

## Evaluation of Species Diversity on Two Artificially Created Vernal Pools in Sonoma County, California

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**ABSTRACT:** Vernal pool ecosystems, once commonly found in many landscapes throughout California, are becoming endangered habitats due to increased urban and suburban development. However, little information is available regarding the dynamics of created vernal pools and their contribution to species biodiversity. This study focuses on this issue of species diversity, particularly aquatic invertebrate diversity, and the relative abundance of such animals as they occur in two mitigated wetland properties in Sonoma County. Two study sites located within five miles of each other on the Santa Rosa Plain were compared using physical measurements (pool size, dissolved oxygen, pH, water depth, water temperature, etc.) as well as invertebrate counts and classification. Species diversity in a total of four pools at each site was evaluated using the Shannon Index. Likewise, statistical analysis using a grouped means one-way ANOVA was applied to compare any significant ecological differences between the two sites studied. It was concluded that there were no significant differences in water depth, water temperature, pH, or dissolved oxygen between the Alba Lane and Gobbi Ranch sites (grouped means one-way ANOVA  $p > 0.05$ ). When comparing the invertebrates collected, 1½ times more individual invertebrates were noted at the Alba Lane site than the Gobbi Ranch site yet species richness was equal at both sites ( $n=16$ ). Species diversity was slightly higher at the Gobbi ranch site than the Alba Lane site according to the Shannon indexes (2.01 versus 1.82 respectively).

### INTRODUCTION

Vernal pool ecosystems are unique ephemeral habitats for animal and plant communities. Many plants and several animals that inhabit vernal pools in California are listed as threatened or endangered. In Sonoma County two species of animals and thirteen species of plants are listed as threatened (CH2M Hill, 1995). Organisms that are able to reproduce efficiently and quickly in these pools have adapted cyst, egg and seed production enabling them to tolerate the dry summer months (California Biodiversity News, 1996). These adaptations make the survival of these organisms all the more interesting from both an evolutionary and ecological view.

California vernal pool habitat loss has been estimated to range from 50 to 90 percent since Europeans settled in California (California Biodiversity News, 1996). This loss of habitat has increased substantially in recent years as urban and suburban development increased. Seasonal and year-round wetlands are being placed into mitigation banks in an effort to re-create an environment for the plant and animal species that inhabit these unique environments. It is hoped that these mitigation wetlands can mirror the natural conditions that have been lost for both the macro- and microbiological populations (Zedler, 1987).

Biological abundance and richness are important components of biodiversity in a biological system. Healthy

ecosystems should have adequate numbers of individuals in each species that will allow for self-perpetuating populations. The questions in this study are (1) whether or not artificial vernal pools simulate natural pools in their aquatic animal species diversity, and (2) do the 2 sites vary in their species composition. It is hoped that this knowledge can be applied toward current issues regarding mosquito and vector control and vernal pool development and management.

### Methods

Two sites were chosen for collection and identification of the aquatic invertebrates that inhabit vernal pools. These areas were chosen for the following reasons:

1. created within the same year (1997),
2. developed by the same contractor,
3. exist within a few miles of each other on the Santa Rosa Plain,
4. developed on land that was previously grazed by cattle and considered pasture land,
5. exist at approximately the same elevation,
6. contain about 20 pools of varying sizes,
7. ease of access to both sites.

### Sampling procedures:

Four pools of approximately the same size at each site

were sampled randomly using an aquatic net. Sampling occurred in the center of the pool as well as along the edges to collect organisms that may inhabit both areas of the pools. A twenty-foot swath at the water's surface was utilized and the net rinsed into a 15 liter bucket with about 1 liter of water from the pool being sampled. Benthic sampling was not done. Each pool was sampled twice within a 10 day period at approximately noon. At that time, GPS location, perimeter measurements, air and water temperature, pool depth, pH and dissolved oxygen measurements were taken at each pool as well as a general description of weather (Tables 1a and 1b). Pools with 150-180 meter perimeters were chosen to be a part of the study.

Once collected, each sample was placed in a plastic 1 liter container and refrigerated for 1-3 days until identification of the invertebrate organisms could be performed. All organisms were individually counted and classified such as ostracod, cladoceran, mayfly, etc. The samples from each site were grouped collectively and the Shannon index (Molles, 1999) was calculated for both sites. Additionally, an analysis of variance was evaluated when comparing significant physical differences between the pools at each study site.

## RESULTS

### Environmental conditions:

The water level decreased from approximately 5-13 centimeters in all pools during the study period except Alba 3, which remained at a depth of 18 centimeters (Tables 1a and

1b). The Alba pools average loss was 6 centimeters, while the pools at the Gobbi site averaged a loss of 15 centimeters (Tables 1a and 1b). As this occurred, dissolved oxygen averages increased at the Alba Lane site from 8.90 mg/L to 9.60 mg/L. Conversely, the pools at Gobbi Ranch averaged a decrease in dissolved oxygen content from 11.53 mg/L to 10.47 mg/L. Pools #4 at both sites dried up prior to sampling on May 4 and May 5 (Table 1b). The average pH at the Gobbi Ranch became much more acidic, from 7.8 to 4.5 yet the Alba Lane pools average pH remained virtually unchanged (6.7 to 6.6). When comparing physicochemical factors of the pools, there were no significant differences in water depth, water temperature, pH, and dissolved oxygen content between the Alba Lane site and the Gobbi Ranch site (grouped means one-way ANOVA  $p > 0.05$ ).

### Invertebrates collected:

The most abundant invertebrates collected were copepods ( $n=742$ ), ostracods ( $n=514$ ) and cladocerans ( $n=817$ ) (Tables 2a and 2b). Dipterans, water boatmen and backswimmers were prevalent at the Gobbi Ranch site (total of all three  $n=202$ ) while snails were prevalent at the Alba Lane site ( $n=157$ ).

### Species diversity:

At the Gobbi Ranch site, 1,093 individual invertebrates were counted and classified into 16 different general orders. The Shannon index calculated for these pools was 2.01 (Table 2a). For the Alba Lane pools, 1,747 individual animals were counted and identified as 16 separate species with a Shannon Index of 1.82 (Table 2b).

Table 1a. April 24 and 25 pool measurements

Pool	GPS location	Pool size (perimeter in m)	Air Temperature (C)	Weather	Water Depth (cm)	Water Temperature (C)	Dissolved oxygen pH	(mg/L)
Alba 1	N. 38 29.29W. 122 44.44	156	24	Sunny/warm	30	19.1	6.6	8.1
Alba 2	N. 38 29.30W. 122 44.44	183	24	Sunny/warm	30	19.3	6.5	8.3
Alba 3	N. 3829.33W. 122 44.33	153	24	Sunny/warm	18	21.7	6.7	9.2
Alba 4	N. 38 29.30W. 122 44.33	152	24	Sunny/warm	10	27.0	6.9	10.0
Gobbi 1	N. 38 23.13W. 122 44.33	152	20	P. cloudy/warm	24	24.6	7.0	9.5
Gobbi 2	N. 38 23.20W. 122 45.19	158	20	P. cloudy/warm	18	24.3	6.8	11.4
Gobbi 3	N. 38 23.15W. 122 45.26	171	20	P. cloudy/warm	25	26.0	8.0	11.3
Gobbi 4	N. 38 23.18W. 122 45.32	155	20	P. cloudy/warm	8	27.8	9.4	13.9

Table 1b. May 5 and 7 pool measurements

Pool	GPS Location	Pool size (perimeter in m)	Air Temperature (C)	Weather	Water Depth (cm)	Water Temperature (C)	Dissolved oxygen pH (mg/L)
Alba 1	N. 38 29.29W. 122 44.44	156	17	Overcast/cool	18	18.1	6.3 9.8
Alba 2	N. 38 29.30W. 122 44.44	183	17	Overcast/cool	13	19.7	6.8 9.7
Alba 3	N. 3829.33W. 122 44.33	153	17	Overcast/cool	18	21.7	6.7 9.2
Alba 4	N. 38 29.30W. 122 44.33	152	17	Overcast/cool	N/A*	N/A*	N/A* N/A*
Gobbi 1	N. 38 23.13W. 122 44.33	152	15	Rainy/cool	17	15.5	3.7 8.1
Gobbi 2	N. 38 23.20W. 122 45.19	158	15	Rainy/cool	5	16.4	6.6 9.0
Gobbi 3	N. 38 23.15W. 122 45.26	171	15	Rainy/cool	13	16.3	4.2 14.3
Gobbi 4	N. 38 23.18W. 122 45.32	155	15	Rainy/cool	N/A*	N/A*	N/A* N/A*

\*N/A refers to pools that had dried up during the study and therefore measurements were not taken.

## DISCUSSION

Approximately one and half times more individual invertebrates were collected at the Alba Lane site than at Gobbi Ranch. The species richness was equal at both sites ( $n=16$ ) yet the species diversity was slightly higher at Gobbi Ranch according to the Shannon indexes. Although the invertebrate species diversity was similar among all pools tested, personal observations point to differences in biodiversity between the two study sites. The Gobbi Ranch vernal pools closely resemble native vernal pools in their plant composition and substrate (Holland and Jain, 1988). The Gobbi Ranch site allows for cattle grazing during the summer months once the pools have dried up. The presence of cattle may have positive effects on the biodiversity of artificial and natural vernal pool ecosystems. The presence of cattle may be two-fold: 1) seasonal grazing may keep non-native grasses in check, thereby allowing native plants to flourish and 2) cattle manure may add organic nutrients vital to the continued existence of the plant and animals species which inhabit the pools (CH2M Hill, 1995). Additionally, the topography at Gobbi Ranch also appears to resemble natural vernal pool systems as the pools are shallower, evaporate sooner and may have less predation by birds, fish and amphibians. Conversely, the Alba Lane pools are subject to flooding from a creek that divides the property and the pools are overall deeper than the Gobbi Ranch pools thus allowing for long periods of water retention during the

Table 2a. Shannon Index for species diversity at Gobbi Ranch site

Species	Species ID	Number of individuals
1	Copepods	323
2	Cladocerans	250
3	Ostracods	171
4	Dipterans	103
5	Water Boatmen	53
6	Back Swimmers	46
7	Amphipods	40
8	Snails	37
9	Damselflies	34
10	Mayflies	8
11	Dragonflies	6
12	Springtails	5
13	Dytiscids	5
14	Water Striders	4
15	Spiders	4
16	Water Beetles	4
<b>TOTAL</b>		<b>1,093</b>
		<b>2.01 diversity</b>

Table 2b. Shannon Index for species diversity at Alba Lane site

Species	Species ID	Number of individuals
1	Cladocerans	567
2	Copepods	419
3	Ostracods	343
4	Snails	157
5	Dipterans	80
6	Water Boatmen	49
7	Damselflies	43
8	Backswimmers	30
9	Water Striders	18
10	Mayflies	18
11	Dytiscids	10
12	Dragonflies	5
13	Leaf Beetles	3
13	Water Beetles	3
14	Water Scorpions	1
15	Water Mites	1
<b>TOTAL</b>		<b>1,747</b>
		<b>1.82 diversity</b>

wet season on into the summer months. Cattails have been noted at the Alba Lane site presumably due to the water depth and the softer substrate.

Another observation of interest is the presence of migratory bird species that visit the pools. The path of migration flyways may affect the biological diversity at the sites as aquatic birds introduce eggs and cysts into the pools from their feet while they feed and rest at the pools. Previous experiences with these sites have shown a difference in bird species that visit the pools. The Alba Lane pools have been noted to have ducks, geese, herons and egrets. At the Todd Road site, only egrets and herons were seen. Additionally, two distinct fish species have been noted to inhabit the Alba Lane site during the first year of operation, presumably due to flooding from a nearby creek.

From a mosquito control aspect, poorly designed vernal pool ecosystems offer many challenges. First would be the disadvantage of providing an excellent habitat for mosquito reproduction, particularly the species *Culex tarsalis* and *Culex stigmatosoma*. Given the fact that many vernal pools provide habitat for migratory birds, the potential transmission of arboviruses such as western equine encephalomyelitis and

West Nile increases greatly. The public health importance of these pools would be heightened by the difficulties involved in the treatment of vernal pools that are harboring mosquito populations. Vehicle access is limited because of the endangered plants that grow along the pool edges and the choice of pesticides is limited to those that do not affect non-target species. Other biological control methods such as the introduction of mosquitofish are impossible due to the possible impact on endangered aquatic invertebrate species such as fairy shrimp.

**Future Work**

Although not studied in this project, benthic animals may be more numerous at the Alba Lane site due to its finer substrate in comparison to the Gobbi Ranch pools. As mentioned earlier, fish and numerous bird species have been seen at the Alba Lane site and may contribute to lower species diversity although much more intensive work is warranted to confirm this hypothesis. It would be interesting to look at aquatic invertebrate populations monthly during the wet season. Of greater value may be a study that compares directly biodiversity in natural versus artificial vernal pool systems. Other future studies could include introduction of threatened or endangered species such as fairy shrimp, red-legged frogs and plants (Sonoma Sunshine, Sebastopol meadowfoam) and a comparison made between natural and artificial vernal pools. Completion of such studies could aid in developing guidelines for future mitigated wetland projects. This ecosystem-based approach may allow for continued urban/suburban development while protecting and conserving vernal pool habitats and the animals and plants that thrive within these unique communities.

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