Patterns in Time and Space for Rare Macroinvertebrates and Vascular Plants in Vernal Pool Ecosystems at the Vina Plains Preserve, and Implications for Pool Landscape Management

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Abstract. This report combined spring-aquatic observations (starting in March 1995) of select macroinvertebrates, with summer-dry observations (extending through August 1995) of select plants from the same vernal pool ecosystems at the Vina Plains Preserve, southern Tehama County, California. Density indices were developed from catch-and-release collections of *Lepidurus packardi* and *Branchinecta conservatio; L. packardi* carapace lengths were also measured. The plants, *Chamaesyce hooveri*, *Orcuttia tenuis*, *Orcuttia pilosa*, and *Tuctoria greenei* were sampled for frequency and density using quadrats along pool transects. *Lepidurus packardi* density indices were 20-85 individuals per m² of pool floor with juveniles and adults, and near 10 individuals per m² with adults only. Different populations displayed variable time of second generation, maximum carapace size (24-39 mm) and time of adult mortality (April to June). *Branchinecta conservatio* density index ranged from 3-99 individuals per m³ of water sampled, with four pools having large and three having small populations. Nine of the larger pools contained one to three species of the plants, with *Tuctoria* alone most of the time. Transect sampling in different pools showed variation (e.g., for *Chamaesyce*) in frequency (0.006-0.141), density (0.1 to 6 plants/m²), population size (2,000-183,400) and distribution in individual pools. These features, as well as co-occurring exotic plants, distinguished each pool in this complex as unique. This documented population biodiversity implies that these ecosystems have different environmental conditions that control the break in dormancy and growth. Successful vernal pool species preservation requires long-term monitoring of individual species considering the pattern interface between these populations and vernal pool ecosystems. Population differences of these aquatic macroinvertebrates and summer plants can only be maintained in a series of pools as part of an extensive landscape. This calls for the preservation of landscape units with diverse vernal pool ecosystems. Vina Plains Preserve is an ideal area for preserve expansion.

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Introduction

This study documents chronological and spatial patterns shown by rare macroinvertebrates and vascular plants in the annual vernal pool ecosystems at the Vina Plains Preserve. Major objectives included establishing quantitative baseline data for future studies and formulating vernal pool landscape preservation and management strategies. Vina Plains Preserve, owned and managed by the California Nature Conservancy, is located near the southern boundary of Tehama County, California, east of Highway 99, south of Lassen Road and west of Singer Creek, about 19 km north of Chico. Our study was restricted to one year, in this area of Mediterranean climate noted for its seasonal and year-to-year variability. This preserve contains a variety of vernal pools that are very rich in pool species.

The species studied include: 1. Two macroinvertebrates (Federal Register, 1994), *Branchinecta conservatio*, Conservancy Fairy Shrimp (federally endangered), and *Lepidurus packardi*, Vernal Pool Tadpole Shrimp (federally endangered); and 2. Four vascular plants (Skinner and Pavlik, 1994; Federal Register, 1997), *Chamaesyce hooveri*, Hoover's Spurge (federally threatened), *Orcuttia pilosa*, Hairy Orcutt Grass (endangered for California, federally endangered), *Orcuttia tenuis*, Slender Orcutt Grass (endangered for California, federally threatened), and *Tuctoria greenei*, Greene's Tuctoria (rare for California, federally endangered). The macroinvertebrates were studied in the larger pools, starting in March 1995, and the plants were studied in the same ecosystems during the summer. King's (1992) pool numbering system was used (Figure 1). A more detailed description of this activity is in Alexander and Schlising (1997).

METHODS

Macroinvertebrates

A sequential collection system (modified from Kistner et al., 1995) extended from early March through pool drydown. A plankton net (1-mm mesh), held by hand in contact with the pool floor, was pulled a 2-m distance at independent locations along pool transects. Pools were typically visited from 5-9 different dates, and at each visit 5-10 samples were made in small pools, and 8-23 samples were made in large pools. The organisms that accumulated in the collection jar were placed in an enamel pan held on a stand over the water. A taped record was made of the number of individuals, number of individuals with cysts in the egg sac, and the tadpole shrimp carapace lengths. The collections were then returned at the point of capture. The number of individuals observed was used to simultaneously determine a density index for *Lepidurus packardi* (individuals per m^2 of pool floor sampled) and *Branchinecta conservatio* (individuals per m^3 of pool water sampled). Major populations of *Branchinecta conservatio* and the larger and long-lasting populations of *Lepidurus packardi* were studied. Some observations were also made on *Linderiella occidentalis* (California Linderiella), an unlisted fairy shrimp, and *Cyzicus californicus* (California Clam Shrimp).

Vascular Plants

The nine pools containing populations of the four rare plants were sampled once. Six of the pools were overlaid with parallel, east-west running-transects that were equal distances apart. A rectangular quadrat frame, 0.05 m^2 in area, was placed at one-meter intervals along each transect, and all green and/or reproducing species within each quadrat were recorded. Frequency (proportion of samples occupied) was determined for the four rare species and for several of their most common summer associates. Spatial patterns for summer species in these six pools were identified by mapping each pool's transect lines. For ease in comparing maps, the spaces from north to south between transect lines were omitted, producing "condensed" maps comparable in the east-west direction.

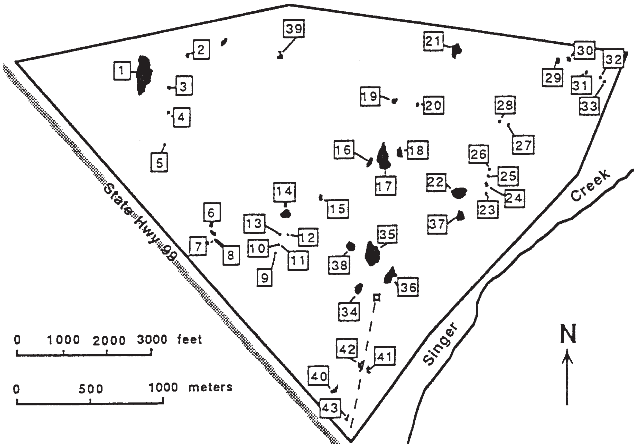

FIGURE 1. The vernal pool numbering system established by King (1992) for vernal pools 30 square meters or larger, found on the main tract of Vina Plains Preserve.

Density was determined for the rare species by using randomly-selected quadrats of each transect and counting all individuals within the 0.05 m^2 frame. The average was used to determine mean crude density in plants/m^2. This number was then multiplied by the area of the pool basin (estimated by summing the square meters in pool bands south of each transect) to get an estimate of total population size for the pool. In three of the nine pools containing populations of rare plants, transects and quadrats to determine density and frequency were used only in the portions of the pool where the plants occurred.

RESULTS AND DISCUSSION

Macroinvertebrates

The pools flooded in November and all pools reached maximum capacity by early January. Although the pools decreased in depth through February into March, they were filled to maximum levels by March storms. This survey was initiated in early March and continued until drydown. Several of the smaller pools dried up in early April, and only five pools (1, 17, 35, 22, and 34) supported aquatic invertebrate populations in May. Two pools (17 and 1) had surface water in June and Pool 17 (the last to dry), on 7 July, had low water and did not contain the species considered. *Linderiella occidentalis* was absent from the two largest pools (1 and 17) and observed in most of the other pools sampled. *Cyzicus californicus* was only observed in Pools 17 and 22.

Branchinecta conservatio. This species initiates development after a cold-water flooding of pool basins and requires weeks to mature. With the exception of an early April sample in Pool 1, no samples contained prereproductive individuals. The 1995 samples (Figure 2) found higher densities and population continuance in four pools (1,17, 22, and 35) and low densities in three pools (16, 34, and 38). The four major populations declined through the season and the last individuals were sampled before drydown. Early season high densities of the established populations must result in a large contribution to the cyst bank. The decline in density reflects population mortality. Avian and insect predation must be important, and two samples recorded predation of *B. conservatio* by *Lepidurus packardi*. Natural death was indicated by the sample of corpses with a film of aquatic

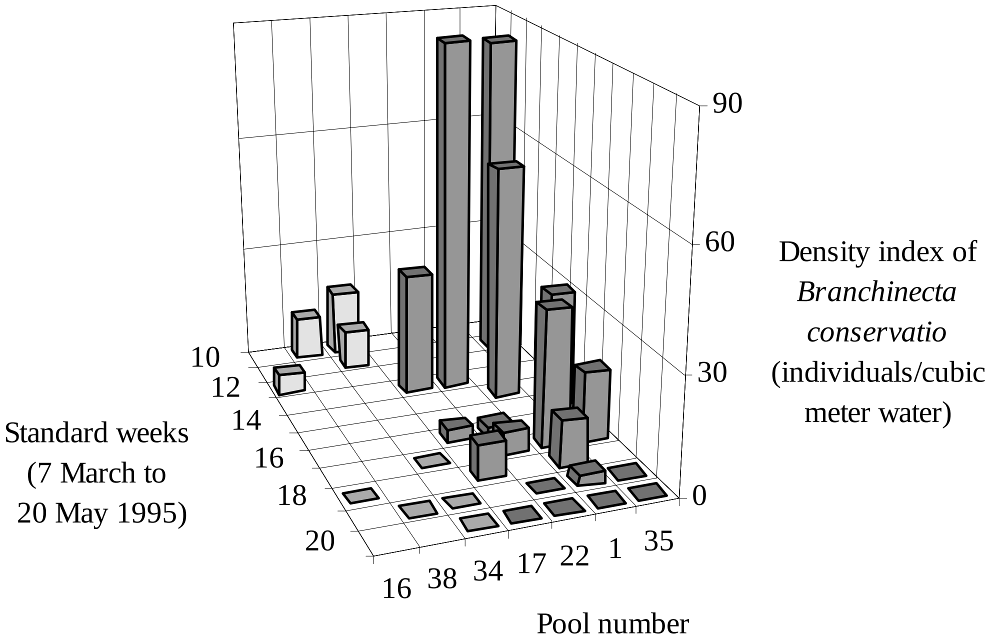

FIGURE 2. The density index (individuals per m³ water) for *Branchinecta conservatio* observed in vernal pools on Vina Plains Preserve in spring 1995. Sample dates are placed on a scale that treats the standard week (weeks numbered starting at the first of the year) as the basic unit. The high-density pools are shown in dark and the low-density pools in lighter gray.

fungi on the exoskeletons. The low density pools (all located within 50 m of the large pools) could to be maintained by dispersal. Dispersal could be explained by the movement on or in vertebrates (especially birds) and by water connections. A water connection between 17 and 16, observed in 1995, may explain the difference between no individuals in 1992 (Syrdahl, 1993), and a few individuals in 1995. Apparently this species does not persist from year to year in Pool 16, as water connections undoubtedly occurred prior to 1992. When individuals are not present in the water, habitat characteristics or cysts in the sediments must be used to determine if individuals were present. Cyst presence cannot identify pools with different population dynamics.

Lepidurus packardi. Mature (carapace 10 mm and longer) *Lepidurus packardi* were observed in the first samples. The small (carapace 3 mm) individuals indicate the second generation hatch as reported by Ahl (1983; 1991). First and second generation adults increased in size and cyst production. This species was sampled in ten pools (Figure 3), and exoskeletons indicated it was present in additional pools (29, 30, 37, 14, and 21). The density indices were high (generally 20-40, but up to 80/m²) when prereproductive individuals were present, and low (near 10/m²) in late season samples with adults only. Samples included some dead individuals with mold growing on their exoskeletons. Total population mortality was observed on 18 May in Pools 22 and 34.

The life history dynamics observed in 1995 generally placed the pools into three different groups (Figure 3): 1. Larger, long-lasting pools (1, 17, and 35) had a delayed second generation that grew to a large size. Large first generation adults (31, 39, and 27 mm carapace length, respectively) were observed in these pools. Samples dropped to zero just before these pools were completely dry. 2. Intermediate size pools (22 and 34) displayed total population mortality in a single day, before pool drydown. At the time of mortality, the second generation carapace sizes ranged from 9.4-19 mm. 3. Smaller pools (16, 36, 38, 41, 42, and others not sampled) had a second generation, but dried down in April. Accelerated maturation is assumed to be associated with warmer water temperatures in these shallow pools. Individuals of a variety of sizes were killed at pool drydown of the smaller pools. These three pool types form a series with a decreasing total number of cysts produced (from type 1 to type 3). Type 1 pools will contribute to the long-term maintenance of these populations, because large individuals produce more cysts and the large pools support more individuals.

Vascular Plants

Frequencies for rare plants and summer associates are shown in Table 1. Inclusion of frequency data for eight species occurring with the four rare species helps show that these larger pools have complex communities in the summer. “Condensed” maps for four populations of *Chamaesyce hooveri*, four populations of *Orcuttia viscida*, and two of the five populations of *Tuctoria*

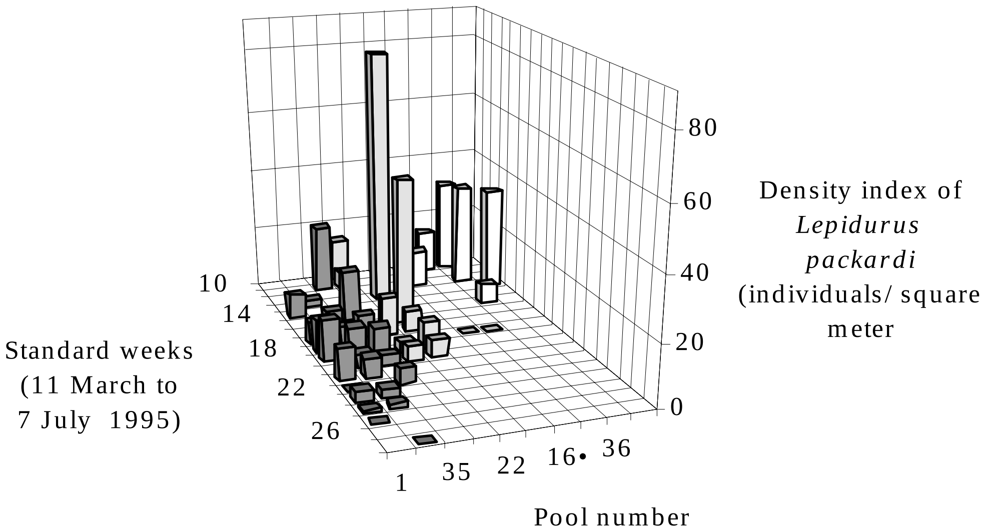

FIGURE 3. The density index (individuals per m² of pool floor) for *Lepidurus packardi* observed in vernal pools on Vina Plains Preserve, in spring 1995. Sample dates are placed on a scale that treats the standard week (weeks numbered starting at the first of the year) as the basic unit. The pools are divided into three types: 1. Pools that supported two generations are shown in the darkest shade. 2. Pools that displayed total mortality of the second generation are shown in an intermediate shade. 3. Pools that had only one generation are shown in the lightest shade.

greenei found on the Preserve are shown, along with several exotic species, in Figure 4. Mean densities and total pool population estimates for the four rare species are shown in Table 2.

Plant patterns in space. Frequencies, densities, and pool maps show different patterns for each species in different pools. For example, *Chamaesyce hooveri* occurred with high frequency (0.141) and density (6 plants/m²) in the northern half of the largest pool (Pool 1, Figure 1). In the next largest pools (17 and 35), *Chamaesyce* occurred with low frequency (0.006 and 0.010) and density (both 0.1 plant/m²), and in a scattered pattern. The fourth occurrence of this species, in Pool 34, showed an irregular ring, with a higher frequency (0.047) and density (1 plant/m²). Soil differences (Soil Survey of Tehama County, 1967) and competition with exotic plant species (Stone et al., 1988) may help explain the patterns. High frequencies of the introduced bindweed and cocklebur (*Convolvulus arvensis* and *Xanthium strumarium*, Table 1 and Figure 4) in Pool 17 may be impacting the *Chamaesyce*.

Orcuttia pilosa occurred in the same four pools as *Chamaesyce*, but it was found within broad regions that tended to be central in each pool, and the *Orcuttia* consistently had higher frequencies (ranging from 0.231 to 0.559) and densities (from 45 to 474 plants/m²). In Pool 1, this species occurred on the south end, only slightly overlapping *Chamaesyce hooveri* (Figure 4). The other species of *Orcuttia* (*O. tenuis*), only occurred in the southern half of Pool 29.

Tuctoria greenei more clearly suggested a spatial pattern related to soil regions within particular pools (Stone et al., 1988, Griggs, 1980). This species was usually the sole rare plant in a pool, as in Pools 14, 21 (Figure 4), 22, and 37, but occurred sympatrically with *O. pilosa* and *Chamaesyce hooveri* in Pool 35 (Figure 4). Spatial patterns formed by this species of *Tuctoria* on the Preserve correspond to regions in pools with clayey soils that prolong water retention and that crack deeply when desiccated.

Plant patterns in time. The baseline data obtained from 1995 sampling will likely show that frequency and density, as well as total pool population size, vary considerable through the years for these rare plants (Holland, 1987). Broyles (1983) gave estimates of total population size for 1983, and although they are not based on sampling, all the estimates are considerably lower than our estimates (Table 2). In fact, two other pools had a few individuals of *Orcuttia pilosa* appear in 1995 where the species had not been seen before (i.e., in Pools 16 and 18). In addition, several populations recorded by Broyles (1983) were not relocated in pools in 1994 and 1995. These observations emphasize the differing and dynamic nature of these rare plant populations through time, possibly explained by soil conditions within pool basins varying from year to year. Phenological differences, reflected in propagule germination, production, dispersal and survival, are controlled in part by these soil differences.

Ecology and Management of Vernal Pool Ecosystems

Vernal pools as semi-independent ecosystems. Pool systems interconnected by surface water, adjacent topography, and natural soils that receive and remove water from these pools are

Table 1. Frequency (proportion of the total samples occupied by the species) to the nearest 0.001, 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. For pools 14, 22, and 37 frequency is shown for only portions of the pool.

Pool (and no. samples)	*Amaranthus albus*	*Asclepias fascicularis*	*Chamaesyce hooveri*	*Convolvulus arvensis*	*Eremocarpus setigerus*	*Eryngium castrense*	*Marsilea vestita*	*Orcuttia pilosa*	*Orcuttia tenuis*	*Proboscidea louisianica*	*Tuctoria greenei*	*Xanthium strumarium*
Pool 1 (2997 samples)	.001	.001	0.141	.017	.002	.157	.501	.231	0	.014	0	.002
Pool 14[a] (145 samples)	0	0	0	0	.103	.655	.269	0	0	0	.317	0
Pool 17 (2824 samples)	.001	.016	0.006	.444	.001	.277	.081	.402	0	.001	0	.297
Pool 21 (828 samples)	0	0	0	0	.013	.388	.400	0	0	0	.063	0
Pool 22[b] (356 samples)	.003	0	0	0	.090	.890	.146	0	0	0	.354	.003
Pool 29 (425 samples)	0	0	0	0	.002	.005	.226	0	.405	0	0	0
Pool 34 (808 samples)	.084	0	.047	.011	.009	.312	.032	.559	0	.001	0	0
Pool 35 (1684 samples)	.013	.024	.010	.007	.002	.200	.429	.548	0	0	.048	0
Pool 37[c] (195 samples)	0	.046	0	0	.831	.974	.359	0	0	0	.436	0

[a] Pool 14 had only the northern portion (where *Tuctoria greenei* occurred), sampled.

[b] Pool 22 had only the eastern half (where *Tuctoria greenei* occurred) sampled.

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

semi-independent ecosystems. Our observations advance the hypothesis that these ecosystems have interactions through the movement and dispersal of key organisms. The conservation of populations dependent upon vernal pools will require the preservation of a series of pools and adjacent topography.

Vernal pool as non-uniform ecosystems. Pools in one landscape unit are so diverse it is unrealistic to talk about an average pool. Species can not be used to classify pools, because each pool has a different combination of species. Population presence and dynamics vary between pools and in different microhabitats within single pools. Pool 29, a small pool, contained *Lepidurus packardi* and *Orcuttia tenuis* (the only location of *O. tenuis* on the Preserve). On the other hand, the large pools (1 and 17) supported important populations of a number of rare species (*Branchinecta conservatio*, *Lepidurus packardi*, *Chamaesyce hooveri*, *Orcuttia pilosa*). Pool 35, also a fairly large pool, contained the largest assemblage of rare species (*Branchinecta conservatio, Lepidurus packardi, Chamaesyce hooveri*, *Orcuttia pilosa*, and *Tuctoria greenei).* The invertebrates and plants, except for *Tuctoria greenei*, are found throughout the pool area (Figure 4). Although endangered invertebrates are found in a number of pools, high level cyst production may well be restricted to only a few of these pools (Figures 2 and 3). These biotic patterns are undoubtedly influenced by a variety of factors including the more obvious differences in flooding and drydown (controlled by geomorphology and soil depth, texture and distribution) as well as reproductive activity in past years.

Combining habitat preservation and population management. The specific habitat demands of vernal pool invertebrates and plants make these pool landscapes an appropriate level at which management can move from recovery that primarily considers populations, to recovery that uses population characteristics combined with ecosystem characteristics to monitor success. The preservation of a vernal pool landscape complex will favor a number of species. The possibility for multispecies preservation is challenged by a need to understand the interface between populations and ecosystems (Levin, 1992).

Expansion of Vina Plains Preserve. The Vina Plains area, including and extending all directions from the existing Vina Plains Preserve, represents a natural vernal pool landscape that has a variety of semi-independent, interdigitating vernal pool ecosystems. Preserve expansion, including blocks of land that contain distinctive pools, should effectively preserve many vernal

Table 2. Density and population size of the four rare plant species, Vina Plains Preserve, in 1995. The mean crude density is to the nearest plant per m^2. The largest plant count, converted to plants per m^2, is shown in parentheses. Total population size is estimated to the nearest 100 plants. 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
17 (n = 290)	0.1 (1)	3,900	142 (1,880)	3,987,900	0	0	0	0
21 (n = 162)	0	0	0	0	0	0	26 (1300)	106,300
22[a] (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[a] (n = 157)	0.1 (1)	2,000	266 (3,780)	4,205,300	0	0	14 (640)	225,600
37[b] (n = 195)	0	0	0	0	0	0	7 (94)	1,319

[a] Mean density of *Tuctoria greenei* in Pools 14, 22, and 35 is based on only the portion of the pool sampled, where the plants occurred, rather than on the entire pool area.

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

pool species. Because pool 29 receives water directly from the culvert under Lassen Road, expanding the Preserve to include an equivalent pool (e.g., one containing *Orcuttia tenuis* without human impact) should have a high priority. Preserve expansion, including clusters of smaller pools around important pools, will preserve population biodiversity of the rare species we studied, as well as the spring flora and other Crustacea, such as *Branchinecta lynchi* found in the smaller pools (Gallagher, 1996). An expanded preserve could easily include natural pool landscape north of Lassen Road, west of Highway 99, east of Singer Creek and south of Pine Creek. The Vina Plains area represents an outstanding natural landscape that has the potential to be formed into a regional vernal pool preserve. The inclusion of cooperative land use arrangements on grazing lands provides the opportunity to expand the pool preserve beyond simple land purchase. A larger vernal pool preserve should enhance natural waterfowl use and contribute to the preservation of species in adjacent grassland-wildflower fields and temporary streams. A large natural area will also expand the use of the area by avian predators. The preservation objectives of this specific region should be integrated into a vernal pool preservation system including all California vernal pools (Alexander and Gallagher, 1995).

Specific life history dynamics in vernal pool management. Rare vernal pool obligate species are totally dependent upon these pools for survival, and we must consider population dynamics of individual species to determine which components of the vernal pool landscape are essential for each population. A list of the number of pools that contain a particular species within a pool complex must be augmented with information on the importance of each pool to the reproduction of the population in question. Observations in a pool complex made on the same date are potentially misleading because the populations in different pools are at different life history stages on this date. These population differences also question the effectiveness of a diversity index to record pool viability (Alexander and Syrdahl, 1992).

Monitoring of vernal pool species will have cost savings because the plants and animals are tied to the same ecosystems. This paper presents population density and life history characteristics during the time scale of a single pool season. Without long-term monitoring of specific populations, management strategies that stress habitat preservation can only be considered theoretical.

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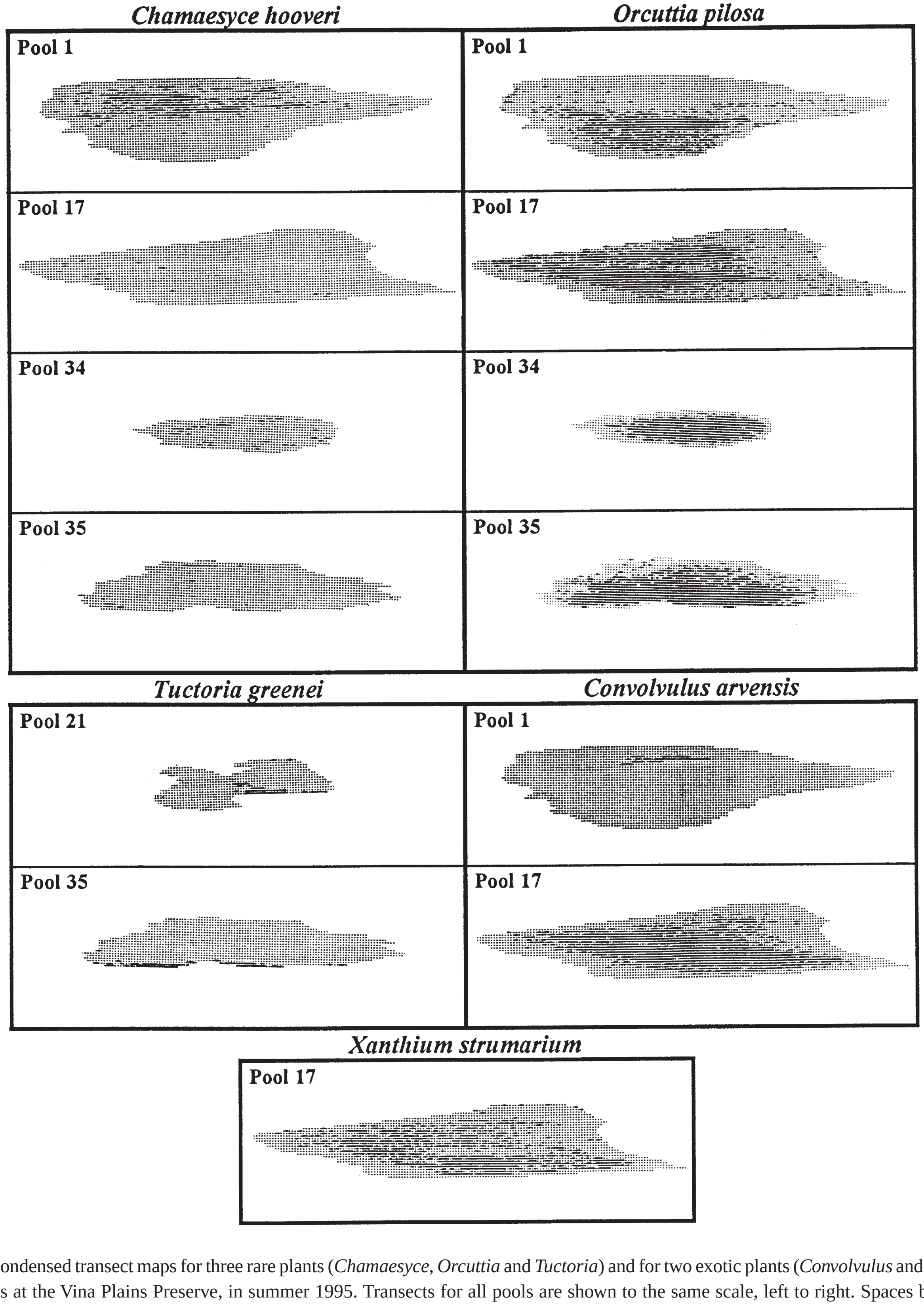

FIGURE 4. Condensed transect maps for three rare plants (*Chamaesyce, Orcuttia* and *Tuctoria*) and for two exotic plants (*Convolvulus* and *Xanthium*), in pools at the Vina Plains Preserve, in summer 1995. Transects for all pools are shown to the same scale, left to right. Spaces between the transects (either 4 m or 9 m) have been omitted in the maps; thus the mapped pools can not be directly compared in the north-south (top to bottom) direction. Marks represent quadrats placed every meter on the transects; bolder marks represent presence of the plant.

aging this work on the Preserve. Invertebrates were collected under U. S. Fish and Wildlife Service Permit PRT – 797266.

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