LONG TERM VEGETATION AND FAUNAL SUCCESSION IN AN ARTIFICIAL NORTHERN CALIFORNIA VERNAL POOL SYSTEM

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16. ABSTRACT

We evaluated 3 sets of 5 artificial vernal pools located on Travis AFB in Solano County CA. Research was done to determine if artificial vernal pools constructed at Travis AFB in 1993 maintained vernal pool characteristics and to determine if any of the five treatments used to develop the artificial pools are useful for mitigating vernal pool impacts. The artificial vernal pools support a diverse plant population, but lack the biodiversity of natural pools. The vegetation of artificial pools are dependent on the design of the pool. The depth of the artificial pools allows a longer inundation period than the surrounding natural pools. Plant species associated with longer inundation periods (*Spergula arvensis)* are benefiting from the design. The steep sides of the artificial pools lack vegetation and give an unnatural appearance. Vacuuming in terms of native and non-native coverage outperformed the other treatments. The block treatment is not successful; there was limited growth of plants between block treatments within the artificial pools.

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DISCLAIMER STATEMENT

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INTRODUCTION

This is the final report for project E 99 TL 01 Long Term Vegetation and Faunal Succession in an Artificial Northern California Vernal Pool System, Phase 1. This report also serves as an interim report for project F 2000 EN 214 Long Term Vegetation and Invertebrate Succession in an Artificial Northern California Vernal Pool System Phase 2.

These projects have the following objectives:

- to determine if artificial vernal pools constructed at Travis AFB in 1993 maintained vernal pool characteristics,
- to update vernal pool literature,
- to determine if any of the five treatments used to develop the artificial pools are useful for mitigating vernal pool impacts.

Vernal pools are seasonal wetlands forming in shallow depressions underlain by a shallow substrate that restricts the percolation of water. The pools fill during the winter rainy season. There may be several cycles of inundation and drying during an individual season, but the soils in the pool usually remain saturated until spring. Inundation periods vary greatly from a few days to several months. In most years inundation occurs when temperatures are high enough for plant growth. The pools finally dry out during the spring or early summer and remain desiccated for several months until the rains of the following wet season. When completely dry the soil moisture in the pool is the same as the soil moisture of the adjacent uplands. The seasonal variation between inundation and complete desiccation limits the flora that can occupy vernal pool habitat. Most upland plants are precluded by the presence of freestanding water and saturated soil for extended periods during the rainy season, while most wetland plants are precluded by the complete desiccation of the pool soils during the summer. Only a few species tolerate the alternately extreme conditions of inundation and drought. Several species of shrimp and plants that are restricted to vernal pools are listed as threatened or endangered under the federal Endangered Species Act. Because of the presence of these listed species and other factors, vernal pool impacts from transportation projects may require mitigation. Yet there is significant controversy concerning the use of habitat creation and restoration to mitigate vernal pool losses (Sutter and Francisco 1998). Attempts at creating vernal pools for mitigation have only been partially successful (Barbour 1998, De Weese 1998).

This study is the continuation of a study begun in the autumn 1993 at Travis AFB, CA. In November 1993, fifteen 3m x 10m rectangular artificial vernal pools were constructed to determine if then current methods of artificial vernal pool restoration could be successful in the southern Sacramento Valley. The deep end of each pool was excavated to a depth of 80 cm on the downhill side. The pool was then excavated to form a plane that merged with the soil surface at the uphill end of the pool. Side slopes were graded to approximately 30 degrees. The pools were constructed in this way to facilitate statistical comparisons among the treatments.

The artificial vernal pools at Travis AFB were developed to compare four different planting techniques:

- scraping and vacuuming source materials from the soil surface of natural pools and placing the collected materials on the natural soil surface of artificial pools,

- cutting blocks of soil from the bottom of source pools and placing these blocks in shallow trenches in artificial pools,
- spreading crushed vernal pool soil on the bottom of artificial pools,
- letting artificial pools lie fallow.

Vegetation, hydrology, and invertebrates were monitored during 1993, 1994, 1995 and 1996. This work was performed for the Department by Sonoma State University under contract 65T343. The final report for the original project is: Northen, Philip T., Susan Holve-Hensill and Doug Eakins. April 15, 1998. *Techniques for Mitigating Loss of Vernal Pools: an Experimental Approach*. California Department of Transportation. Sacramento CA.

The Sonoma State team reached the following major conclusions.

1. All artificial pools behaved as functional vernal pools during the 2-3 year period of observation.
2. Waiting through one wet season before inoculating a vacuum/scrape pools did not improve success.
3. Inoculating artificial pools with pulverized soil is superior to vacuum/scrape pools and block methods in creating successful vernal pools.
4. The source pools in the study lost plant diversity rapidly over the four years of observation and began developing thatch. Central valley vernal pools may require regular disturbance to maintain high diversity and other wetland values.
5. The propagule removal methods differed in how they affected the source pools. Creating shallow, unfilled depressions by removing soil had no adverse effects, and is the preferred method for removing inoculum.

For habitat mitigation to be successful one must not only show that the habitat can be initially created, but that the habitat can be maintained over time. De Weese noted that in her experience, constructed vernal pools appear to have comparable plant diversity to natural source pools for the first two years (De Weese 1998). However, later species that prefer longer inundation periods begin to become more dominant. The major question in this current study is whether or not the constructed vernal pools at Travis AFB continue to maintain the hydrological, faunal, and floral characteristics of vernal pools.

Vegetation Methods

Study Site

The study site is located on Travis AFB in Solano County CA southwest of the David Grant USAF Medical Center and near the western boundary of the base. A complete description of the study site including maps and aerial photographs is found in Northen, Holve-Hensill and Eakins (1998). The location of Natural pool SP1 is westerly of TR16 and SP2 is directly behind artificial pool C2.

Sampling Design

The vernal pool blooming season, when plants can be best identified, occurs during a relatively short period in the spring. Over this period, the vegetation apparent in the

vernal pools changes rapidly as temperatures rise and the soil becomes dry. It was not practical to use manual methods to develop the needed quantities of data over the available time. Therefore, we used an Olympus 2500 digital camera to rapidly gather high quality vegetation data for analysis. Color fidelity and image sharpness of the digital camera allow proper identification of plant species, estimates of percent cover and analysis of other vegetation characteristics. The series of electronic images provides an accurate record of the conditions within the pools over the course of time. Images can be compared within a season and from year to year.

We visited the site on: 04/26/01, 05/03/01, and 06/08/01 to gather vegetation data. On each visit wide angle and close up images were taken of each artificial and natural pool. One wide-angle image of each entire pool was taken from the pools shallow end. Close ups were taken of the deep, middle, and shallow zone of each artificial pool as defined by pool depth. The close up images were of representative homogenous areas of the strata in the pools. Plant species in each artificial and natural pool were identified on site. If we were not able to identify the plant on site a close up image or sample of the plant in question was collected for identification. Species identifications are according to the corrected third printing of The Jepson Manual: Higher Plants of California (Hickman ed., 1996).

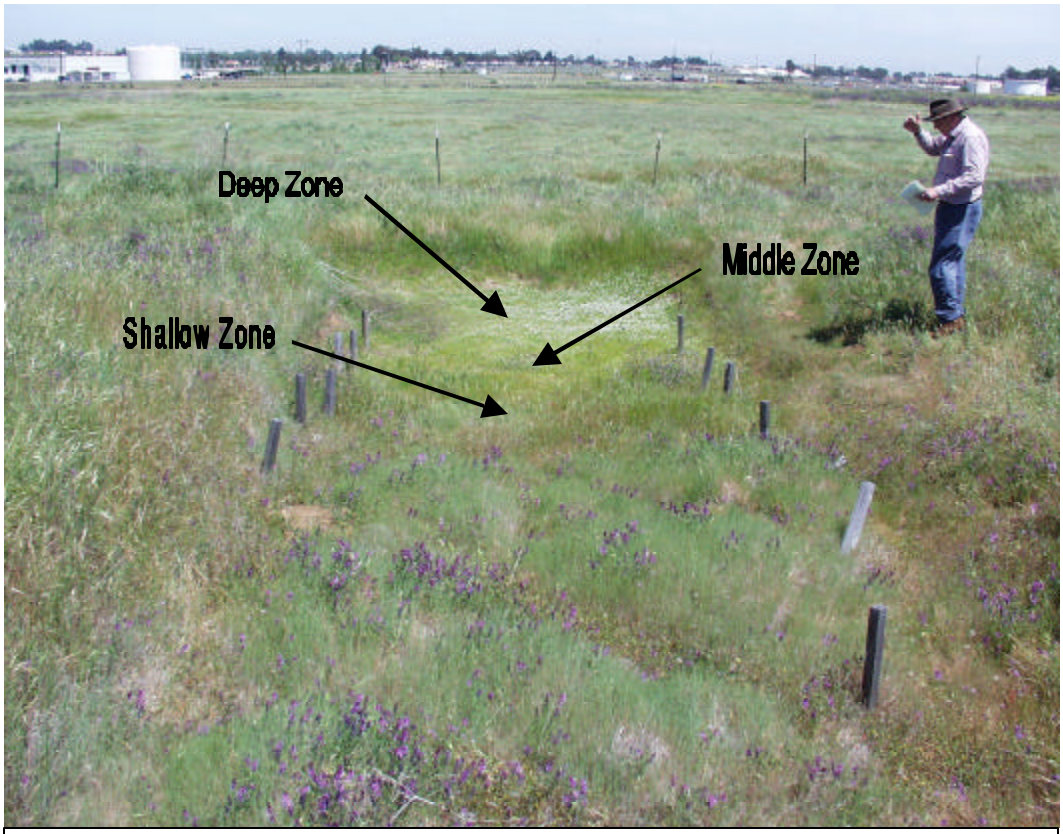


Photo 1. Artificial Pool C5 on 04/26/01. Wide angle image of Artificial Pool C5 with arrows indicating deep, middle, and shallow zones. (Harold Hunt)

Data Analysis

In the original study design for the artificial pools there were three replicates for each of the four inoculation methods and parametric comparisons were made among the sets (Northern, Holve-Hensil, Eakins, 1998). Subsequent observation indicated high variability within the replicate sets. This high variability and the small number of replicates precluded parametric statistical analysis in the current study. We can determine where different plants grew, relative cover of the plants, and general trends of different plant groups. The photos of each artificial and natural pool were analyzed using 2001 Vernal Pool Classification – Releve Data Forms (Witham, 2000).

Each individual image was used as a releve. Each plant species on the image was identified and the percentage of cover abundance for each species was ocularly estimated. The percentages of plant cover for each plant species were converted to an absolute scale value using the Braun – Blanquet Cover Abundance Scale Table (Mueller – Dombois and Ellenberg, 1974).

Table 1. *Braun-Blanquet Cover-Abundance Scale.*

Absolute scale value	Percentage of relative cover
5	Any number, with cover more than ¾ of the reference area. (>75%)
4	Any number, with ½ - ¾ cover (50 – 75%)
3	Any number, with ¼ - ½ cover (25 – 50%)
2	Any number with 1/20 – ¼ cover (5 – 25%)
1	Numerous, but less than 1/20 cover, or scattered, with cover up to 1/20 (5%)
+	Few, with small cover
r	Solitary, with small cover

(Mueller – Dombois and Ellenberg, 1974)

For each date and for each zone a Raw Table and a Constancy Table were constructed following the method of Mueller – Dombois and Ellenberg (1974). The Raw Table is assembled with a vertical column allotted for each releve or picture. The species are listed in a horizontal column and the percentage number of species found in the releve is entered beneath. This table allows certain species to be emphasized right away (i.e. those that are more abundant are clearly visible). Following the Data Table, species were sorted according to their "degree of constancy." Constancy refers to the number of times a species occurs for a given number of releves. The order of species is then arranged from high to low "constancy." The purpose of the constancy table is to show an immediate comparison of the individual releves; for example, species that are similar in constancy can be distinguished.

The Zone Average Table represents an average cover of species present in all zones of the artificial pools on each date. An average of bare soil and algae matting was also calculated. From this data, each artificial pool was added together, including total vegetation cover and excluding bare soil and algae matting. This was designated as the Relative Cover. After calculating the relative cover a figure was constructed showing Cover Abundance.

The Native vs. Non-native Species Tables were compiled using the Zone Average Tables for each date. The Cover Abundance for native and non-native species is based on the addition of the averages. The Cover Abundance Tables compare relative cover of the native versus non-native species in each artificial pool and natural vernal pools.

Vegetation Results

Species Present in the Shallow, Middle and Deep Zones on 04/26/01

We observed 11 plant species growing in the artificial pool on 04/26/01 (Tables 2-4). *Downingia concolor* appears to succeed in the shallow to middle zones, while the most abundant and constant species is *Psilocarphus brevissimus*. In the deep zone, *Spergula arvensis* was the most abundant and constant species. The grasses appeared in the shallow zones on this date.

Table 2. *Species present in Shallow Zone on 04/26/01.*

	Shallow Zone														
Constancy Table 042601	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Psilocarphus brevissimus	2	2	2	1	2		1	4	4		1		2	3	3
Downingia concolor			1	1	r		+	1	r	r				+	1
Lasthenia glaberrima		3		3	+	2		+			5				
Erodium botrys			1			2		1					1		
Eryngium aristulatum				1			+			1	2				
Spergula arvensis	+	2				+								+	1
Convolvulus arvensis	2				+			+							
Lupinus bicolor						2	+								
Anagalis arvensis							1								
Hemizonia fitchii			2												
Lasthenia macrantha ssp. bakeri															
Eremocarpus setigerus															
Centaurium muehlenbergii															
Xanthium strumarium															
Asclepias fascicularis															
Cyperus eragrostis															
Rumex crispus															
Eleocharis macrostachya															
Grasses															
Hordeum murinum	2			2	3	3	3	2	1	3			2	3	2
Taeniatherum caput-medusae															
Polypogon monspeliensis															
Lolium multiflorum															
Other															
bare soil	2	2	3	2	2	1	2	1	3	3	1		3	3	2
algae/algal matting															

Table 3. *Species present in the Middle Zone on 04/26/01.*

	Middle Zone														
Constancy Table 042601	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Psilocarphus brevissimus	2	1	5		1	2	3	2	4	2	1		3	3	3
Spergula arvensis		2	1	1	5	2		1	2	1	2	3		2	4
Lasthenia glaberrima	r	4		5	1		1	3		3	5	3			
Eryngium aristulatum	2	1		1			1		1		2				
Downingia concolor			r			1	+			1		1			
Convolvulus arvensis										1			r		
Anagalis arvensis						1									
Erodium botrys													+		
Lupinus bicolor															
Lasthenia macrantha ssp. bakeri															
Hemizonia fitchii															
Eremocarpus setigerus															
Centaurium muehlenbergii															
Xanthium strumarium															
Asclepias fascicularis															
Cyperus eragrostis															
Rumex crispus															
Eleocharis macrostachya															
Grasses															
Hordeum murinum	2		1			2	1			1			1		
Taeniatherum caput-medusae															
Polypogon monspeliensis															
Lolium multiflorum															
Other															
bare soil	2	2	2	1		1	3	2	2	2	1	1	3	2	2
algae/algal matting					2										

Table 4. *Species present in the Deep Zone on 04/26/01.*

	Deep Zone														
Constancy Table 042601	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Spergula arvensis	4	5	4	5	5	5	3	3	4	3	5	5		3	5
Psilocarphus brevissimus	1		2				3	2				1	3	2	2
Eryngium aristulatum	1	1		1					2	1	+		1		
Lasthenia glaberrima				1			2	2		3	1				
Convolvulus arvensis							1			+					
Anagalis arvensis															
Downingia concolor															
Erodium botrys															
Lupinus bicolor															
Lasthenia macrantha ssp. bakeri															
Hemizonia fitchii															
Eremocarpus setigerus															
Centaurium muehlenbergii															
Xanthium strumarium															
Asclepias fascicularis															
Cyperus eragrostis															
Rumex crispus															
Eleocharis macrostachya															
Grasses															
Hordeum murinum							2	1					1		
Taeniatherum caput-medusae															
Polypogon monspeliensis															
Lolium multiflorum															
Other															
bare soil	2	2	3		1	1	1	2	2	2		1	3		2
algae/algal matting				2	2						2			2	

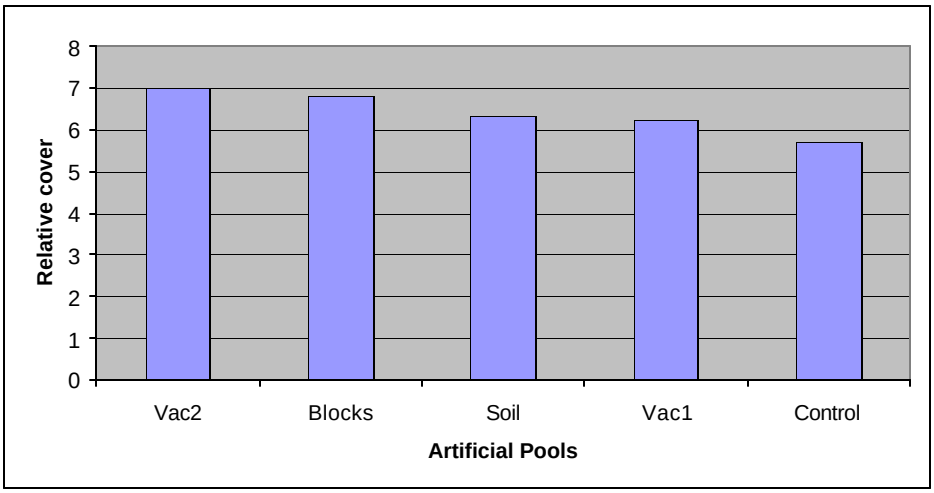
Spergula arvensis had the highest average cover among species present on 04/26/01. Among the inoculation treatment, Vac2, had the highest cover abundance (7.02) The cover abundance ranged from 5.69 to 7.02 on 04/26/01 (Table 5 and Figure1).

Photo 2. Close-up image of deep zone artificial pool C5 on 04/26/01.

Table 5. *Average cover of species present in all zones in each inoculation treatment on 04/26/01.*

Zone Averages 042601	Inoculation Treatments				
List of Species	Vac1	Blocks	Vac2	Soil	Control
Spergula arvensis	2.01	2.56	1.44	2.11	1.67
Psilocarphus brevissimus	1.89	0.67	2.56	0.56	2.67
Eryngium aristulatum	0.56	0.33	0.45	0.67	0.11
Downingia concolor	0.11	0.22	0.12	0.22	0.12
Lasthenia glaberrima	0.78	1.34	0.89	2.22	
Erodium botrys	0.11	0.22	0.11		0.12
Convolvulus arvensis	0.22	0.006	0.12	0.12	
Anagalis fascicularis		0.11	0.11		
Lupinus bicolor		0.11	0.11		
Hemizonia fitchii		0.11			
Eremocarpus setigerus					
Centaurium muehlenbergii					
Xanthium strumarium					
Asclepias asperula					
Cyperus eragrostis					
Lasthenia macrantha ssp. bakeri					
Rumex crispus					
Eleocharis macrostachya					
Grasses					
Hordeum murinum	0.56	1.11	1.11	0.44	1
Lolium multiflorum					
Taeniatherum caput-medusae					
Polypogon monspeliensis					
Other					
bare soil	2.22	1	1.89	1.22	2.22
algae/algal matting		0.67		0.22	0.22
Relative Cover (average)	6.24	6.79	7.02	6.34	5.69

Figure 1. *Cover Abundance on 04/26/01.*



Species Present in the Shallow, Middle, and Deep Zones on 05/03/01

There were 10 plant species present in the artificial pools on 05/03/01 (Tables 6-8). On this date, we observed that drier conditions led to a decrease in the early blooming vernal pool species. *Downingia concolor* was the most constant species, but *Psilocarphus brevissimus* had a greater amount of cover abundance. The cover abundance of grasses increased compared to 04/26/01. In the middle zones, *Psilocarphus brevissimus* was the most constant and abundant species. *Lasthenia glaberrima* grew in all zones, but was more successful in the middle zone on this date. In the deep zone, *Spergula arvensis* was the most abundant and constant species.

Table 6. *Species present in the Shallow Zone on 05/03/01.*

	Shallow Zone														
Constancy Table 050301	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Downingia concolor	+		+	1	1	1	+	+	+	1	r	1		1	
Psilocarphus brevissimus	2	3	4	2	4		2	3	4		3		2	3	4
Eryngium aristulatum	2	2		1			2	1	1	1	2		1		
Lasthenia glaberrima	+	1		2	1	1	1	+	+		1				
Spergula arvensis		+			2	1								+	+
Erodium botrys						1	+					1			
Anagalis arvensis							1					1			
Convolvulus arvensis			+												
Hemizonia fitchii															
Lasthenia macrantha ssp. bakeri															
Lupinus bicolor															
Eremocarpus setigerus															
Centaurium muehlenbergii															
Xanthium strumarium															
Asclepias fascicularis															
Cyperus eragrostis															
Rumex crispus															
Eleocharis macrostachya															
Grasses															
Hordeum murinum	2	2		3		4	2	3	1	4	2	4	3	3	1
Lolium multiflorum		1					1								
Taeniatherum caput-medusae															
Polypogon monspeliensis															
Other															
bare soil	3	3	2	2	2	2	1	3	2	2	1	1	3	3	3
algae/algal matting															

Table 7. *Species present in the Middle Zone on 05/03/01.*

	Middle Zone														
Constancy Table 050301	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Psilocarphus brevissimus	2	2	3	1	2	3	3	3	4	2	2	1	3	2	4
Spergula arvensis		1	1	+	4	+		+	+	1	1	1		2	2
Lasthenia glaberrima	+	2		3	1		+	1		2	4	1			
Eryngium aristulatum	2	1		2			1	1	2		2		2		
Downingia concolor				1		2	+			1		1		1	
Convolvulus arvensis			+	1						+			+		
Hemizonia fitchii			2												
Asclepias fascicularis															
Erodium botrys															
Lasthenia macrantha ssp. bakeri															
Lupinus bicolor															
Eremocarpus setigerus															
Centaurium muehlenbergii															
Xanthium strumarium															
Asclepias asperula															
Cyperus eragrostis															
Rumex crispus															
Eleocharis macrostachya															
Grasses															
Hordeum murinum	2						2	1					1	1	
Lolium multiflorum													1		
Taeniatherum caput-medusae															
Polypogon monspeliensis															
Other															
bare soil	3	2	3	3	1	+	3	2	3	3	1	+	3	3	3
algae/algal matting					2										

Table 8. *Species present in the Deep Zone on 05/03/01.*

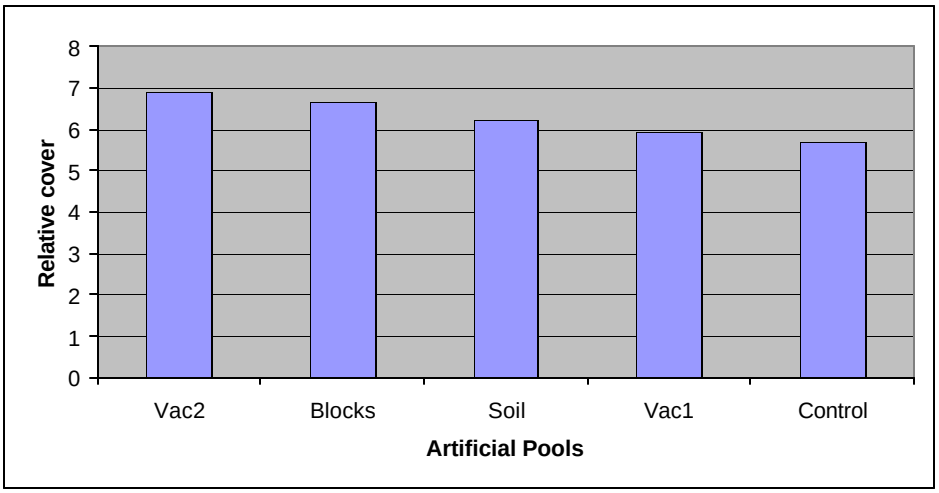
	Deep Zone														
Constancy Table 050301	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Spergula arvensis		2	4	r	3	4	+	+	3	r	4	2		3	3
Psilocarphus brevissimus	1	2	1		1		3	2	1			1	2		2
Eryngium aristulatum	1	2		2			2	+	2	2	1		1		
Lasthenia glaberrima		1		2			1			2	+			+	
Convolvulus arvensis	1						1						1		
Downingia concolor	1			1						1					
Anagalis arvensis															
Erodium botrys															
Lupinus bicolor															
Hemizonia fitchii															
Lasthenia macrantha ssp. bakeri															
Eremocarpus setigerus															
Centaurium muehlenbergii															
Xanthium strumarium															
Asclepias fascicularis															
Cyperus eragrostis															
Rumex crispus															
Eleocharis macrostachya															
Grasses															
Hordeum murinum	1					2	2	2				3	+		2
Lolium multiflorum															
Taeniatherum caput-medusae															
Polypogon monspeliensis															
Other															
bare soil	4	2	3	3		1	2	4	3	3	3	2	4		3
algae/algal matting					3									3	

Psilocarphus brevissimus had the highest average cover on 05/03/01, due to the decrease in the early blooming species (Table 9). *Spergula arvensis* dominated the deep zone early in the season and declined over time. Inoculation treatment, Vac2, had the highest relative cover (6.92), which is consistent with earlier data in Table 5. Cover Abundance on 05/03/01 ranged from 5.69 to 6.92 (Figure 2).

Table 9. *Average cover of species present in each inoculation treatments on 05/03/01.*

Zone Averages 050301	Artificial Pools				
List of Species	Vac1	Blocks	Vac2	Soil	Control
Psilocarphus brevissimus	2.22	1.44	2.78	1	2.44
Spergula arvensis	0.89	1.57	0.36	1	1.12
Eryngium aristulatum	1.11	0.56	1.34	0.89	0.44
Lasthenia glaberrima	0.46	1.11	0.35	1.12	0.006
Downingia concolor	0.12	0.78	0.35	0.56	0.22
Convolvulus arvensis	0.12	0.11	0.11	0.006	0.12
Asclepias fascicularis		0.11	0.006	0.11	
Erodium botrys			0.11	0.11	
Hemizonia fitchii	0.11				
Lasthenia macrantha ssp. bakeri					
Lupinus bicolor					
Eremocarpus setigerus					
Centaurium muehlenbergii					
Xanthium strumarium					
Asclepias asperula					
Cyperus eragrostis					
Rumex crispus					
Eleocharis macrostachya					
Grasses					
Hordeum murinum	0.78	1	1.4	1.4	1.23
Lolium multiflorum	0.11		0.11		0.11
Taeniatherum caput-medusae					
Polypogon monspeliensis					
Other					
bare soil	2.78	2.11	2.56	1.78	1.23
algae/algal matting		0.56			0.33
Relative Cover (average)	5.92	6.68	6.92	6.2	5.69

Figure 2. *Cover Abundance on 05/03/01.*



Species Present in the Shallow, Middle, and Deep Zones on 06/08/01

We observed 15 plant species growing in the artificial pools on 06/08/01 (Tables 10-12). On this date, the early blooming vernal pool species or flowering plants were no longer apparent in the artificial pools and the number of grass species increased. *Psilocarphus brevissimus* dominated the shallow and middle zones and there was an increase in the summer blooming species, which appeared in all zones. Those summer blooming species were *Eremocarpus setigerus*, *Hemizonia fitchii*, and *Eryngium aristulatum. Eremocarpus setigerus* was the most constant species in the deep zone.

Table 10. *Species present in the Shallow Zone on 06/08/01.*

	Shallow Zone														
Constancy Table 060801	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Psilocarphus brevissimus	2	2	1	1	3		2	3	2		1		2	3	3
Hemizonia fitchii		2	2		2	1		2	2		1		1	2	2
Eryngium aristulatum	3	2		2	+		3	+		1	3		1		
Eremocarpus setigerus		1			1			1		+	1	2		2	2
Convolvulus arvensis	1				1			1					1		1
Asclepias fascicularis															r
Centaurium muehlenbergii									1						
Rumex crispus											r				
Anagalis arvensis															
Lasthenia macrantha ssp. bakeri															
Lasthenia glaberrima															
Cyperus eragrostis															
Downingia concolor															
Erodium botrys															
Eleocharis macrostachya															
Lupinus bicolor															
Spergula arvensis															
Xanthium strumarium															
Grasses															
Hordeum murinum	2	2	2	2	3	3	2	2	1	2	2	3	3	4	2
Lolium multiflorum	2	+	1	1	+	1	2	+	1	3	1	1	2	+	+
Taeniatherum caput-medusae	2	+	1	2	+	1	2	1	2	1	1	1	2	1	1
Polypogon monspeliensis					1						1	2			
Other															
bare soil	2	3	2	1	2	2	2	2	1	+	2	2	2	2	2
algae/algal matting															

Table 11. *Species present in the Middle Zone on 06/08/01.*

	Middle Zone														
Constancy Table 060801	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Psilocarphus brevissimus	1	2	2	1	3		2	2	2	1	1		2	2	3
Hemizonia fitchii		2	2		2	1		2	2		1		1	2	2
Eryngium aristulatum	3	2		2			2	1	1	1	3	2	1		
Eremocarpus setigerus		1			1			1		1	1	2		2	1
Convolvulus arvensis		1		1						1			1		1
Eleocharis macrostachya				1											
Xanthium strumarium										1					
Anagalis arvensis															
Lasthenia macrantha ssp. bakeri															
Lasthenia glaberrima															
Cyperus eragrostis															
Downingia concolor															
Erodium botrys															
Asclepias fascicularis															
Lupinus bicolor															
Centaurium muehlenbergii															
Rumex crispus															
Spergula arvensis															
Grasses															
Hordeum murinum	2	1	2	2	1	2	1	3	1	2	2	2	2	2	
Lolium multiflorum	1	+	1	2	1	+	2	+	+	1	1	+	+	1	2
Taeniatherum caput-medusae	1	1	1	+		1	1	+	2		1	1	+	1	
Polypogon monspeliensis											1	+			
Other															
bare soil	3	3	2	1	3	2	2	2	2	2	2	2	3	2	3
algae/algal matting															

Table 12. *Species present in the Deep Zone on 06/08/01.*

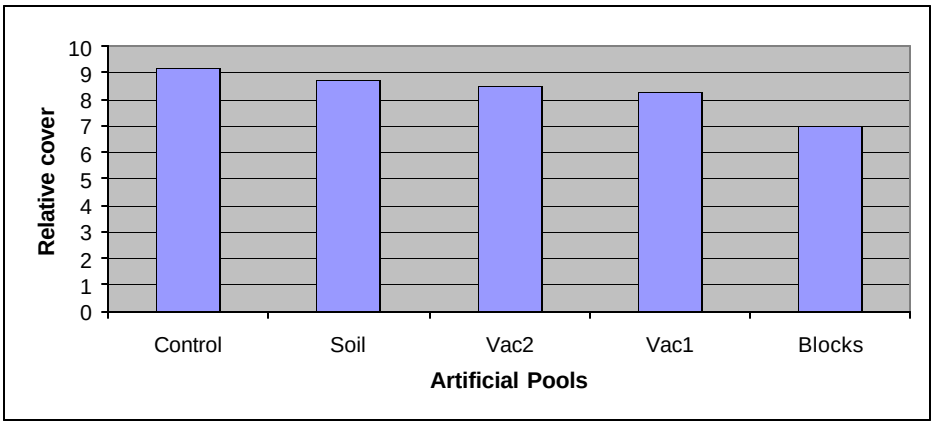
	Deep Zone														
Constancy Table 060801	Vac1			Blocks			Vac2			Soil			Control		
List of Species	A1	B4	C3	A4	B1	C5	A2	B2	C2	A5	B5	C4	A3	B3	C1
Eremocarpus setigerus		+		r	1	1		2		+	2	2		2	2
Eryngium aristulatum	2	2		2	1		2	1	1	3	2		1		
Psilocarphus brevissimus	1	1	2		2		1	+	2			1	1		2
Hemizonia fitchii		1	2		1			2	2		1		1	+	2
Convolvulus arvensis			2	1	1		1			+			+		
Cyperus eragrostis	r														
Eleocharis macrostachya				1											
Xanthium strumarium										1					
Anagalis arvensis															
Lasthenia macrantha ssp. bakeri															
Lasthenia glaberrima															
Downingia concolor															
Erodium botrys															
Asclepias fascicularis															
Lupinus bicolor															
Centaurium muehlenbergii															
Rumex crispus															
Spergula arvensis															
Grasses															
Taeniatherum caput-medusae	1	1	+	+	1	1	1	+	2	+	1	1	2	1	1
Hordeum murinum	1		1		+	2	1	1	1	2	1	1	+	2	+
Lolium multiflorum	1	1	1	1	1	+	2	+	+	1		1	1	1	
Polypogon monspeliensis											1	2			1
Other															
bare soil	4	3	3	2	4	2	2	3	3	2	3	3	4	2	3
algae/algal matting															

On 06/08/01, *Psilocarphus brevissimus* had the highest average cover throughout the artificial pools (Table 13). The control had the highest cover abundance (9.15) compared to the other artificial pools. The increase in cover abundance was due to the increase in summer blooming species and grass species in the control pools. Cover abundance ranged from 7.02 to 9.15 on 06/08/01 (Figure 3).

Table 13. *Average cover of species present in all zones in each inoculation treatments on 06/08/01.*

Zone Averages 060801	Artificial Pools				
List of Species	Vac1	Blocks	Vac2	Soil	Control
Psilocarphus brevissimus	1.56	1.11	1.67	0.78	2.11
Hemizonia fitchii	1.22	0.78	1.33	0.33	1.45
Eryngium aristulatum	1.56	0.78	1.23	1.67	0.33
Eremocarpus setigerus	0.23	0.44	0.44	1.23	1.22
Convolvulus arvensis	0.44	0.44	0.22	0.12	0.45
Xanthium strumarium				0.11	
Centaurium muehlenbergii			0.11		
Eleocharis macrostachya		0.22			
Anagalis arvensis					
Lasthenia macrantha ssp. bakeri					
Lasthenia glaberrima					
Cyperus eragrostis					
Downingia concolor					
Erodium botrys					
Rumex crispus					
Lupinus bicolor					
Spergula arvensis					
Asclepias fascicularis					
Grasses					
Hordeum murinum	1.44	1.67	1.44	1.89	1.68
Lolium multiflorum	0.9	0.79	0.81	1.01	0.79
Taeniatherum caput-medusae	0.9	0.68	1.23	0.78	1.01
Polypogon monspeliensis		0.11		0.78	0.11
Other					
bare soil	2.78	2.11	2.11	2.01	2.56
algae/algal matting					
Relative Cover (average)	8.25	7.02	8.48	8.7	9.15

Figure 3. *Cover Abundance on 06/08/01.*



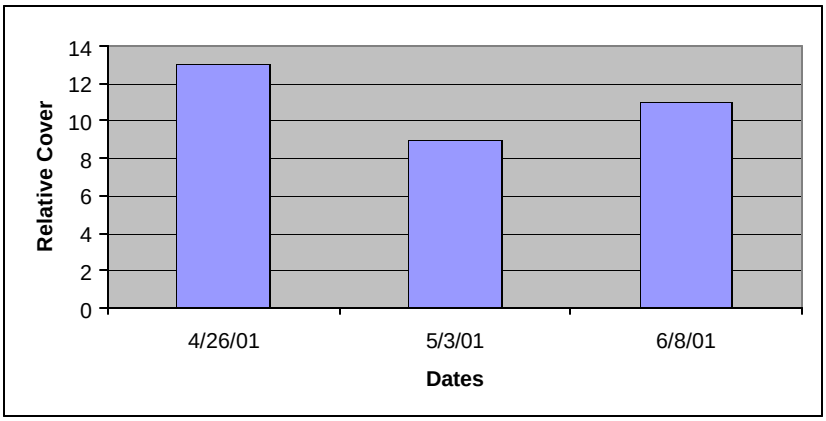
Cover Abundance for Natural pool TR 16

Psilocarphus brevissimus and *Eryngium aristulatum* were the most constant and abundant species. We observed *Lasthenia macrantha ssp. bakeri* in TR16. *Lasthenia macrantha ssp. bakeri* was absent from all the artificial pools. The coverage of *Lasthenia macrantha ssp. bakeri* was highest on 04/26/01 and 05/03/01, but was not apparent on 06/08/01 (Table 14). TR16 was not used as a source of propagules for the artificial pools due to the presence of *Lasthenia macrantha ssp. bakeri*. In TR16 there were relatively small amounts of grass species and bare soil throughout the season. In the early bloom season, the cover abundance was high (13). By 05/03/01, the flowering species declined, showing a cover abundance of 9. The cover abundance increased to 11 by 06/08/01, due to an increase in summer blooming species (Figure 4).

Table 14. *Species present in TR16 according to each date.*

Constancy Table	TR16		
List of Species	4/26/01	5/3/01	6/8/01
Eryngium aristulatum	2	2	2
Psilocarphus brevissimus	2	2	2
Rumex crispus	1	1	1
Convolvulus arvensis	1	1	1
Lasthenia macrantha ssp. bakeri	2	2	
Downingia concolor	2		
Lasthenia glaberrima	2		
Eremocarpus setigerus			3
Hemizonia fitchii			1
Asclepias fascicularis			r
Spergula arvensis			
Lupinus bicolor			
Anagalis arvensis			
Centaurium muehlenbergii			
Xanthium strumarium			
Erodium botrys			
Cyperus eragrostis			
Eleocharis macrostachya			
Grasses			
Hordeum murinum	1	1	1
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Lolium multiflorum			
Other			
bare soil	1	1	1
algae/algal matting			
Relative Cover	13	9	11

Figure 4. *Cover Abundance for TR16 for each date listed.*



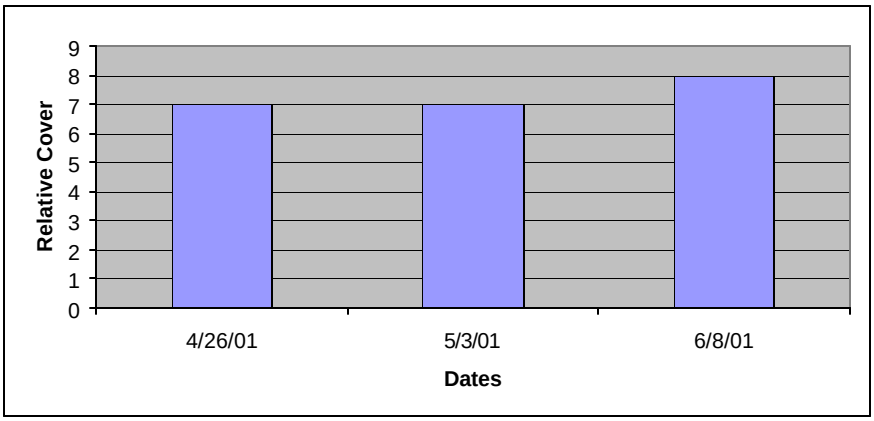
Cover Abundance for Natural pool SP1

SP1 is smaller than the other natural pools and the artificial pools. Throughout the season, *Eryngium aristulatum* was the most constant and dominant species observed. *Psilocarphus brevissimus* was the second most constant species. *Lasthenia macrantha ssp. bakeri* appeared in small numbers on 04/26/01. SP1 showed an increase in grass cover abundance over time. Summer blooming species were not present (Table 15). In the early bloom season, the cover abundance was 7. By 05/03/01, the flowering species declined. A cover abundance of 7 was recorded for that date. The cover abundance increased to 8 by 06/08/01, caused by an increase in grass cover (Figure 5).

Table 15. *Species present in SP1 according to each date.*

Constancy Table	Small Pool 1 (SP1)		
List of Species	4/26/01	5/3/01	6/8/01
Eryngium aristulatum	2	4	3
Psilocarphus brevissimus	2	1	1
Lasthenia macrantha ssp. bakeri	1		
Downingia concolor			
Lasthenia glaberrima			
Hemizonia fitchii			
Eremocarpus setigerus			
Asclepias fascicularis			
Convolvulus arvensis			
Spergula arvensis			
Lupinus bicolor			
Anagalis arvensis			
Centaurium muehlenbergii			
Xanthium strumarium			
Erodium botrys			
Cyperus eragrostis			
Rumex crispus			
Eleocharis macrostachya			
Grasses			
Hordeum murinum	1	1	2
Lolium multiflorum	1	1	2
Polypogon monospeliensis			
Taeniatherum caput-medusae			
Other			
bare soil	2	2	2
algae/algal matting			
Relative Cover	7	7	8

Figure 5. *Cover Abundance for Small Pool 1.*



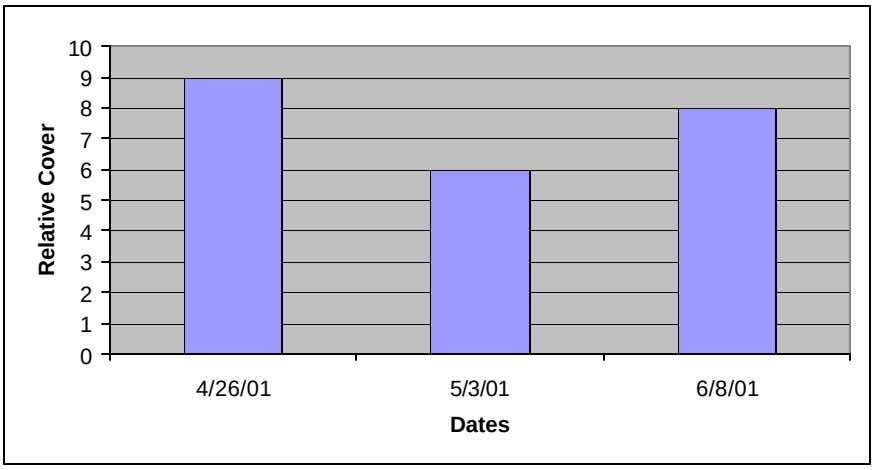
Cover Abundance for Natural pool SP2

Eryngium aristulatum has the highest amount of cover on each of the three dates in SP2 (Table 16). *Lasthenia glaberrima* appears in 04/26/01 and 05/03/01, but was not apparent on 06/08/01. *Spergula arvensis* had high amount of cover on 04/26/01, but was not apparent in SP2 on 06/08/01. The summer blooming species, *Eremocarpus setigerus* and *Hemizonia fitchii* appeared on 06/08/01. *Psilocarphus brevissimus* was absent on all the dates. The grass species and the amount of bare soil slightly increased over time. The cover abundance follows a trend similar to TR16. During early blooming season, cover abundance was high (9), and then decreased to 6 on 05/03/01 as the flowering species declined. During late blooming season, the cover abundance increased to 8 with the appearance of the summer blooming species (Figure 6).

Table 16. *Plant species in SP2 according to each date.*

Constancy Table	Small Pool 2 (SP2)		
List of Species	4/26/01	5/3/01	6/8/01
Eryngium aristulatum	2	3	2
Lasthenia glaberrima	3	1	
Spergula arvensis	3	1	
Hemizonia fitchii			2
Eremocarpus setigerus			2
Psilocarphus brevissimus			
Lasthenia macrantha ssp. bakeri			
Asclepias fascicularis			
Convolvulus arvensis			
Downingia concolor			
Lupinus bicolor			
Anagalis arvensis			
Centaurium muehlenbergii			
Xanthium strumarium			
Erodium botrys			
Cyperus eragrostis			
Rumex crispus			
Eleocharis macrostachya			
Grasses			
Hordeum murinum	1	1	2
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Lolium multiflorum			
Other			
bare soil	1	2	2
algae/algal matting			
Relative Cover	9	6	8

Figure 6. *Cover Abundance for SP2.*



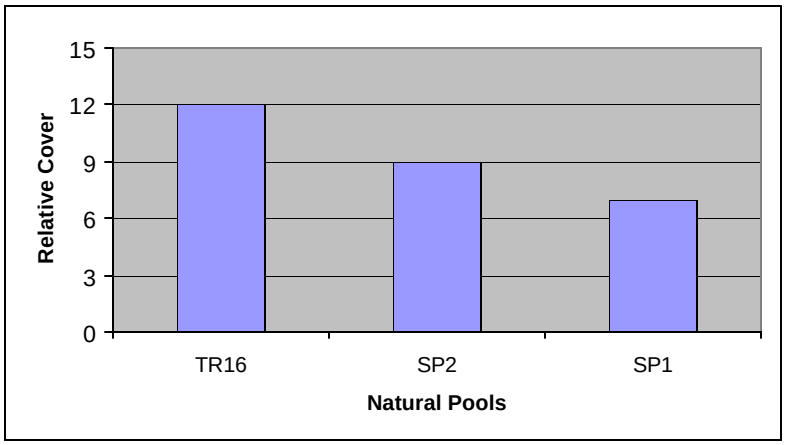
Species present in each Natural pool on 04/26/01

Eryngium aristulatum was observed in each natural pool and was the most constant species on 04/26/01 (Table 17). *Psilocarphus brevissimus* and *Lasthenia macrantha ssp. bakeri* were absent in SP2, but both were present in TR16 and SP1. *Lasthenia glaberrima* was absent in SP1, but was present in TR16 and SP2. *Spergula arvensis* only appeared in SP2, while *Downingia concolor* and *Convolvulus arvensis* only appeared in TR16. Overall, TR16 had the highest cover abundance (12) of any natural or artificial pool at Travis AFB (Figure 7).

Table 17. *Species present in each natural pool on 04/26/01.*

Constancy Table - Natural Pools 04/26/01	Natural Pool		
List of Species	**TR16**	**SP2**	**SP1**
Eryngium aristulatum	2	2	2
Psilocarphus brevissimus	2		2
Lasthenia macrantha ssp. bakeri	2		1
Lasthenia glaberrima	2	3	
Spergula arvensis		3	
Downingia concolor	2		
Convolvulus arensis	1		
Xanthium strumarium			
Centaurium muehlenbergii			
Eleocharis macrostachya			
Eremocarpus setigerus			
Rumex crispus			
Anagalis arvensis			
Erodium botrys			
Lupinus bicolor			
Cyperus eragrostis			
Asclepias fascicularis			
Hemizonia fitchii			
Grasses			
Hordeum murinum	1	1	1
Lolium multiforum			1
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Other			
bare soil	1	1	2
algae/algal matting			
Relative Cover	12	9	7

Figure 7. *Cover Abundance of each Natural Pool on 04/26/01.*



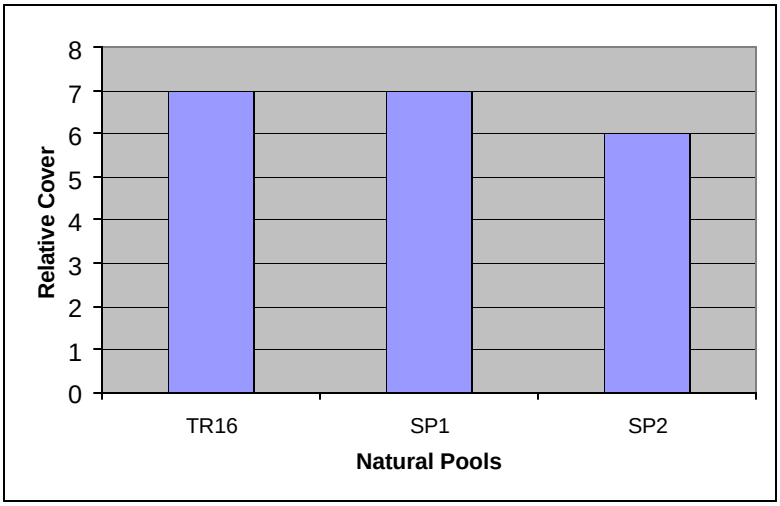
Species present in each Natural pool on 05/03/01

Eryngium aristulatum was present in all natural pools on 05/03/01 (Table 18). *Psilocarphus brevissimus* was absent in SP2; however, the species maintains constancy in TR16 and SP1. *Lasthenia glaberrima* and *Spergula arvensis* were present in SP2, but slowly declined. It was observed that *Lasthenia macrantha ssp. bakeri* was present in TR16, but absent in SP2. Cover abundance declined in the natural pools on 05/03/01 compared to 04/26/01 (Figure 8).

Table 18. *Species present in each natural pool on 05/03/01.*

Constancy Table-Natural Pools 05/03/01	Natural Pools		
List of Species	**TR16**	**SP2**	**SP1**
Eryngium aristulatum	2	3	4
Psilocarphus brevissimus	2		1
Lasthenia glaberrima		1	
Spergula arvensis		1	
Lasthenia macrantha ssp. bakeri	2		
Downingia concolor			
Convolvulus arensis			
Xanthium strumarium			
Centaurium muehlenbergii			
Eleocharis macrostachya			
Eremocarpus setigerus			
Rumex crispus			
Anagalis arvensis			
Erodium botrys			
Lupinus bicolor			
Cyperus eragrostis			
Asclepias fascicularis			
Hemizonia fitchii			
Grasses			
Hordeum murinum	1	1	1
Lolium multiforum			1
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Other			
bare soil	1	2	2
algae/algal matting			
Relative Cover	7	6	7

Figure 8. *Cover Abundance of each Natural Pool on 05/03/01.*



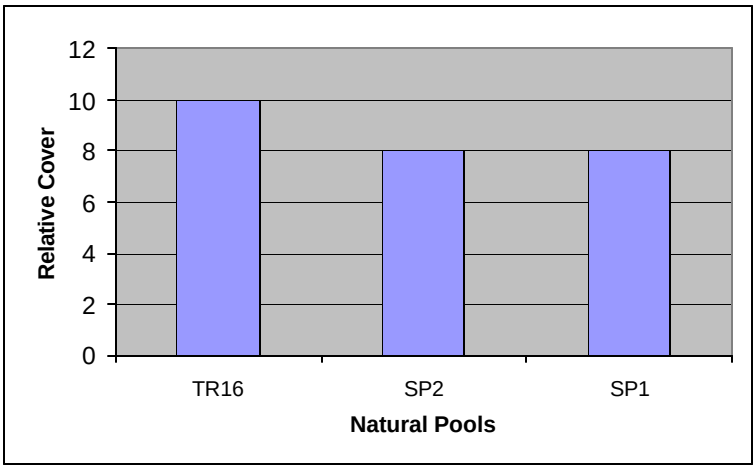
Species present in each Natural Pool on 06/08/01

The floral characteristics on 06/08/01 were similar to those on 05/03/01, with the addition of the late blooming vernal pool species (Table 19). *Eryngium aristulatum* and *Psilocarphus brevissimus* both remain constant in the natural pools. The late summer blooming species, *Eremocarpus setigerus* and *Hemizonia fitchii* were present in TR16 and SP2, but absent in SP1. The number of grass species increased and the cover abundance of grasses increased, with the highest coverage in SP1. Overall, the cover abundance increased from the previous date (Figure 9).

Table 19. *Species present in each natural pool on 06/08/01.*

Constancy Table-Natural Pools 6/8/2001	Natural Pools		
List of Species	**TR16**	**SP2**	**SP1**
Eryngium aristulatum	2	2	3
Psilocarphus brevissimus	2		1
Hemizonia fitchii	1	2	
Eremocarpus setigerus	3	2	
Rumex crispus	1		
Asclepias fascicularis	r		
Convolvulus arensis			
Xanthium strumarium			
Centaurium muehlenbergii			
Eleocharis macrostachya			
Lasthenia glaberrima			
Lasthenia macrantha ssp. bakeri			
Anagalis arvensis			
Erodium botrys			
Lupinus bicolor			
Cyperus eragrostis			
Downingia concolor			
Spergula arvensis			
Grasses			
Hordeum murinum	1	2	2
Lolium multiforum			2
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Other			
bare soil	1	2	2
algae/algal matting			
Relative Cover	10	8	8

Figure 9. *Cover Abundance of each Natural Pool on 06/08/01.*



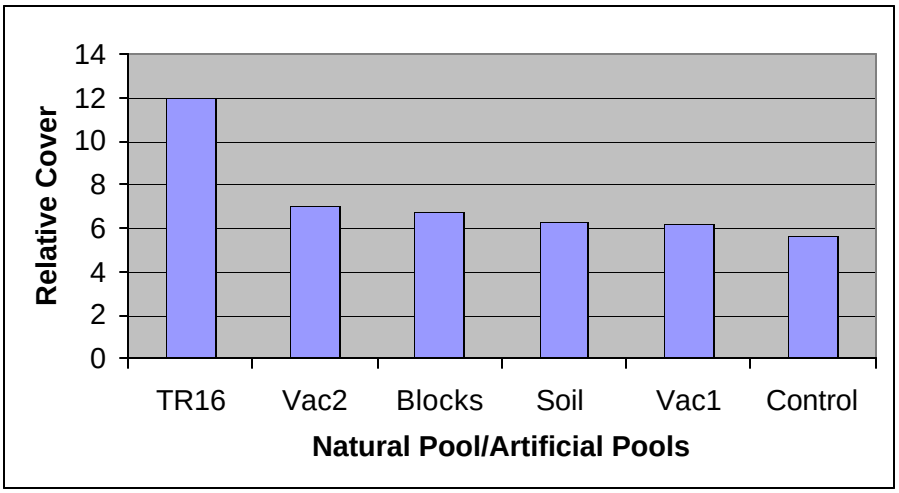
Cover Abundance Comparison of TR16 vs. Artificial Pools 04/26/01

The following species were present in TR16 and in all of the artificial pools: *Psilocarphus brevissimus, Eryngium aristulatum, and Downingia concolor (Table 20)*. *Lasthenia macrantha ssp. bakeri* was present in TR16, but was not present in any of the artificial pools. *Spergula arvensis* was not apparent in TR16, but was present in all the artificial pools. The cover abundance for TR16 was 12, compared to Vac2, which had the highest cover abundance, 7.02 (Figure 10).

Table 20. *Comparison of species present in TR16 vs. Artificial Pools on 04/26/01.*

Constancy Table-Natural Pool and Artificial Pools 04/26/01.						
List of Species	**TR16**	**Blocks**	**Vac2**	**Vac 1**	**Control**	**Soil**
Psilocarphus brevissimus	2	0.67	2.56	1.89	2.67	0.56
Eryngium aristulatum	2	0.33	0.45	0.56	0.11	0.67
Downingia concolor	2	0.22	0.12	0.11	0.12	0.22
Lasthenia glaberrima	2	1.34	0.89	0.78		2.22
Convolvulus arvensis	1	0.006	0.12	0.22		0.12
Spergula arvensis		2.56	1.44	2.01	1.67	2.11
Erodium botrys		0.22	0.11	0.11	0.12	
Anagalis arvensis		0.11	0.11			
Lupinus bicolor		0.11	0.11			
Hemizonia fitchii		0.11				
Lasthenia macrantha ssp. bakeri	2					
Asclepias fascicularis						
Xanthium strumarium						
Rumex crispus						
Cyperus eragrostis						
Eleocharis macrostachya						
Centaurium muehlenbergii						
Eremocarpus setigerus						
Grasses						
Hordeum murinum	1	1.11	1.11	0.56	1	0.44
Lolium multiforum						
Taeniatherum caput-medusae						
Polypogon monospeliensis						
Other						
bare soil	1	1	1.89	2.22	2.22	1.22
algae/algal matting		0.67			0.22	0.22
Relative Cover (average)	12	6.79	7.02	6.24	5.69	6.34

Figure 10. *Cover Abundance on 04/26/01.*



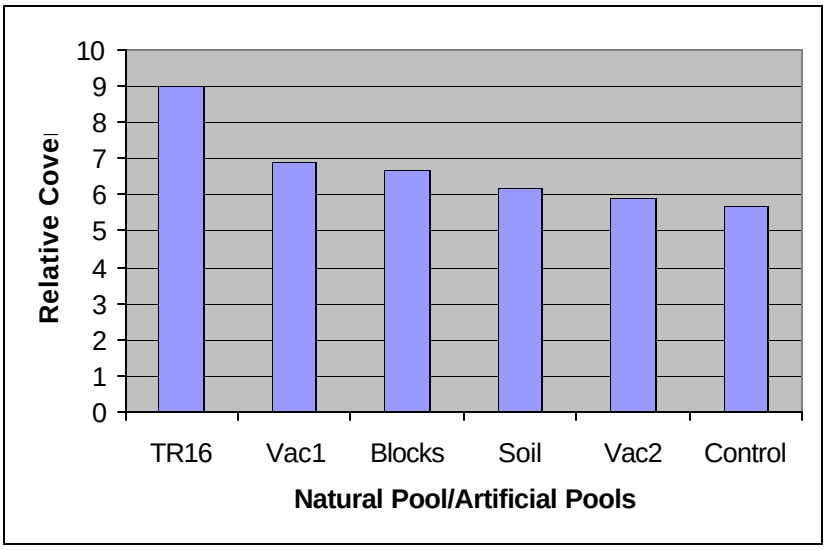
Cover Abundance Comparison of TR16 vs. Artificial Pools 05/03/01

On 05/03/01, the following species were present in TR16 and in all of the artificial pools: *Psilocarphus brevissimus*, *Eryngium aristulatum*, and *Lasthenia glaberrima*. *Downingia concolor* was present in all the artificial pools, but was not present in TR16. Again, *Lasthenia macrantha ssp. bakeri* was only present in TR16 (Table 21). The cover abundance for TR16 was 9, compared to Vac2, which had the highest cover abundance, 6.92 (Figure 11).

Table 21. *Comparison of species present in TR16 vs. Artificial Pools on 05/03/01.*

Constancy Table-Natural Pool and Artificial Pools 05/03/01.						
List of Species	**TR16**	**Blocks**	**Vac 1**	**Vac2**	**Soil**	**Control**
Psilocarphus brevissimus	2	1.44	2.22	2.78	1	2.44
Eryngium aristulatum	2	0.56	1.11	1.34	0.89	0.44
Lasthenia glaberrima	2	1.11	0.46	0.35	1.12	0.006
Spergula arvensis		1.57	0.89	0.36	1	1.12
Convolvulus arvensis		0.11	0.12	0.11	0.006	0.12
Downingia concolor		0.78	0.12	0.35	0.56	0.22
Erodium botrys				0.11	0.11	
Anagalis arvensis				0.006	0.11	
Hemizonia fitchii			0.11			
Asclepias fascicularis		0.11				
Lasthenia macrantha ssp. bakeri	2					
Xanthium strumarium						
Eleocharis macrostachya						
Rumex crispus						
Lupinus bicolor						
Cyperus eragrostis						
Centaurium muehlenbergii						
Eremocarpus setigerus						
Grasses						
Hordeum murinum	1	1	0.78	1.4	1.4	1.23
Lolium multiforum			0.11	0.11		0.11
Taeniatherum caput-medusae						
Polypogon monospeliensis						
Other						
bare soil	1	2.11	2.78	2.56	1.78	1.23
algae/algal matting		0.56				0.33
Relative Cover (average)	9	6.68	5.92	6.92	6.2	5.69

Figure 11. *Cover Abundance on 05/03/01.*



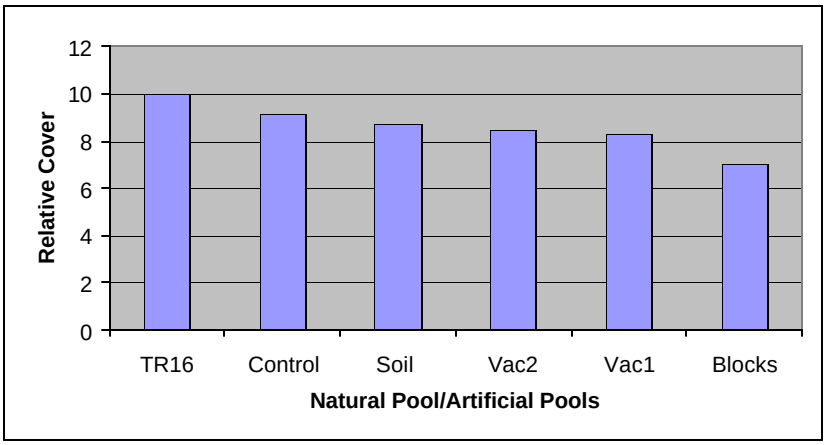
Cover Abundance Comparison of TR16 vs. Artificial Pools 06/08/01

On 06/08/01, the following species were present in TR16 and in all of the artificial pool: *Psilocarphus brevissimus*, *Eryngium aristulatum*, *Hemizonia fitchii*, and *Eremocarpus setigerus*. It was observed that TR16 had fewer grass species than the artificial pools (Table 22). The cover abundance for TR16 was 10, compared with the Control, which had the highest cover abundance, 9.15 (Figure 12).

Table 22. *Comparison of species present in TR16 vs. Artificial Pools on 06/08/01.*

Constancy Table-Natural Pool and Artificial Pools 06/08/01.						
List of Species	**TR16**	**Blocks**	**Vac2**	**Soil**	**Vac 1**	**Control**
Psilocarphus brevissimus	2	1.11	1.67	0.78	1.56	2.11
Eryngium aristulatum	2	0.78	1.23	1.67	1.56	0.33
Hemizonia fitchii	1	0.78	1.33	0.33	1.22	1.45
Eremocarpus setigerus	3	0.44	0.44	1.23	0.23	1.22
Convolvulus arvensis		0.44	0.22	0.12	0.44	0.45
Xanthium strumarium				0.11		
Asclepias fascicularis	r					
Rumex crispus	1					
Centaurium muehlenbergii			0.11			
Eleocharis macrostachya		0.22				
Lasthenia glaberrima						
Lasthenia macrantha ssp. bakeri						
Anagalis arvensis						
Erodium botrys						
Lupinus bicolor						
Cyperus eragrostis						
Downingia concolor						
Spergula arvensis						
Grasses						
Hordeum murinum	1	1.67	1.44	1.89	1.44	1.68
Lolium multiforum		0.79	0.81	1.01	0.9	0.79
Taeniatherum caput-medusae		0.68	1.23	0.78	0.9	1.01
Polypogon monospeliensis		0.11		0.78		0.11
Other						
bare soil	1	2.11	2.11	2.01	2.78	2.56
algae/algal matting						
Relative Cover (average)	10	7.02	8.48	8.7	8.25	9.15

Figure 12. *Cover Abundance on 06/08/01.*



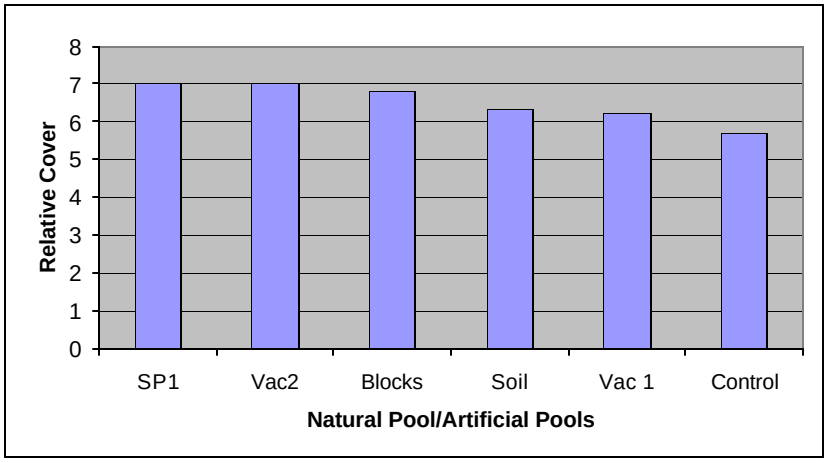
Cover Abundance Comparison of SP1 vs. Artificial Pools 04/26/01

On 04/26/01, *Psilocarphus brevissimus* and *Eryngium aristulatum* were present in SP1 and the artificial pools. *Lasthenia macrantha ssp. bakeri* was only observed in SP1, which was not present in the artificial pools. *Downingia concolor* and *Spergula arvensis* were present in all of the artificial pools, but absent from SP1 (Table 23). The cover abundance for SP1 was 7, compared to Vac2, which had the highest cover abundance, 7.02 (Figure 13).

Table 23. *Comparison of species present in SP1 vs. Artificial Pools on 04/26/01.*

Constancy Table-Natural Pool and Artificial Pools 04/26/01.						
List of Species	**SP1**	**Blocks**	**Vac2**	**Vac 1**	**Control**	**Soil**
Psilocarphus brevissimus	2	0.67	2.56	1.89	2.67	0.56
Eryngium aristulatum	2	0.33	0.45	0.56	0.11	0.67
Downingia concolor		0.22	0.12	0.11	0.12	0.22
Lasthenia glaberrima		1.34	0.89	0.78		2.22
Convolvulus arvensis		0.006	0.12	0.22		0.12
Spergula arvensis		2.56	1.44	2.01	1.67	2.11
Erodium botrys		0.22	0.11	0.11	0.12	
Anagalis arvensis		0.11	0.11			
Lupinus bicolor		0.11	0.11			
Hemizonia fitchii		0.11				
Lasthenia macrantha ssp. bakeri	1					
Asclepias fascicularis						
Xanthium strumarium						
Rumex crispus						
Cyperus eragrostis						
Eleocharis macrostachya						
Centaurium muehlenbergii						
Eremocarpus setigerus						
Grasses						
Hordeum murinum	1	1.11	1.11	0.56	1	0.44
Lolium multiforum	1					
Taeniatherum caput-medusae						
Polypogon monospeliensis						
Other						
bare soil	2	1	1.89	2.22	2.22	1.22
algae/algal matting		0.67			0.22	0.22
Relative cover (average)	7	6.79	7.02	6.24	5.69	6.34

Figure 13. *Cover Abundance on 04/26/01.*



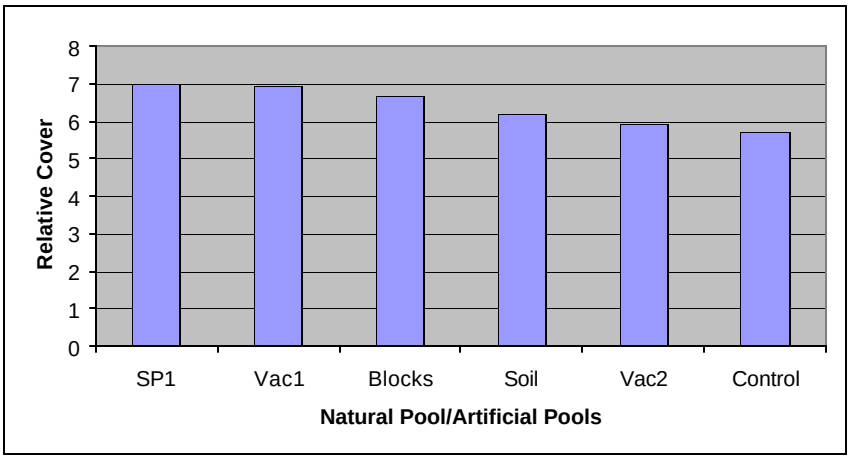
Cover Abundance Comparison of SP1 vs. Artificial Pools 05/03/01

On 05/03/01 *Psilocarphus brevissimus* and *Eryngium aristulatum* were present in SP1 and the artificial pools. *Lasthenia glaberrima, Convolvulus arvensis*, *Downingia concolor* and *Spergula arvensis* were present in all of the artificial pools, but were absent in SP1. We observed that grasses *Hordeum murinum* and *Lolium multiflorum* in SP1 (Table 24). The cover abundance for SP1 was 7, compared to Vac2, which had the highest cover abundance, 6.92 (Figure 14).

Table 24. *Comparison of species present in SP1 vs. Artificial Pools on 05/03/01.*

Constancy Table-Natural Pool and Artificial Pools 05/03/01.						
List of Species	**SP1**	**Blocks**	**Vac1**	**Vac 2**	**Soil**	**Control**
Psilocarphus brevissimus	1	1.44	2.22	2.78	1	2.44
Eryngium aristulatum	4	0.56	1.11	1.34	0.89	0.44
Lasthenia glaberrima		1.11	0.46	0.35	1.12	0.006
Spergula arvensis		1.57	0.89	0.36	1	1.12
Convolvulus arvensis		0.11	0.12	0.11	0.006	0.12
Downingia concolor		0.78	0.12	0.35	0.56	0.22
Erodium botrys				0.11	0.11	
Anagalis arvensis				0.006	0.11	
Lasthenia macrantha ssp. bakeri						
Hemizonia fitchii			0.11			
Asclepias fascicularis		0.11				
Xanthium strumarium						
Eleocharis macrostachya						
Rumex crispus						
Lupinus bicolor						
Cyperus eragrostis						
Centaurium muehlenbergii						
Eremocarpus setigerus						
Grasses						
Hordeum murinum	1	1	0.78	1.4	1.4	1.23
Lolium multiforum	1		0.11	0.11		0.11
Taeniatherum caput-medusae						
Polypogon monospeliensis						
Other						
bare soil	2	2.11	2.78	2.56	1.78	1.23
algae/algal matting		0.56				0.33
Relative Cover (average)	7	6.68	5.92	6.92	6.2	5.69

Figure 14. *Cover Abundance on 05/03/01.*



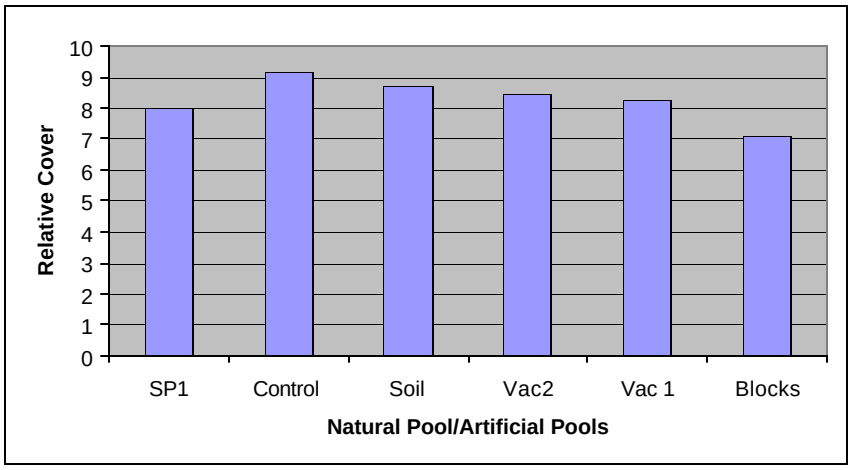
Cover Abundance Comparison of SP1 vs. Artificial Pools 06/08/01

On 06/08/01 the summer blooming species *Hemizonia fitchii* and *Eremocarpus setigerus* were not apparent in SP1; however, these late blooming species were in all the artificial pools. *Psilocarphus brevissimus* and *Eryngium aristulatum* were present in SP1 and the artificial pools. The non-native *Convolvulus arvensis* was present in all of the artificial pools, but was absent in SP1. There was a small amount of *Xanthium strumarium* noted in the soil inoculation treatment. It was observed that SP1 had greater cover abundance of grasses (*Hordeum murinum* and *Lolium multiflorum*) than on 04/26/01 and 05/03/01 (Table 25). The cover abundance for SP1 was 8, compared to the Control, which had the highest cover abundance, 9.15 (Figure 15).

Table 25. *Comparison of species present in SP1 vs. Artificial Pools on 06/08/01.*

Constancy Table-Natural Pool and Artificial Pools 06/08/01.						
List of Species	**SP1**	**Blocks**	**Vac2**	**Soil**	**Vac 1**	**Control**
Psilocarphus brevissimus	1	1.11	1.67	0.78	1.56	2.11
Eryngium aristulatum	3	0.78	1.23	1.67	1.56	0.33
Hemizonia fitchii		0.78	1.33	0.33	1.22	1.45
Eremocarpus setigerus		0.44	0.44	1.23	0.23	1.22
Convolvulus arvensis		0.44	0.22	0.12	0.44	0.45
Xanthium strumarium				0.11		
Centaurium muehlenbergii			0.11			
Eleocharis macrostachya		0.22				
Asclepias fascicularis						
Rumex crispus						
Lasthenia glaberrima						
Lasthenia macrantha ssp. bakeri						
Anagalis arvensis						
Erodium botrys						
Lupinus bicolor						
Cyperus eragrostis						
Downingia concolor						
Spergula arvensis						
Grasses						
Hordeum murinum	2	1.67	1.44	1.89	1.44	1.68
Lolium multiforum	2	0.79	0.81	1.01	0.9	0.79
Taeniatherum caput-medusae		0.68	1.23	0.78	0.9	1.01
Polypogon monospeliensis		0.11		0.78		0.11
Other						
bare soil	2	2.11	2.11	2.01	2.78	2.56
algae/algal matting						
Relative Cover (average)	8	7.02	8.48	8.7	8.25	9.15

Figure 15. *Cover Abundance on 06/08/01.*



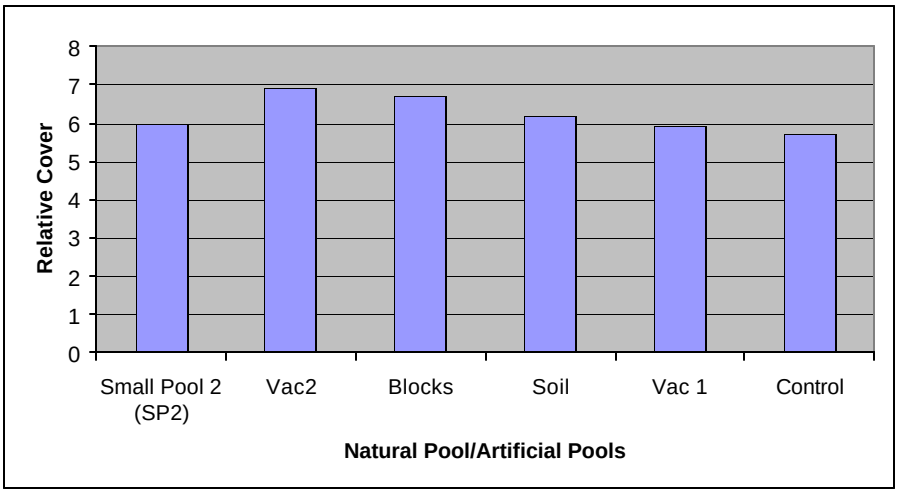
Cover Abundance Comparison of SP2 vs. Artificial Pools 04/26/01

On 04/26/01, *Eryngium aristulatum* and *Spergula arvensis* were present in SP2 and all the artificial pools. *Psilocarphus brevissimus* and *Downingia concolor* were absent in SP2, but present in all of the artificial pools. *Lasthenia glaberrima* was present in SP1 and all the artificial pools except the control pools (Table 26). The cover abundance for SP2 was 9, compared to Vac2, which had the highest cover abundance, 7.02 (Figure 16).

Table 26. *Comparison of species present in SP2 vs. Artificial Pools on 04/26/01.*

Constancy Table-Natural Pool and Artificial Pools 04/26/01.						
List of Species	SP2	Blocks	Vac2	Vac 1	Control	Soil
Psilocarphus brevissimus		0.67	2.56	1.89	2.67	0.56
Eryngium aristulatum	2	0.33	0.45	0.56	0.11	0.67
Downingia concolor		0.22	0.12	0.11	0.12	0.22
Lasthenia glaberrima	3	1.34	0.89	0.78		2.22
Convolvulus arvensis		0.006	0.12	0.22		0.12
Spergula arvensis	3	2.56	1.44	2.01	1.67	2.11
Erodium botrys		0.22	0.11	0.11	0.12	
Anagalis arvensis		0.11	0.11			
Lupinus bicolor		0.11	0.11			
Hemizonia fitchii		0.11				
Lasthenia macrantha ssp. bakeri						
Asclepias fascicularis						
Xanthium strumarium						
Rumex crispus						
Cyperus eragrostis						
Eleocharis macrostachya						
Centaurium muehlenbergii						
Eremocarpus setigerus						
Grasses						
Hordeum murinum	1	1.11	1.11	0.56	1	0.44
Lolium multiforum						
Taeniatherum caput-medusae						
Polypogon monospeliensis						
Other						
bare soil	1	1	1.89	2.22	2.22	1.22
algae/algal matting		0.67			0.22	0.22
Relative Cover (average)	9	6.79	7.02	6.24	5.69	6.34

Figure 16. *Cover Abundance on 04/26/01.*



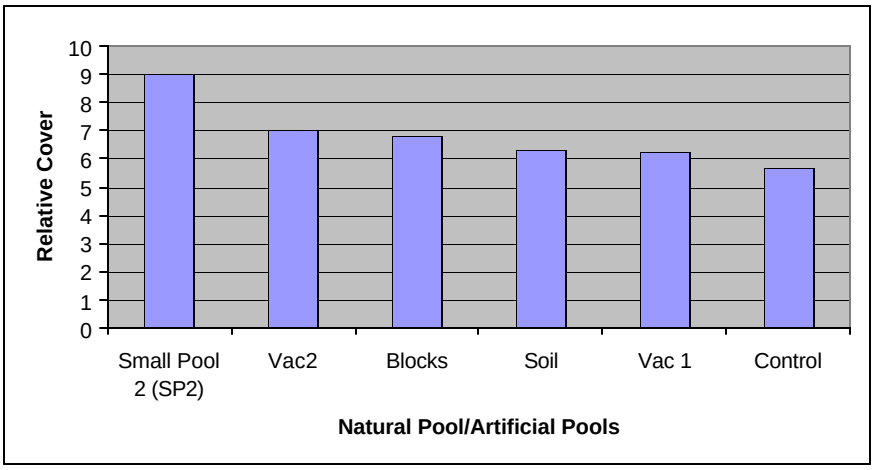
Cover Abundance Comparison of SP2 vs. Artificial Pools 05/03/01

Eryngium aristulatum, *Spergula arvensis*, and *Lasthenia glaberrima* were present in SP2 and in all of the artificial pools on (Table 27). *Psilocarphus brevissimus*, *Downingia concolor,* and *Convolvulus arvensis* were absent in SP2, but present in all of the artificial pools. The cover abundance for SP2 was 6, compared to Vac2, which had the highest cover abundance, 6.92 (Figure 17).

Table 27. *Comparison of species present in SP2 vs. Artificial Pools on 05/03/01.*

Constancy Table-Natural Pool and Artificial Pools 05/03/01.						
List of Species	SP2	Blocks	Vac 1	Vac2	Soil	Control
Psilocarphus brevissimus		1.44	2.22	2.78	1	2.44
Eryngium aristulatum	3	0.56	1.11	1.34	0.89	0.44
Lasthenia glaberrima	1	1.11	0.46	0.35	1.12	0.006
Spergula arvensis	1	1.57	0.89	0.36	1	1.12
Convolvulus arvensis		0.11	0.12	0.11	0.006	0.12
Downingia concolor		0.78	0.12	0.35	0.56	0.22
Erodium botrys				0.11	0.11	
Anagalis arvensis				0.006	0.11	
Hemizonia fitchii			0.11			
Asclepias fascicularis		0.11				
Lasthenia macrantha ssp. bakeri						
Xanthium strumarium						
Eleocharis macrostachya						
Rumex crispus						
Lupinus bicolor						
Cyperus eragrostis						
Centaurium muehlenbergii						
Eremocarpus setigerus						
Grasses						
Hordeum murinum	1	1	0.78	1.4	1.4	1.23
Lolium multiforum			0.11	0.11		0.11
Taeniatherum caput-medusae						
Polypogon monospeliensis						
Other						
bare soil	2	2.11	2.78	2.56	1.78	1.23
algae/algal matting		0.56				0.33
Relative Cover (average)	6	6.68	5.92	6.92	6.2	5.69

Figure 17. *Cover Abundance on 05/03/01.*



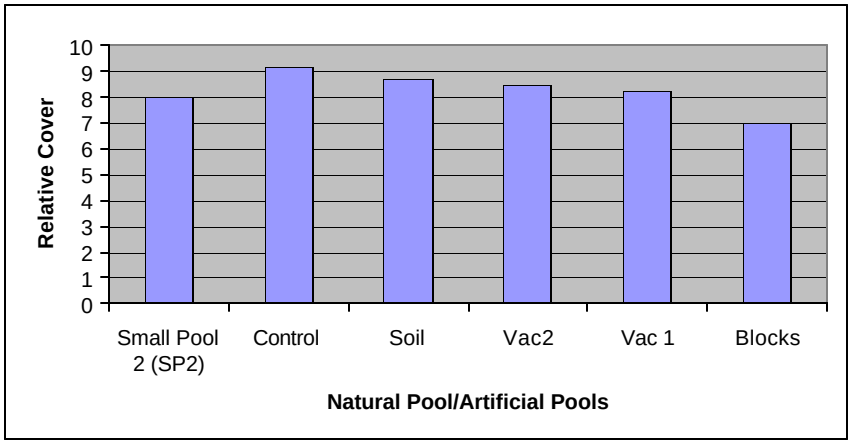
Cover Abundance Comparison of SP2 vs. Artificial Pools 06/08/01

The summer blooming species; *Eryngium aristulatum*, *Hemizonia fitchii*, and *Eremocarpus setigerus* were present in SP2 and in all of the artificial pools (Table 28). *Convolvulus arvensis* and *Psilocarphus brevissimus* were absent from SP2, but present in all of the artificial pools. SP2 had fewer grass species than any of the artificial pools. The cover abundance for SP2 was 8, compared to the Control, which had the highest cover abundance, 9.15 (Figure 18).

Table 28. *Comparison of species present in SP2 vs. Artificial Pools on 06/08/01.*

Constancy Table-Natural Pool and Artificial Pools 06/08/01.						
List of Species	SP2	Blocks	Vac2	Soil	Vac 1	Control
Psilocarphus brevissimus		1.11	1.67	0.78	1.56	2.11
Eryngium aristulatum	2	0.78	1.23	1.67	1.56	0.33
Hemizonia fitchii	2	0.78	1.33	0.33	1.22	1.45
Eremocarpus setigerus	2	0.44	0.44	1.23	0.23	1.22
Convolvulus arvensis		0.44	0.22	0.12	0.44	0.45
Xanthium strumarium				0.11		
Asclepias fascicularis						
Rumex crispus						
Centaurium muehlenbergii			0.11			
Eleocharis macrostachya		0.22				
Lasthenia glaberrima						
Lasthenia macrantha ssp. bakeri						
Anagalis arvensis						
Erodium botrys						
Lupinus bicolor						
Cyperus eragrostis						
Downingia concolor						
Spergula arvensis						
Grasses						
Hordeum murinum	2	1.67	1.44	1.89	1.44	1.68
Lolium multiforum		0.79	0.81	1.01	0.9	0.79
Taeniatherum caput-medusae		0.68	1.23	0.78	0.9	1.01
Polypogon monospeliensis		0.11		0.78		0.11
Other						
bare soil	2	2.11	2.11	2.01	2.78	2.56
algae/algal matting						
Relative Cover (average)	8	7.02	8.48	8.7	8.25	9.15

Figure 18. *Cover Abundance on 06/08/01.*



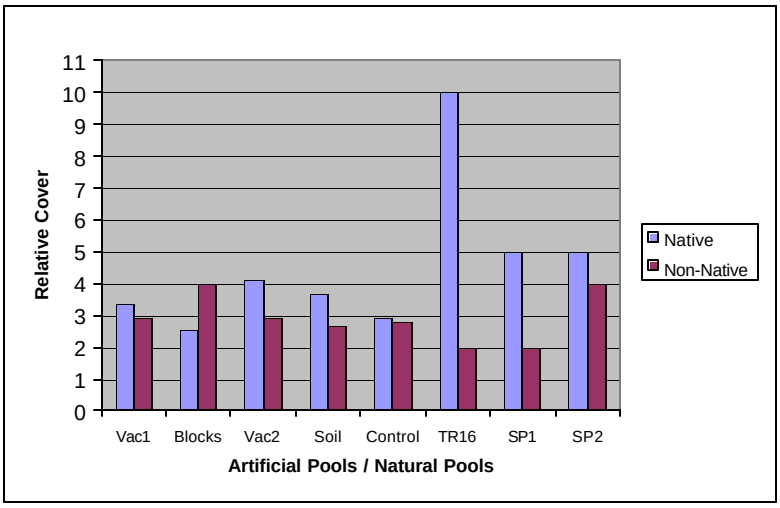
Native vs. Non-Native Cover Abundance on 04/26/01

On 04/26/01, there was more native plant cover abundance than non-native in each pool, with the exception of the Blocks treatment. We observed six native species in the artificial pools and five native species in the natural pools. The six species are constant with the exception of *Hemizonia fitchii*, *Lupinus bicolor*, and *Lasthenia macrantha ssp. bakeri*. *Hemizonia fitchii and Lupinus bicolor* were present only in the artificial pools, while *Lasthenia macrantha ssp. bakeri* was present in the natural pools. Five non-native species were present in the artificial pools and four non-native species were present in the natural pools. Among the non-native species, *Erodium botrys* and *Anagalis arvensis* were only present in the artificial pools. *Lolium multiflorum* was present in SP1 and absent in all the other pools (Table 29).

Table 29. *Native vs. Non-Native Species on 04/26/01.*

Constancy Table-Native vs. Non-native spp. 042601	Artificial Pools					Natural Pools		
Native Species	Vac1	Blocks	Vac2	Soil	Control	TR16	SP1	SP2
Eryngium aristulatum	0.56	0.33	0.45	0.67	0.11	2	2	2
Psilocarphus brevissimus	1.89	0.67	2.56	0.56	2.67	2	2	
Lasthenia glaberrima	0.78	1.12	0.89	2.22		2		3
Downingia concolor	0.11	0.22	0.12	0.22	0.12	2		
Lasthenia macrantha ssp. bakeri						2	1	
Lupinus bicolor		0.11	0.11					
Hemizonia fitchii		0.11						
Eleocharis macrostachya								
Eremocarpus setigerus								
Cyperus eragrostis								
Asclepias fascicularis								
Centaurium muehlenbergii								
Xanthium strumarium								
Relative Cover (Native Species)	3.34	2.56	4.13	3.67	2.9	10	5	5
Non-Native Species								
Hordeum murinum	0.56	1.11	1.11	0.44	1	1	1	1
Spergula arvensis	2.01	2.56	1.44	2.11	1.67			3
Convolvulus arvensis	0.22	0.006	0.12	0.12		1		
Erodium botrys	0.11	0.22	0.11		0.12			
Anagalis arvensis		0.11	0.11					
Lolium multiflorum							1	
Rumex crispus								
Taeniatherum caput-medusae								
Polypogon monspeliensis								
Relative Cover (Non-Native Species)	2.9	4.01	2.89	2.67	2.79	2	2	4
Other								
bare soil	2.22	1	1.89	1.22	2.22	1	2	1
algae/algal matting		0.67		0.22	0.22			

Figure 19. *Native vs. Non-Native Cover Abundance on 04/26/01.*



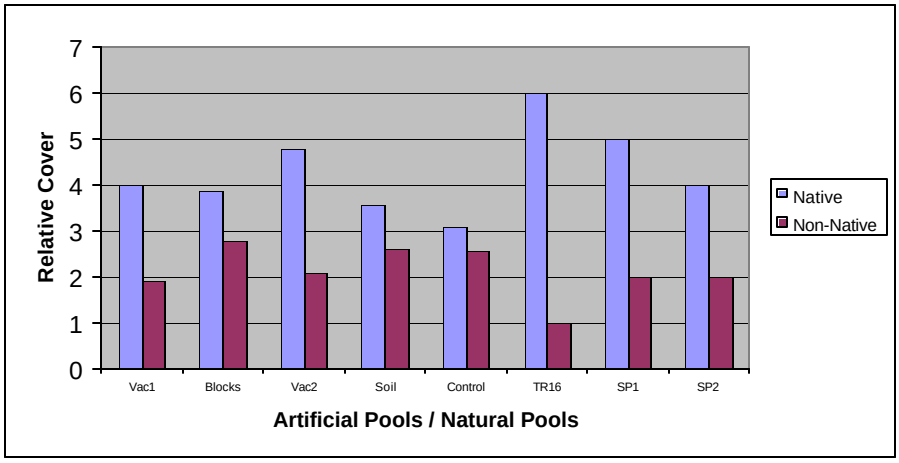
Native vs. Non-Native Cover Abundance on 05/03/01

On 05/03/01, we observed five native species in the artificial pools and four native species in the natural pools. *Lasthenia macrantha ssp. bakeri* remained present in the natural pools, while *Hemizonia fitchii* was present in the artificial pools. There are six non-native species in the artificial pools compared to only three species in the natural pools. Among the non-native species, *Convolvulus arvensis*, *Taeniatherum caput-medusae*, *Anagalis arvensis*, and *Erodium botrys* were present in the artificial pools and *Lolium multiflorum* was present in the SP1. There was a greater amount of native coverage than non-native coverage in each artificial and natural pools (Table 30).

Table 30. *Native vs. Non-Native Species on 05/03/01.*

Constancy Table-Native vs. Non-Native Species 050301	Artificial Pools					Natural Pools		
Native Species	Vac1	Blocks	Vac2	Soil	Control	TR16	SP1	SP2
Eryngium aristulatum	1.11	0.56	1.34	0.89	0.44	2	3	4
Psilocarphus brevissimus	2.22	1.44	2.78	1	2.44	2	1	
Lasthenia glaberrima	0.46	1.11	0.35	1.12	0.006		1	
Downingia concolor	0.12	0.78	0.35	0.56	0.22			
Lasthenia macrantha ssp. bakeri						2		
Hemizonia fitchii	0.11							
Cyperus eragrostis								
Xanthium strumarium								
Eremocarpus setigerus								
Lupinus bicolor								
Centaurium muehlenbergii								
Asclepias fascicularis								
Eleocharis macrostachya								
Relative Cover (Native Species)	4.02	3.89	4.82	3.57	3.11	6	5	4
Non-Native Species								
Hordeum murinum	0.78	1	1.4	1.4	1.23	1	1	2
Spergula arvensis	0.89	1.57	0.36	1	1.12			
Convolvulus arvensis	0.12	0.11	0.11	0.006	0.12			
Taeniatherum caput-medusae	0.11		0.11		0.11			
Anagalis arvensis		0.11	0.006	0.11				
Erodium botrys			0.11	0.11				
Lolium multiflorum							1	
Polypogon monspeliensis								
Rumex crispus								
Relative Cover (Non-Native Species)	1.9	2.79	2.1	2.63	2.58	1	2	2
Other								
bare soil	2.78	2.11	2.56	1.78	1.23	1	2	2
algae/algal matting		0.56			0.33			

Figure 20. *Native vs. Non-Native Cover Abundance on 05/03/01.*



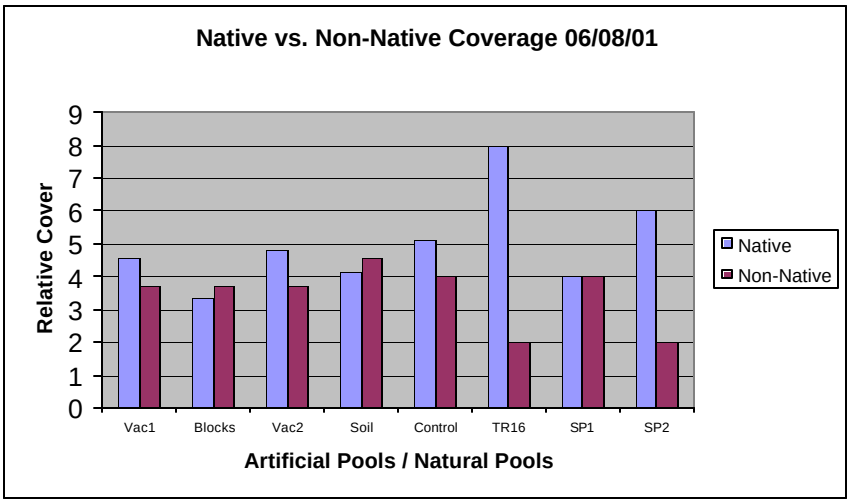
Native vs. Non-Native Cover Abundance on 06/08/01

On 06/08/01, Vac1, Vac2, Control, TR16, and SP2 all had a greater amount of native versus non-native cover abundance. The Blocks and Soil treatments had a greater amount of non-native cover abundance. SP1 had equal amounts of native and non-native cover abundance. We observed seven native species in the artificial pools and five native species in the natural pools. *Xanthium strumarium*, *Eleocharis macrostachya* and *Centaurium muehlenbergii* were present in the artificial pools and absent in the natural pools. A small coverage of *Asclepias fascicularis* was in TR16 only. There are five non-native species in the artificial pools and three in the natural pools. Among the non-native species, *Convolvulus arvensis*, *Taeniatherum caput-medusae*, and *Polypogon monspeliensisi* were present in the artificial pools, but were absent in the natural pools. *Rumex crispus* was present in the natural pools, but absent in the artificial pools (Table 31).

Table 31. *Native vs. Non-Native on 06/08/01.*

Constancy Table-Native vs. Non-Native Species 060801	Artificial Pools					Natural Pools		
Native Species	Vac1	Blocks	Vac2	Soil	Control	TR16	SP1	SP2
Eryngium aristulatum	1.56	0.78	1.23	1.67	0.33	2	3	2
Hemizonia fitchii	1.22	0.78	1.33	0.33	1.45	1		2
Eremocarpus setigerus	0.23	0.44	0.44	1.23	1.22	3		2
Psilocarphus brevissimus	1.56	1.11	1.67	0.78	2.11	2	1	
Xanthium strumarium				0.11				
Eleocharis macrostachya		0.22						
Asclepias fascicularis						r		
Centaurium muehlenbergii			0.11					
Lasthenia glaberrima								
Lupinus bicolor								
Lasthenia macrantha ssp. bakeri								
Cyperus eragrostis								
Downingia concolor								
Relative Cover (Native Species)	4.57	3.33	4.78	4.12	5.11	8	4	6
Non-Native Species								
Hordeum murinum	1.44	1.67	1.44	1.89	1.68	1	2	2
Lolium multiflorum	0.9	0.79	0.81	1.01	0.79		2	
Convolvulus arvensis	0.44	0.44	0.22	0.12	0.45			
Taeniatherum caput-medusae	0.9	0.68	1.23	0.78	1.01			
Polypogon monspeliensis		0.11		0.78	0.11			
Rumex crispus						1		
Anagalis arvensis								
Erodium botrys								
Spergula arvensis								
Relative Cover (Non-Native Species)	3.68	3.69	3.7	4.58	4.04	2	4	2
Other								
bare soil	2.78	2.11	2.11	2.01	2.56	1	2	2
algae/algal matting								

Figure 21. *Native vs. Non-Native Cover Abundance on 06/08/01.*



Vegetation Conclusions

The following conclusions are based on the observations made in Spring 2001. The season had low rainfall producing short inundation periods in the artificial pools and in the natural pools.

1. The vegetation of artificial pools is dependent upon the design of the pool. The artificial pools were constructed with a downhill slope with a deep end of 80 cm and side slopes graded to 30 degrees. This design resulted in a lack of vegetation on the side slopes. In recent years artificial pools have been designed with gentle slopes that are more likely to have vegetated slopes (De Weese, 1998).

2. *Psilocarphus brevissimus* grows best in areas of bare ground or with less competition from other species. In some of our artificial pools *Psilocarphus brevissimus* dominated the deeper zones in the absence of *Spergula arvensis.* This is evident by *Spergula arvensis* growing significantly higher in the deep zones where little or no amounts of *Psilocarphus brevissimus* were apparent.

3. There is a shift from early blooming species to late blooming species. For instance, *Downingia concolor and Lasthenia glaberrima* were apparent early in the season and disappeared later in the season. Compared to *Hemizonia fitchii and Eremocarpus setigerus*, which grew significantly in the late season.

4. Vac2 outperformed the other inoculation treatments in terms of native and non-native cover abundance. Blocks, Soil, and Control treatments had greater amounts of species that are not characteristic of vernal pools. In Northen, Holve-Hensill and Eakins report, the Soil treatment outperformed Vac2 and Blocks (Northen, Holve-Hensill and Eakins, 1998).

5. After eight years, vegetation spread is limited in the Blocks treatment. The Blocks treatment appears to be the least desirable inoculation treatment.

Photo 3. *Artificial Pool A4 on 04/10/01. Wide angle image of Artificial Pool C5 with arrows indicating limited growth between block treatment.*

6. The increased depth of the artificial pools led to longer inundation periods compared to the natural pools, which have shallow depths with shorter inundation periods. *Spergula arvensis* dominated the deeper zones in most of the artificial pools, but is absent in TR16 and SP1. De Weese observed that starting in the third year and sometimes sooner, there is a shift in species cover, with species preferring longer inundation periods (De Weese 1998).

7. The non-native grass species grew in greater amounts in the artificial pools compared to the natural pools. *Hordeum murinum*, *Lolium multiflorum*, and *Taeniatherum caput-medusae* successfully invaded the shallow to middle zones of all the artificial pools. This may be due to natural pool boundaries, which will be considered for Phase 2.

8. The artificial pools appear to have lost plant species since 1996. From 1993 to 1996 Northen, Holve-Hensill and Eakins concluded that out of twenty-four native wetland plants, sixteen showed good to high coverage in the artificial pools (Northen, Holve-Hensill and Eakins, 1998). In 2001, ten native species in the artificial pools with six native species having good coverage.

9. Phase 2 is needed to collect sufficient data to conclude the vegetative success of the vernal pools over time. We will need comparative data on all the source pools TR 17, TR1 – TR5. By collecting this data, we can effectively compare the source pools with the artificial pools.

Hydrology

Vernal pools are seasonal wetlands occurring in shallow depressions over a substrate that limits water percolation. During the winter rainy season water accumulates in the pools and remains present for a variable period of time depending on such factors as: rainfall, evaporation, volume of the pool and permeability of the underlying layer. Pools remain inundated for periods ranging from a few days to several months. It is this seasonal inundation and drying that creates the physical habitat conditions in which the vernal pool biota lives. Therefore, to restore or replicate vernal pool conditions to a site, seasonal inundation must be developed and maintained.

The Travis AFB vernal pool study is primarily a vegetation and invertebrate study. In the original design only limited consideration was given to hydrology. The Sonoma State team used water depth measurements to determine zones for vegetation analysis. They measured the water depth in the artificial pools at each meter point from a sampling baseline at approximately two-week intervals during the 1995/1996 rainy season. Additionally, invertebrate collectors noted the presence or absence of surface water during collections in all years of the original study (Northen, Holve-Hensill and Eakins, 1998).

Hydrology Methods

For the present study, we visited the natural and artificial pools at Travis AFB in February 2000 and from February through July 2001. On each visit we recorded electronic images of each pool to document the presence or absence of surface water. Surface water presence or absence data from Northen, Holve-Hensill and Eakins for the 1993/1994, 1994/1995 and 1995/1996 rainy seasons was compared to the 2001 data.

Hydrology Results

Tables 32-34 summarize the inundation data derived from Northen, Holve-Hensill and Eakins. Table 35 summarizes the inundation data from the rainy season of 2000/2001. Table 36 summarizes the rainfall in the nearby city of Fairfield from 1993/1994 to 2001. On tables 32-36; *Yes* indicates standing water was present, while *No* indicates the absence of standing water in the pool on the date.

Table 32. *Presence of Surface Water in Travis Pools for the 1993/1994 Rainy Season.*

Date	2/4	2/18	3/4	3/18	4/1	4/15	4/22	4/30	5/14
Pool									
A-1	*Yes*	Yes	Yes	*Yes*	Yes	Yes	Yes	Yes	Yes
A-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-3	Yes	Yes	Yes	No	No	No	No	No	No
A-4	Yes	Yes	Yes	*Yes*	Yes	Yes	Yes	Yes	Yes
A-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-4	Yes	Yes	Yes	Yes	No	No	No	No	No
B-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	*Yes*
C-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
C-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	*Yes*
C-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	*Yes*
TR17	No	Yes	Yes	No	No	No	No	No	No

Table 33. *Presence of Surface Water in Travis Pools for the 1994/1995 Rainy Season.*

Date	12/17	12/29	1/16	1/30	2/13	2/25	3/11	3/26	4/8	4/21	5/7
Pool											
A-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-3	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No
A-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
B-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
B-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
C-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
C-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
C-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TR17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No

Table 34. *Presence of Surface Water in Travis Pools for the 1995/1996 Rainy Season.*

Date	12/16	12/30	1/14	1/28	2/11	2/25	3/10	3/24	4/6	4/21
Pool										
A-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
A-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
A-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
B-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C-5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TR17	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

Table 35. *Presence of Surface Water in Travis Pools for the 2000/2001* Rainy Season.

Date	2/1/01	3/1/01	3/22/01	3/29/01	4/10/01	4/26/01
Pool						
A-1	No	**Yes**	**Yes**	**Yes**	No	No
A-2	No	**Yes**	**Yes**	**Yes**	No	No
A-3	No	**Yes**	**Yes**	No	No	No
A-4	No	**Yes**	**Yes**	**Yes**	No	No
A-5	No	**Yes**	**Yes**	No	No	No
B-1	No	**Yes**	**Yes**	**Yes**	**Yes**	No
B-2	No	**Yes**	**Yes**	**Yes**	No	No
B-3	No	**Yes**	**Yes**	**Yes**	**Yes**	No
B-4	No	**Yes**	**Yes**	**Yes**	No	No
B-5	No	**Yes**	**Yes**	**Yes**	**Yes**	No
C-1	No	**Yes**	**Yes**	**Yes**	**Yes**	No
C-2	No	**Yes**	**Yes**	**Yes**	**Yes**	No
C-3	No	**Yes**	**Yes**	**Yes**	**Yes**	No
C-4	No	**Yes**	**Yes**	**Yes**	No	No
C-5	No	**Yes**	**Yes**	**Yes**	No	No
SP1	No	**Yes**	No	No	No	No
SP2	No	**Yes**	No	No	No	No
TR14	No	**Yes**	No	No	No	No
TR15	No	**Yes**	No	No	No	No
TR16	No	**Yes**	**Yes**	No	No	No
TR17	No	**Yes**	**Yes**	No	No	No

On 02/15/2000 all of the pools, both natural and artificial, contained surface water. On 02/01/2001 none of the pools contained surface water. On 03/01/2001 all of the pools, both natural and artificial, contained surface water. No pools contained surface water on or after 04/26/01. The smaller natural pools SP1, SP2, TR14 and TR15 contained no surface water by 03/22/01. The large pool TR17 contained surface water through 03/22/01, but was dry by 03/29/01. TR16 contained no surface water by 04/01/01.

The winter of 2000/2001 was dry and the periods of inundation tended to be shorter than those of any of the previous years. TR17 however contained surface water longer than it did in 1993/1994 when it was dry by March 18. All of the artificial vernal pools contained surface water longer than did the smaller natural pools SP1, SP2, TR14 and TR15. A3 and A5 the artificial pools that dried out most quickly held water for about as long as the natural pools TR16 and TR17. The other artificial pools contained surface water longer than any natural pool in the immediate vicinity. The artificial vernal pools generally contained surface water longer than TR17 during the Sonoma State study (Northen, Holve-Hensill and Eakins, 1998).

During the observations it became clear that pools constructed in close proximity to one another with the same design do not necessarily have the same inundation period. Pools A3 and A5 were dry by 3/29/01, while pools B1, B3, B5, C1, C2 and C3 still contained surface water on 4/10/01. A3 also had a shorter inundation period than most of the other artificial pools in 1993/1994, 1994/1995 and 1995/1996. A5 had a shorter inundation period than most of the other artificial pools in 1994/1995 and 1995/1996.

Table 36. Monthly Rainfall for Fairfield CA.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Year												
93/94	0.59	2.65	2.39	2.71	4.31	0.14	1.19	1.26	0.00	0.00	0.00	0.02
94/95	0.28	5.30	4.49	12.47	0.14	9.21	0.88	1.21	1.83	0.00	0.00	0.00
95/96	0.0	0.08	10.02	8.65	8.34	2.32	2.18	3.03	0.0	0.00	0.00	0.00
96/97	1.61	3.58	11.67	11.07	0.28	0.52	0.20	0.47	0.27	0.00	0.41	0.00
97/98	0.81	6.73	2.30	8.95	14.71	2.35	2.30	3.29	0.00	0.00	0.00	0.34
98/99	0.71	4.29	1.57	2.11	6.97	2.85	1.73	0.03	0.00	0.00	0.00	0.04
99/00	0.56	2.91	0.52	5.98	11.25	2.87	1.29	0.98	0.17	0.00	0.00	0.08
00/01	2.54	1.16	1.13	3.36	6.35	1.37	0.62	0.00	0.08	0.00	0.00	----
Mean	1.25	2.88	3.79	5.11	3.96	3.12	1.33	0.51	0.18	0.02	0.07	0.28

Hydrology Discussion

The artificial vernal pools were designed to provide statistically oriented data to evaluate four inoculation treatments for vernal pool plants and invertebrates. The small rectangular design with a sloping plane from ground level to 80 cm in depth may in itself be a significant determinant of the type of plant community that can ultimately become established in each individual pool. De Weese observed that the lack of microhabitat variation along with increased inundation time due to increased depth may ultimately develop habitat that favors the dominance of species such as *Eleocharis machrostachya*, whose abundance is correlated with longer inundation periods (De Weese, 1998). In 2001 most artificial pools at Travis were inundated for a longer period of time than the natural pools.

The rainy season 2000/2001 was drier than normal. The composition of vegetation in the pools this year may, at least in part, be a reflection of the low rainfall.

Hydrology Conclusions

1. The 2000/2001 rainy season was drier than the average season. Inundation periods for the artificial pools were shorter than the inundation periods for previously measured years.

2. The artificial pools generally had longer inundation periods during the 2000/2001 season than the nearby natural pools.

3. The inundation periods for the artificial pools exhibit significant variability limiting the use of parametric statistics for comparisons among pools.

4. The design of the artificial pools is probably a major factor in the type of vegetative community that will ultimately develop in those pools. Plant species associated with longer inundation periods are likely to be benefited by the design.

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Appendix A-

Raw Data Tables

Tables A

A1 Species present in each zone of the listed artificial pools on 04/26/01.

A2 Species present in each zone of the listed artificial pools on 05/03/01.

A3 Species present in each zone of the listed artificial pools on 06/08/01.

A4. Species present in TR16 on each date listed.

A5. Species present in SP1 on each date listed.

A6. Species present in SP2 on each date listed.

Table A1. *Raw Data Table indicating species present in each zone of the artificial pools on 04/26/01.*

Raw Data 042601	Shallow Zone															Middle Zone														Deep Zone													
List of Species	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
Erodium botrys	+		1				1						1		2			+																										
Eryngium aristulatum	2	+		1	1					2						2	1		1					1	2		1				1		1	1	1				1	+		2			
Psilocarphus brevissimus	2	1	2	1		2	4	3	2	1	3	4	2			2	3	3		2	1	2	3	1	1	3	4	5		2	1	3	3				2	2			2		2	1	
Anagalis arvensis		1																												1															
Downingia concolor		+		1	r	r	1	+			1	r	1				+			1								r	1	1															
Lupinus bicolor		+													2																													
Lasthenia glaberrima				3		+	+		3	5					2	r	1		5	3	1	3		4	5				3			2		1	3		2			1					
Convolvulus arvensis						+	+											r		1											1			+										
Spergula arvensis								+	2		1				+				1	1	5	1	2	2	2	4	2	1	3	2	4	3		5	3	5	3	3	5	5	5	4	4	5	5
Hemizonia fitchii													2																															
Lasthenia macrantha ssp. bakeri																																												
Eremocarpus setigerus																																												
Centaurium muehlenbergii																																												
Xanthium strumarium																																												
Asclepias fascicularis																																												
Cyperus eragrostis																																												
Rumex crispus																																												
Eleocharis macrostachya																																												
Grasses																																												
Hordeum murinum	2	3	2	2	3	3	2	3			2	1			3	2	1	1		1								1		2		2	1				1							
Taeniatherum caput-medusae																																												
Polypogon monspeliensis																																												
Lolium multiflorum																																												
Other																																												
algae/algal matting																					2																								
bare soil	2	3	3	2	3	2	1	3	2	1	2	3	3		1	2	3	3	1	2		2	2	2	1	2	2	2	1	1	2	1	3		2	1	2		2		2	2	3	1	1

Table A2. *Raw Data Table indicating species present in each zone of the artificial pools on 05/03/01.*

Raw Data 050301	Shallow Zone															Middle Zone														Deep Zone													
List of Species	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
Erodium botrys		+												1	1																														
Eryngium aristulatum	2	2	1	1	1		1		2	2		1				2	1	2	2			1		1	2		2				1	2	1	2	2		+		2	1		2			
Psilocarphus brevissimus	2	2	2	2		4	3	3	3	3	4	4	4			2	3	3	1	2	2	3	2	2	2	4	4	3	1	3	1	3	2		1	2			2		2	1	1	1	
Anagalis arvensis		1												1																														
Downingia concolor	+	+		1	1	1	+	1		r		+	+	1	1		+		1	1			1						1	2	r			1	r										
Lupinus bicolor																																													
Lasthenia glaberrima	+	1		2		1	+		1	1		+			1	+	+		3	2	1	1		2	4				1		1		2	2			+	1	+					
Convolvulus arvensis			+					+										+	1	+								+		1	1	1											
Spergula arvensis						2		+	+		+				1				+	1	4	+	2	1	1	2	+	1	1	+		+		r	r	3	+	3	2	4	3	3	4	2	4
Hemizonia fitchii													+															2																
Eremocarpus setigerus																																													
Centaurium muehlenbergii																																													
Xanthium strumarium																																													
Asclepias fascicularis																																													
Lasthenia macrantha ssp. bakeri																																													
Cyperus eragrostis																																													
Rumex crispus																																													
Eleocharis macrostachya																																													
Grasses																																													
Hordeum murinum	2	2	3	3	4		3		2	2	1	1		4	4	2	2	1				1	1					4	2	1	2	+		2		2				2			3	2
Taeniatherum caput-medusae																																													
Polypogon monospeliensis																																													
Lolium multiflorum		1							1									1																										
Other																																													
algae/algal matting																					2															3		3							
bare soil	3	1	3	2	2	2	3	2	3	1	3	2	2	1	2	3	3	3	3	3	1	2	3	2	1	3	3	3	+	+	4	2	4	3	2		4		2	3	3	3	3	2	1

Table A3. *Raw Data Table indicating species present in each zone of the artificial pools on 06/08/01.*

Raw Data 060801	Shallow Zone															Middle Zone														Deep Zone												
List of Species	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
Erodium botrys																																												
Eryngium aristulatum	3	3	1	2	1	+	+		2	3						3	2	1	2	1		1		2	3		1		2		2	2	1	2	3	1	1		2	2		1			
Psilocarphus brevissimus	2	2	2	1		3	3	3	2	1	3	2	1			1	2	2	1	1	3	2	2	2	1	3	2	2			1	1	1			2	+		1		2	2	2	1	
Anagalis arvensis																																												
Downingia concolor																																												
Lasthenia macrantha ssp. bakeri																																												
Lupinus bicolor																																												
Lasthenia glaberrima																																												
Convolvulus arvensis	1		1			1	1				1							1	1	1				1		1						1	+	1	+	1						2		
Spergula arvensis																																												
Hemizonia fitchii			1			2	2	2	2	1	2	2	2		1			2			2	2	2	1	1	2	2	2	2	1			1			1	2	+	1	1	2	2	2		
Eremocarpus setigerus					+	1	1	2	1	1	2			2						1	1	1	2	1	1	1			2					r	+	1	2	2	+	2	2			2	1
Centaurium muehlenbergii												1																																
Xanthium strumarium																				1															1									
Asclepias fascicularis											r																																	
Cyperus eragrostis																															r													
Rumex crispus									r																																			
Eleocharis macrostachya																			1															1										
Grasses																																												
Hordeum murinum	2	2	3	2	2	3	2	4	2	2	2	1	2	3	3	2	1	2	2	2	1	3	2	1	2		1	2	2	2	1	1	+		2	+	1	2		1	+	1	1	1	2
Taeniatherum caput-medusae	2	2	2	2	1	+	1	1	+	1	1	2	1	1	1	1	1	+	+			+	1	1	1		2	1	1	1	1	1	2	+	+	1	+	1	1	1	1	2	+	1	1
Polypogon monospeliensis						1				1				2											1				+											1	1			2	
Lolium multiflorum	2	2	2	1	3	+	+	+	+	1	+	1	1	1	1	1	2	+	2	1	1	+	1	+	1	2	+	1	+	+	1	2	1	1	1	1	+	1	1			+	1	1	+
Other																																												
algae/algal matting																																												
bare soil	2	2	2	1	+	2	2	2	3	2	2	1	2	2	2	3	2	3	1	2	3	2	2	3	2	3	2	2	2	2	4	2	4	2	2	4	3	2	3	3	3	3	3	2

Table A4. *Raw Data Table indicating species present in TR16 on each date.*

Raw Data Table	**TR16**		
List of Species	4/26/01	5/3/01	6/8/01
Lasthenia macrantha ssp. bakeri	2	2	
Eryngium aristulatum	2	2	2
Psilocarphus brevissimus	2	2	2
Downingia concolor	2		
Lasthenia glaberrima	2		
Hemizonia fitchii			1
Eremocarpus setigerus			3
Asclepias fascicularis			r
Convolvulus arvensis	1		
Spergula arvensis			
Lupinus bicolor			
Anagalis arvensis			
Centaurium muehlenbergii			
Xanthium strumarium			
Erodium botrys			
Cyperus eragrostis			
Rumex crispus			1
Eleocharis macrostachya			
Grasses			
Hordeum murinum	1	1	1
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Lolium multiflorum			
Other			
bare soil	1	1	1
algae/algal matting			

Table A5. *Raw Data Table indicating species present in SP1 on each date.*

Raw Data Table	Small Pool 1 (SP1)		
List of Species	4/26/01	5/3/01	6/8/01
Lasthenia macrantha ssp. bakeri	1		
Eryngium aristulatum	2	4	3
Psilocarphus brevissimus	2	1	1
Downingia concolor			
Lasthenia glaberrima			
Hemizonia fitchii			
Eremocarpus setigerus			
Asclepias fascicularis			
Convolvulus arvensis			
Spergula arvensis			
Lupinus bicolor			
Anagalis arvensis			
Centaurium muehlenbergii			
Xanthium strumarium			
Erodium botrys			
Cyperus eragrostis			
Rumex crispus			
Eleocharis macrostachya			
Grasses			
Hordeum murinum	1	1	2
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Lolium multiflorum	1	1	2
Other			
bare soil	2	2	2
algae/algal matting			

Table A6. Raw Data Table indicating species present in SP2 on each date.

Raw Data Table	Small Pool 2 (SP2)		
List of Species	4/26/01	5/3/01	6/8/01
Lasthenia macrantha ssp. bakeri			
Eryngium aristulatum	2	3	2
Psilocarphus brevissimus			
Downingia concolor			
Lasthenia glaberrima	3	1	
Hemizonia fitchii			2
Eremocarpus setigerus			2
Asclepias asperula			
Convolvulus arvensis			
Spergula arvensis	3	1	
Lupinus bicolor			
Asclepias fascicularis			
Centaurium muehlenbergii			
Xanthium strumarium			
Erodium botrys			
Cyperus eragrostis			
Rumex crispus			
Eleocharis macrostachya			
Grasses			
Hordeum murinum	1	1	2
Taeniatherum caput-medusae			
Polypogon monospeliensis			
Lolium multiflorum			
Other			
bare soil	1	2	2
algae/algal matting			