognize the importance of small preserves as stepping stone corridors bridging large pool preserves

Discussion

The animal and plant taxa of vernal pools display different kinds of metapopulatiaons. For example, *Branchinecta conservatio* and *Chamaesyce hooveri* have highly disjunct (displaced in space) populations, and other species, such as *Lepidurus packardi* and *Orcuttia tenuis* are found in adjacent vernal pool landscapes.

Population dynamics of invertebrates (e.g., *Branchinecta conservatio* and *Lepidurus packardi* in this report) indicate some pools as high production (source) pools and other pools in the same landscape as low production (sink) pools.

Resident horned larks (as well as their droppings), are frequently seen on *Chamaesyce* plants in summer and fall--apparently eating seeds and possibly dispersing them from pool to pool. Pollen vectors (Thorp 1990), including some specialist bees, visiting spring and possibly summer flowers in different pools, doubtless promote gene flow in the plants.

We assume that avian use contributes to the dispersal of organisms between pool ecosystems. The preservation of mega-preserves that include adjacent natural areas (that preserve wildlife diversity) and the expansion of waterfowl populations throughout the valley will intensify dispersal.

Species displacement in time and space potentially changes diversity in any single pool from year to year, and makes the diversity of a pool complex greater than any one pool. The test for community viability is biodiversity (Kistner, et al. 1995), which must be surveyed for many years.

In summary, the preservation of vernal pool species requires a knowledge of landscape units and population dynamics (including gene flow) over large areas.

6. Native species that spend part of their life cycle in vernal pools and exotics that have the potential to survive in this unique environment influence the dynamics of the vernal pool ecosystems.

Management recommendation

Management requires a commitment of many years to remove exotics. Management must develop a permanent program to remove future invasions attempting eradication with the first observation of exotics.

Management must differ with specific pools, and in the same pool from year to year, when these pools have high periodic use by native nonresident species (especially vertebrate use). Management must recognize the importance of adjacent ecosystems (of a variety of types) to support vertebrates (e.g., amphibians) and invertebrates (e.g., insects) that use vernal pools. The management of non-vernal pool wetlands and factors that control waterfowl population size throughout California's Central Valley impact the level of avian predation in vernal pools.

Discussion

The pools that dry last tend to provide suitable habitat for exotic plants. Exotic species, such as *Xanthium* and *Convolvulus* have most likely been introduced by vertebrates especially cattle. These populations are expanding in size and will require special control techniques. The use of chemicals to control exotics requires extreme care because of the potential of accumulating herbicide breakdown products.

Pools adjacent to longer-lasting wetlands will support amphibian use and this can even include temporary use by non-native bullfrog (*Rana catesbeiana*) young.

Water boatmen (Corixidae) are early invaders and their reproductive success is attributed to an ability to feed on the detritus food chain. In contrast, although the backswimmers (Notonectidae) are predators found regularly in the pools, and often breed in the pools, their larvae are more often unable to complete development before dry down. These patterns with some successful reproduction and some failure is found in a variety of insects (e.g., beetle herbivores and carnivores) that are annually observed in the warmer aquatic stages. It appears that insect predation has been an important component in influencing adaptations of vernal pool crustaceans.

Vina Plains Preserve supports a water bird concentration in the winter and spring. Baker, et al. (1990) point out the importance of larger pools as attracting resting and feeding birds. A larger vernal pool preserve should enhance what we assume is a natural waterfowl use. This expanded water bird density will also be an important factor in expanding the use of the area by predators. The predator base is further supported by preserves that contain native grassland (and fall mulch cover) that favors increased populations of ground and subsurface vertebrates, especially in areas with low or no grazing,

In summary, the vernal pool communities contain native and non-native individuals that potentially change ecosystem dynamics. A commonly observed yet stochastic occurrence of nonresident species places unique pressure on the occurrence of native species. This challenges the use of a diversity index (Alexander and Syrdahl 1992)

7. Communities found in the summer-dry pool floors and those of winter pools are interacting components of the same ecosystem. These populations and communities are potentially linked by the flow of energy and cycle of matter.

Management recommendation

Management should consider that impacts on one component of the ecosystem will have impacts throughout the year on other components of the ecosystem (e.g., a change in summer annual biomass will impact crustacean density in winter).

Discussion

Aquatic invertebrate adaptations that relate to predator-prey interactions include a variety of topics such as high biotic potential, rapid development in cool waters, transparency of some suspended filter feeders, dark color of benthic organisms, large size. It appears that the Branchiopods as a group have many adaptations that are associated with invertebrate predation. Complex interactions undoubtedly also exist. For example, although the tadpole shrimp are fairy shrimp predators, their bottom feeding will put available food into the water that potentially could benefit filter feeding organisms including the fairy shrimp.

Monarch butterflies (as well as other specialist herbivores) oviposit on milkweeds in some of the pools, with their immature stages producing different degrees of plant damage.

The development of adaptive characteristics that resist herbivory (e.g. highly glandular stems of *Orcuttia*) indicate that some plants have been subjected to high levels of herbivory through time.

The lack of eutrophic development of vernal pools supports a relative balance between production and respiration. A preliminary scenario describing displaced interactions that tie the chronologically displaced communities into the same ecosystem could involve the following: The rapid development of some crustacean species during the winter pool season indicates a dependence upon the detritus food chain using organic phytomass developed during the summer. Efficient filter feeding on organisms that feed on the remains of summer plants, and rapid growth by crustaceans is an adaptation to avoid warm water insect predation. If insects are using crustacean biomass after cyst development, these crustaceans are indirectly supporting insect predators that reduce the reproductive success of future insect invaders (e.g. mosquitoes).

In summary, ecosystem dynamics tie together populations and communities from the same habitat that are active at different seasons.

8. Preservation of vernal pool species requires a combination of population and habitat approaches. As vernal pool habitats are lost in any part of California's Central Valley, the ecological quality of the whole area is lowered, compromising the quality of any individual pool ecosystem.

Management recommendation

Management must recognize that viable populations are dependent upon both a basic habitat area and numerous population interactions. Management goals that are based exclusively upon the number of individuals in a population (winter invertebrates or summer plants) are misleading.

Discussion

We agree with Jokerst (1993) that preserve expansion is a preferable alternative to the attempted construction of new vernal pools.

We must address the conflict caused by land modification on vernal pool landscapes throughout the state. There is a special opportunity to develop and maintain a preserve system in the Vina Plains Region.

In summary, habitat loss any location of the California Central Valley has compromised our ability to preserve vernal pools throughout this area. Preservation of individual populations as well as vernal pool habitat requires an integrated preserve system extending through the Central Valley of California (Alexander and Gallagher 1995).

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LITERATURE CITED

Ahl, J. S. 1983. The reproductive biology and the availability of eggs to oversummer in the tadpole shrimp, *Lepidurus packardi,* M. S. Thesis in Biological Sciences, California State University, Chico.

______. 1991. Factors affecting contributions of the tadpole shrimp, *Lepidurus packardi,* to its oversummering egg reserves. *Hydrobiologia* 212: 137-143.

Alexander, D. G. 1976. Ecological aspects of temporary annual pool fauna. *In* S. Jain (ed.), *Vernal pools, their ecology and conservation.* Institute of Ecology Publication 9, University of California, Davis.

______. and S. P. Gallagher. 1995. A proposal to form a committee to identify and coordinate vernal pool preserves and to oversee vernal pool mitigation in California's Central Valley. *Anostracan News* 3: 1-2.

______. and R. L. Syrdahl. 1992. Invertebrate biodiversity in vernal pools. *The Northwest Environmental Journal* 8: 162-163.

Baker, W. S., F. S. Hayes, and E. W. Lathrop. 1990. Avian use of vernal pools at the Santa Rosa Plateau Preserve, Santa Ana Mountains, California. *The Southwestern Naturalist* 37: 392-403.

Ballantyne, R. J. 1994. Feeding Dynamics of *Hesperodiaptomus eiseni* from California vernal pools. M. S. Thesis in Biological Sciences, California State University, Chico.

Broyles, P. 1983. A flora of The Nature Conservancy's Vina Plains Preserve, Tehama County, California. M. S. Thesis in Botany, California State University, Chico.

______. 1987. A flora of Vina Plains Preserve, Tehama County, California. *Madrono* 34: 209-227.

California Department of Fish and Game. 1995. Printout of data for the rare rare species in the Vina Plains area, from the California Natural Diversity Data Base, Sacramento.

California Nature Conservancy. 1986. Vernal pool data analysis for the Vina Plains Preserve by B. B. Green. Unpublished information.

Eads, J. A. 1995. A genetic comparison of two populations of the endangered fairy shrimp, *Branchinecta conservatio,* using RAPD techniques. M. S. Thesis in Biological Sciences, California State University, Chico.

Federal Register. 1994. Endangered and threatened plants; determination of endangered status for the conservancy fairy shrimp, longhorn fairy shrimp and the vernal pool tadpole shrimp; and threatened status for the vernal pool fairy shrimp. *Federal Register* 59: 48136-48153.

Gallagher, S.P. 1992. Interpopulation variation and the life history of the vernal vool snail, *Fossaria (Bakerilymnaea) sonomensis* in two pools in Tehama County, California. M. S. Thesis in Biological Sciences, California State University, Chico.

______. 1993. Life history variation in the temporary pool snail, *Fossaria sonomaensis*, in the Northern Sacramento Valley. *American Midland Naturalist* 130: 372-385.

______. 1996. Seasonal occurrence of habitat charcteristics of some vernal pool Branchiopoda in Northern California. *Journal of Crustacean Biology* 16: 323-329.

Griggs, F. T. 1974. Systematics and ecology of the genus *Orcuttia* (Gramineae). M. S. Thesis in Botany, California State University, Chico.

______. 1980. Population studies in the genus *Orcuttia* (Poaceae). Ph. D. Dissertation, University of California, Davis.

Holland, R. F., and V. I. Dains. 1990. The edaphic factor in vernal pool vegetation. *In* D. H. Ikeda and R. A. Schlising (eds.), *Vernal pool plants--their habitat and biology*, 31-48. Studies from the Herbarium No. 8, California State University, Chico.

Ikeda, D. H. 1982. Studies of the reproductive ecology of *Navarretia* (Polemoniaceae) of the Sacramento Valley of California. M. A. Thesis in Botany, California State University, Chico.

Jokerst, J. D. 1993. An alternative approach to vernal pool mitigation planning in Sacramento County. *In* J. Keeley, (ed.), *Interface between ecology and land development in California*, 227-237. Southern California Academy of Science, Los Angeles.

Keeley, J. E. 1990. Photosynthesis in vernal pool macrophytes: relation of structure and function. *In* D. H. Ikeda and R. A. Schlising (eds.), *Vernal pool plants--their habitat and biology*, 61-87. Studies from the Herbarium No. 8, California State University, Chico.

King, G. 1992. Geomorphology of piedmont vernal pool basins, California. *The California Geographer* 32: 19-38.

Kistner, D. H., D. G. Alexander, and H. R. Jacobson 1995. Vernal Pool Creation and Restoration in California: A Study Plan for Evaluating Attainable Quality and Functional Performance. EPA/600/R-95/073.

Lanway, C. S. 1974. Environmental factors affecting crustacean hatching in five temporary ponds. M. A. Thesis in Biological Sciences. California State University, Chico.

Michener, E. A. 1970. Population dynamics of two species of *Diaptomus* (Copepoda: Calanoida) in an ephemeral pond. M. A. Thesis in Biological Sciences, Chico State College, California.

Oswald, V. H. 1989. Survey of the vascular plants of Vina Plains Preserve, Wurlitzer Unit. Unpublished pamphlet, Department of Biological Sciences, California State University, Chico.

Patton, S. 1984. The life history patterns and the distribution of two Anostraca, *Linderiella occidentalis* and *Branchinecta* sp. M. S. Thesis in Biological Sciences. California State University, Chico.

Schlising, R. A. 1989. Yearly fluctuations in a vernal pool annual, *Sidalcea hirsuta*. *In* Bock, J. H., and Y. B. Linhart, *The evolutionary ecology of plants*. Westview Press, Boulder, CO.

Skinner, M. W., and B. M. Pavlik. 1994. *Inventory of rare and endangered vascular plants of California*, 5th ed. California Native Plant Society, Sacramento.

Stone, R. D., W. B. Davilla, D. W. Taylor, G. L. Clifton, and J. C. Stebbins. 1988. Status survey of the grass tribe Orcuttieae and *Chamaesyce hooveri* (Euphorbiaceae) in the Central Valley of California. U. S. Fish and Wildlife Service Technical Report.

Syrdahl, R. L. 1993. Distribution patterns of some key macroinvertebrates in a series of vernal pools at Vina Plains Preserve, Tehama County, California. M. S. Thesis in Biological Sciences, California State University, Chico.

Thorp, R. 1990. Vernal pool flowers and host-specific bees. *In* D. H. Ikeda and R. A. Schlising (eds.), *Vernal pool plants--their habitat and biology*, 109-122. Studies from the Herbarium No. 8, California State University, Chico.

U. S. Department ofAgriculture. 1967. *Soil survey of Tehama County, California*. Washington, DC.

Wolt, T. B. 1972. *Cyzicus mexicanus* (Crustacea: Conchostraca) life history and a comparison of growth, maturity and egg production in five ponds. M. A. Thesis in Biological Sciences, California State University, Chico.

Zedler, P. H. 1987. The ecology of Southern California vernal pools: a community profile. U. S. Fish and Wildlife Service, Biological Report 85(7.11), U. S. Department of the Interior, Washington, D. C.

Appendix 1. Field form used for recording data from the spring transect in a pool; used for 18 pools at Vina Plains Preserve, 1995

INVESTIGATORS: ____________________

TRANSECT NUMBER OR LOCATION: ____________________

TRANSECT UNIT (decimeter units): ____________________

Date: ____________

Time: ____________

Pool Number: ____________

QUADRAT NUMBER:																		
QUADRAT LOCATION:																		
TAXON:																		
Achyrachaena mollis																		
Alopecurus sacatus																		
Briza minor																		
Brodiaea minor (lvs.)																		
Bromus hordeaceus																		
Callitriche marginata																		
Cardamine oligosperma																		
Clarkia sp.																		
Crassula aquatica																		
Crassula connata																		
Cuscuta howelliana																		
Deschampsia danthonioides																		
Downingia cuspidata																		
Downingia ornatissima																		
Epilobium sp.																		
Eremocarpus setigerus																		
Eryngium castrense																		
Hypochaeris glabra																		
Isoetes orcuttii																		
Juncus bufonius																		
Juncus capitatus																		
Juncus uncialis																		
Lasthenia californica																		
Lasthenia fremontii																		
Lasthenia glaberrima																		
Layia fremontii																		
Limnanthes douglasii var. rosea																		
Lolium multiflorum																		
Marsilea sp.																		
Microseris sp.																		
Myosurus minimus																		
Navarretia leucocephala																		
Navarretia tagetina																		
Petroragia dubia																		
Pilularia americana																		
Plagiobothrys stipitatus var. micranthus																		
Plagiobothrys stipitatus var. stipitatus																		
Psilocarphus brevissimus																		
Psilocarphus oregonus																		
Trifolium depauperatum																		
Trifolium microcephalum																		
Veronica peregrina																		

Appendix 2. Field forms used for recording data from summer transects in 9 pools at Vina Plains Preserve, 1995. The first form was used for shorter transects of up to 21 quadrats (21 meters). With the second form two transects could be completed on a single page, or the form could be used to complete one transect that was longer than 21 quadrats.

1 @ 43+ quads

Pool No.	**SUMMER PLANTS DATA SHEET for 1 transect over 43 meters long, to be continued on a second sheet** **Date:** **Data Collectors:**																					
Pool-segment	(NE, NECent, SECent, SE, etc., based on total pool length divided up into +/- equal segments) **Pool length (central baseline) in meters:** **Total transects this segment ,laid in -m intervals**																					
Transect No.	(Numbered anew in each pool segment) **Transects numbered from N or from S?** **Transect length in meters:** (equals total no. frequency quadrats; density quadrat nos. circled below)																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CHHO																						
ORPI																						
TUGR																						
Amaranthus																						
Asclepias																						
Ch. ocellata																						
Convolvulus																						
Crypsis																						
Eryngium																						
Marsilea																						
Xanthium																						

Transect No.	**Continuation of same transect**																					
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
CHHO																						
ORPI																						
TUGR																						
Amaranthus																						
Asclepias																						
Ch. ocellata																						
Convolvulus																						
Crypsis																						
Eryngium																						
Marsilea																						
Xanthium																						

2 @ 21 quads or 1 @ 43 quads

Pool No.	**SUMMER PLANTS DATA SHEET for 2 transects with up to 21 quadrats each, or for 1 transect not over 43 meters long** Date: Data Collectors:																					
Pool-segment	(NE, NECent, SECent, SE, etc., based on total pool length divided up into +/- equal segments) Pool length (central baseline) in meters: Total transects this segment ,laid in -m intervals																					
Transect No.	(Numbered anew in each pool segment) Transects numbered from N or from S? Transect length in meters: (equals total no. frequency quadrats; density quadrat nos. circled below)																					
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CHHO																						
ORPI																						
TUGR																						
Amaranthus																						
Asclepias																						
Ch. ocellata																						
Convolvulus																						
Crypsis																						
Eryngium																						
Marsilea																						
Xanthium																						

Transect No.	**Continuation of same transect? yes no. New transect in same pool segment? yes no. If new transect, length in meters:** (equals total no. frequency quadrats; density quadrat nos. circled below)																					
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
CHHO																						
ORPI																						
TUGR																						
Amaranthus																						
Asclepias																						
Ch. ocellata																						
Convolvulus																						
Crypsis																						
Eryngium																						
Marsilea																						
Xanthium																						

Appendix 3. All vascular plant species encountered in the spring transects for 18 pools, Vina Plains Preseve, 1995. F = frequency (proportion of quadrats occupied; total quadrats per transect are listed at the end of Table 4.4); D = density (number of individuals per square meter); X = present on a transect, but neither frequency or density calculated due to low numbers of occurrences and/or individuals, or because the taxon has been treated in detail in summer pool sampling. Species names are abbreviated, with the first four letters of the generic name followed by the first four letters of the specific epithet. Complete names are listed below.

		Pool number																	
		1	4	14	15	17	18	21	21a	22	29	30	31	34	35	36	37	38	39
AchyMoll	F	–	X	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AlopSacc	F	0	0.18	0.05	0.17	0	0	0	0.13	0	0	0	0.06	0	0	0	0.13	0	0.17
	D	0	18	9	34	0	0	0	16	0	0	0	17	0	0	0	27	0	29
AsclFasc	F	X	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
BlenNanu	F	–	–	–	–	–	X	–	–	–	X	–	–	–	–	–	–	–	–
BrodLevs	F	0.01	0	0	0	0	0	0.02	0.03	0	0.23	0.15	0.11	0	0.02	0.01	0.09	0.07	0
BromHord	F	0	0	0	0	0.02	0	0	0	0	0	0	0	0	0.01	0.01	0	0	0
	D	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	0
CallMarg	F	0	0.45	0	0.51	0	0.44	0.08	0	0	0.23	0.09	0.61	0.01	0	0.01	0.35	0.37	0.03
	D	0	173	0	200	0	250	19	0	0	196	12	328	1	0	2	256	153	3
ChamHoov	F	X	–	–	–	X	–	–	–	–	–	–	–	X	–	–	–	–	–
ConvArve	F	–	–	–	–	X	–	–	–	–	–	–	–	–	–	X	–	–	–
CrasAqua	F	–	X	–	X	–	X	X	–	–	X	X	X	X	–	X	X	X	X
CrypSpp.	F	–	X	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–
CuscHowe	F	0	0.545	0.21	0.713	0	0.063	0.017	0.065	0	0.038	0	0.056	0	0	0	0.146	0.488	0.6

DescDant	F	0	0.18	0	0	0	0.06	0.05	0.06	0	0.31	0	0.50	0.01	0.01	0.01	0.02	0.02	0.06
	D	0	18	0	0	0	19	25	10	0	162	0	194	3	1	1	3	2	6
DownBico	F	–	–	X	–	–	–	X	X	–	–	X	–	X	–	X	X	X	X
DownCusp	F	–	–	X	X	–	X	X	X	–	X	X	X	–	–	X	X	X	–
DownOrna	F	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DownSpp.	F	0.01	0.55	0.92	0.67	0	0.56	0.88	1.00	0.47	0.27	0.18	0.61	0.04	0	0.28	0.80	0.84	0.74
	D	3	195	1846	445	0	213	717	1271	120	150	21	544	7	0	86	1334	1153	291
EleoMinu	F	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–
EleoMach	F	0	0.033	0	1	0.018	0	0	0.056	0	0	0	0	0	0	0	0	0	0
EpilSpec	F	0.03	0.32	0.89	0.23	0.03	0	0.63	0.77	0.29	0	0	0.17	0.04	0.03	0.50	0.45	0.49	0.97
	D	3	195	1846	445	0	213	717	1271	120	150	21	544	7	0	86	1334	1153	291
ErynCast	F	0.06	0.23	0.33	0.09	0.10	0	0.29	0.65	0.61	0.15	0.06	0.06	0.14	0.08	0.36	0	0.23	0.34
	D	6	23	33	9	10	0	29	65	61	15	6	6	14	8	36	0	23	34
GratHete	F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	0	0
HypoGlab	F	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0.01	0.01	0	0
	D	0	0	0	0	0	31	0	0	0	0	0	0	0	0	2	1	0	0
IsoeOrcu	F	0	0	0.06	0.21	0.01	0.88	0.61	0.23	0	0.15	0.03	0.67	0	0.01	0.09	0.74	0.95	0.23
JuncBufo	F	0	0	0	0	0.025	0	0.03	0	0	0	0	0.06	0	0.02	0.02	0.01	0.02	0
	D	0	0	0	0	3	0	3	0	0	0	0	6	0	2	2	1	2	0

JuncUnci	F	0	0.32	0	0.43	0	0.63	0	0.19	0	0.23	0.03	0.50	0	0	0	0.18	0.05	0.06
	D	0	82	0	156	0	338	0	29	0	92	6	233	0	0	0	45	9	20
LastFrem	F	0.00	0.77	0.70	0.87	0.00	0.69	0.41	0.71	0.00	0.73	0.00	0.61	0.00	0.00	0.02	0.66	0.63	0.54
	D	0	318	501	916	0	525	476	548	0	499	0	856	0	0	3	675	405	411
LastGlab	F	0	0	0.19	0	0	0	0.41	0.48	0.05	0	0	0	0	0	0.01	0.27	0.09	0.03
	D	0	0	260	0	0	0	744	606	48	0	0	0	0	0	1	234	67	9
LayiFrem	F	0	0	0.03	0	0	0	0.02	0	0	0	0	0.11	0	0	0.01	0.01	0	0
	D	0	0	3	0	0	0	2	0	0	0	0	11	0	0	1	1	0	0
LimnDoug	F	–	–	–	–	–	–	–	X	–	–	–	–	–	–	–	X	–	–
LoliMult	F	0	0.05	0	0.10	0	0.13	0.02	0	0	0.08	0	0.17	0	0	0.01	0.04	0	0.03
	D	0	5	0	10	0	13	2	0	0	8	0	17	0	0	1	4	0	3
MarsVest	F	0.49	0.00	0.58	0.06	0.00	0.25	0.32	0.03	0.23	0.00	0.00	0.00	0.00	0.05	0.11	0.33	0.00	0.00
MimuTric	F	–	X	–	–	–	–	–	–	–	–	–	X	–	–	X	–	–	–
MyosMini	F	0	0.05	0	0.11	0	0.44	0	0	0	0.04	0	0.17	0	0	0	0.19	0.05	0
	D	0	5	0	11	0	44	0	0	0	4	0	17	0	0	0	19	5	0
NavaLeuc	F	0.02	0.55	0.18	0.81	0	0.69	0.64	0.70	0	0.88	0.06	0.44	0.01	0.02	0.05	0.76	0.14	0.83
	D	6	300	110	572	0	744	429	426	0	1215	6	233	3	10	14	1306	1293	951
OrcuPilo	F	X	–	–	–	X	–	–	–	–	–	–	–	X	X	–	–	–	–
PiluAmer	F	0	0	0.67	0.096	0	0	0	0.438	0	0	0	0	0	0	0.009	0	0	0.429

PlagMicr	F	0.03	0.95	0.88	0.84	0.02	0.56	0.56	0.52	0.65	0.81	0.76	0.17	0.08	0.01	0.61	0.65	0.72	0.86
	D	11	873	1878	921	3	875	693	161	306	1392	473	94	21	21	289	680	933	626
PogoZiph	F	–	–	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–
PsilBrev	F	0.02	0.73	0.88	0.70	0.01	0.50	0.63	0.81	0.25	0.38	0.03	0.39	0.07	0.02	0.31	0.64	0.79	0.83
	D	2	532	978	443	3	238	224	387	86	565	12	78	42	9	64	601	947	1014
SidaHirs	F	X	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–
TaenCapu	F	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–
TrifDepa	F	–	–	–	–	X	X	–	–	–	–	–	–	–	–	–	X	–	–
TrifWild	F	–	–	–	–	–	–	–	–	–	–	–	–	–	–	X	–	–	–
TuctGree	F	–	–	–	–	–	–	X	–	X	–	–	–	–	–	–	–	–	–
VeroPere	F	0	0.05	0.01	0.04	0	0	0	0	0	0.12	0	0	0	0	0	0.02	0	0
	D	0	0	1	4	0	0	0	0	0	12	0	0	0	0	0	2	0	0
XanStrum	F	–	–	–	–	X	–	–	–	–	–	–	–	–	–	–	–	–	–

AchyMoll = *Achyrachaena mollis*, AlliAmpl = *Alliuim amplectens*, AlopSacc = *Alopecurus saccatus*, AmarAlbu = *Amaranthus albus*, ArisOlig = *Aristida oligantha*, AsclFasc =*Asclepias fascicularis*, BlenNanu =*Blennospermum nanum*, BrodLevs = *Brodiaea* leaves, BromHord = *Bromus hordeaceus*, CallMarg = *Callitriche marginata*, CentMini = *Centunculus minimus*, ChamHoov = *Chamaesyce hooveri*, ChamOcel = *Chamaesyce ocellata* ssp. *ocellata*, ConvArve = *Convolvulus arvensis*, CrasAqua = *Crassula aquatica*, CrypSpp. = *Crypsis schoenoides* and C. *vaginiflora*, CuscHowe = *Cuscuta howelliana*, CypSpe. = an unidentified species of *Cyperus*, DescDant = *Deschampsia danthonioides*, DownBico = *Downingia bicornuta*, DownCusp = Downingia cuspidata, DownOrna = *Downingia oranatissima*, DownSpp. = *Downingia species*, EleoMinu = a minute-bodied, unidentified species of *Eleocharis*, EleoMach = *Eleocharis machrostachya*, EpilClei = *Epilobium cleistoganum* , EpilPygm = *Epilobium pygmaeum*, EremSeti = *Eremocarpus setigerus*, ErynCast = *Eryngium castrense*, GratEbra = *Gratiola ebracteata*, GratHete = *Gratiola heterosepala*, HeliEuro = *Heliotropium europaeum*, HemiFitc =*Hemizonia fitchii*, HypoGlab = *Hyperchoeris glabra*, IsoeHowe = *Isoetes howellii*, IsoeOrcu =*Isoetes orcuttii*, JuncBufo = *Juncus bufonius*, JuncUnci = *Juncus uncialis*, LastFrem = *Lasthenia fremontii*, LastGlab = *Lasthenia glaberrima*, LayiFrem = *Layia fremontii*, LimnDoug = *Limnanthes douglasii* ssp. *rosea*, LimnFloc = *Limnanthes floccosa* ssp. *floccosa*, LoliMult = *Lolium multiflorum*, MarsVest = *Marsilea vestita*, MimuGutt = *Mimulus guttatus*, MimuTric = *Mimulus tricolor*, MollVert = *Mollugo verticillata*, MontFont = *Montia fontana*, MyosMini = *Myosurus minimus*, NavaLeuc = *Navarretia leucocephala* ssp. *leucocephala*, OrcuPilo = *Orcuttia pilosa*, OrcuTenu = *Orcuttia tenuis*, PaniSpe. = an unidentified species of *Panicum*, PiluAmer = *Pilularia americana*, PlagStMi = *Plagiobothrys stipitatus* var. *micranthus*, PlagStSt = *Plagiobothrys stipitatus* var. *stipitatus*, PogoZiph = *Pogogyne zizyphoroides*, ProbLoui = Proboscidea *louisianica*, PsilBrev = *Psilocarphus brevissimus*, PsilOreg = *Psilocarphus oregonus*, RumeCris = *Rumex crispus*, SidaHirs = *Sidalcea hirsuta*, TaenCapu = *Taeniatherum caput-medusae*, TrifDepa = *Trifolium depauperatum*, TrifWild = *Trifolium wildenovii*, TuctGree = *Tuctoria greenei*, VeroPere = *Veronica peregrina* ssp. *xalapensis*, XantStru = *Xanthium strumarium*